Learning and Analytics in Intelligent Systems 29

Mirjana Ivanović
Aleksandra Klašnja-Milićević
Lakhmi C. Jain *Editors*

Handbook on Intelligent Techniques in the Educational Process

Vol 1 Recent Advances and Case Studies

Springer

Learning and Analytics in Intelligent Systems

Volume 29

The main aim of the series is to make available a publication of books in hard copy form and soft copy form on all aspects of learning, analytics and advanced intelligent systems and related technologies. The mentioned disciplines are strongly related and complement one another significantly. Thus, the series encourages cross-fertilization highlighting research and knowledge of common interest. The series allows a unified/integrated approach to themes and topics in these scientific disciplines which will result in significant cross-fertilization and research dissemination. To maximize dissemination of research results and knowledge in these disciplines, the series publishes edited books, monographs, handbooks, textbooks and conference proceedings.

Indexed by EI Compendex.

More information about this series at https://link.springer.com/bookseries/16172

Mirjana Ivanović · Aleksandra Klašnja-Milićević ·
Lakhmi C. Jain
Editors

Handbook on Intelligent Techniques in the Educational Process

Vol 1 Recent Advances and Case Studies

Springer

Editors
Mirjana Ivanović
Faculty of Sciences
Department of Mathematics
and Informatics
University of Novi Sad
Novi Sad, Serbia

Aleksandra Klašnja-Milićević
Faculty of Sciences
Department of Mathematics
and Informatics
University of Novi Sad
Novi Sad, Serbia

Lakhmi C. Jain
KES International
Selby, UK

ISSN 2662-3447 ISSN 2662-3455 (electronic)
Learning and Analytics in Intelligent Systems
ISBN 978-3-031-04661-2 ISBN 978-3-031-04662-9 (eBook)
https://doi.org/10.1007/978-3-031-04662-9

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

Preface

As one of the crucial sectors of society, education has a substantial impact on almost all other sectors. Different computer-supported educational systems have been developing for many decades with the intention to make the process of teaching and learning easier and more convenient in modern, dynamic society. Influences of rapid development of ICT and other related technologies on developing more and more quality, sophisticated educational systems are unavoidable and evident. Societal challenges to further development of educational systems for different domains, purposes, and levels of education are manifold and are not limited only to specific situations like the recent one connected to the COVID-19 pandemic.

Over the years, the use of e-learning and tutoring systems brought numerous advantages and benefits over the traditional teaching methods. Research efforts are focused on improving the overall performances and functionalities of these systems further employing emergent technologies. Attention is especially paid to the design of e-learning architectures that support adaptability to students' personal needs and learning habits. In the last decade, the architectures that offer a high level of personalization and intelligent services and provide support to improve the motivation of learners, and better learning outcomes are dominant.

Nowadays, intensive development and wide applications of AI techniques and approaches significantly influence the educational sector and the development of a range of sophisticated intelligent educational systems. We are witnessing that the future of education is coupled with technologies and their advancements. The applications of AI in educational processes are numerous starting from intelligent tutoring systems (ITS), smart learning environments, towards the use of virtual and augmented reality and robots.

Artificial Intelligence has the potential to address some of the biggest challenges in education today, but also in the future in order to establish innovative teaching and learning practices, and ultimately accelerate the progress and performance of learning.

This book presents a collection of 17 chapters that bring interesting aspects of the state-of-the-art of application of intelligent techniques in different educational processes and settings. Chapters are focused on describing the variety of approaches in diverse educational domains and levels of education; discuss their capabilities, benefits, and possible limitations in practical use.

We hope that the works presented in the book will be of interest to readers, will motivate our colleagues and researchers to apply presented and similar approaches, try to enhance them, and propose better and more advanced solutions.

Chapter 1 "Current Trends in AI-based Educational Processes—An Overview" by Mirjana Ivanović, Aleksandra Klašnja-Milićević, Marcin Paprzycki, Maria Ganzha, Costin Bădică, Amelia Bădică, and Lakhmi C. Jain is an introductory one and considers the influence of modern artificial intelligence techniques on educational processes. The authors focus on providing an overview of the current state-of-the-art of developing intelligent educational systems that have significant effects on learning and teaching processes. Recent works that put light on different roles of AI in developing educational systems are discussed: Adaptive personalization systems and intelligent tutoring systems, assessment and evaluation of students' outcomes, and the benefits and the challenges of educational data mining and learning analytics.

Chapter 2 "Digitalization of Education", by Đorđe Nadrljanski, Mila Nadrljanski, and Mira Pavlinović is focused on diversity and features of concepts and initiatives for digitalization in education. The advantages and challenges related to the development of digitalized environments in education, as well as the greater need for professional development of people working in digitalization, are discussed. In addition, they encourage and promote innovation in many different spheres of life. They stated that there is a very strong link between education and skills needed to utilize digital technologies in different sectors of society. The very important conclusion is that digitalization is an important tool for making fundamental changes in the processes, content, and various forms of work in educational settings to increase the quality and relevance of education for all.

Chapter 3 "Remote Teaching and Learning Math in English Through CLIL" by Maria Guida and Letizia Cinganotto focuses on teaching Mathematics by using umbrella methodology CLIL (Content and Language Integrated Learning). Authors investigate the opportunities and challenges of CLIL in Mathematics in remote and hybrid settings due to the pandemic. Examples of repositories, web tools, digital boards used by teachers for remote CLIL teaching are presented as a way to foster students' engagement, interaction, and interactivity. Despite the problems due to the pandemic, the teachers in Italy were able to deliver adequate content in a meaningful way, using problem-based or project-based learning. Communication and interaction among the students and with the teachers through the discussion, explanation, and negotiation of the different CLIL activities are discussed.

Chapter 4 "The Potential of Artificial Intelligence for Assistive Technology in Education" by Katerina Zdravkova discusses the important aspects of the incorporation of assistive technology in education. It is evident that persons with various disabilities should have an equal access to quality education, and chapters show

how assistive technologies support such persons to keep and improve their functioning, which reinforces inclusive education. Further, the chapter presents a plethora of AI-supported educational tools intended to help people with special needs and elderly people, encompassing the tools for visual, hearing, communication, intellectual, cognitive, and motor impairment. Additionally, some ethical challenges of AI-supported educational tools are raised.

In Chap. 5 "Adaptive and Intelligent Web-Based Learning and Control Technologies", Valery M. Kaziev, and Lyudmila V. Glukhova considered the current problem of evolution of adaptive and intelligent technologies of modern education and their influence on the digital infrastructure of educational environments. The purpose of their study is an evolutionary system analysis of the digital opportunities for the effective development of the information and educational space of universities from the Russian model of competence-oriented education. They proposed the formal, mathematical model of adaptive learning decision-making. Key methods, approaches, and technologies of adapting and intellectualizing web learning are considered including didactic aspects. The authors also investigated the issues of self-organization, web education, their adaptation to digital transformations in society, the environment of the educational system and proposed a list of basic intelligent web learning technologies.

The next, Chap. 6 "Exemplar Use-cases for Training Teachers on Learning Analytics" by Arvind W. Kiwelekar, Manjushree D. Laddha, and Laxman D. Netak provide ready-to-use examples for conducting teachers training programs on Learning Analytics. More precisely, the chapter documents a set of exemplars used to demonstrate LA applications in daily classroom activities. These exemplars have been designed and used mainly to train newly recruited teachers on data analysis methods (such as hypothesis testing, analysis of variance (ANOVA), correlation analysis, and regression analysis) during faculty induction programs.

Chapter 7 "Impact of Lesson Planning on Students' Achievement using Learner Profile System" by Munazza A. Mirza, Khawar Khurshid, Zawar Shah, Faryal Shah, Andrew Levula, and Aleksandra Klašnja-Milićević proposed and evaluated a Learner Profile System, which is a web-based solution to generate multiple types of learner profiles. The profiles include the basic information about the learners, preference and interest profile, learning styles, and motivational goal orientation. The pilot study included 60 middle school students to measure the construct validity and reliability. Afterward, an experimental study was done on 307 middle school students to examine the impact of LPS on learners' achievement. Teachers' perception and their perspective regarding the feasibility and use of the LPS is also considered. The authors concluded that the group that learned using the LPS demonstrated significant improvement in their assessment scores in comparison to the controlled group.

Peter Ilic in the Chap. 8 "Towards an Understanding of Student Digital Ecosystems for Education" put attention to the use of ICT for educational purposes. The chapter sheds light on this issue and takes an initial step towards mapping students' digital ecosystems to enable course design that better fits student learning expectations. Further, different methods were employed to obtain a better understanding of the participants' degree of technological adoption and practice in relation to collaborative educational activities. Insight into the structure of Japanese university students' digital ecosystems was developed by capturing and analyzing participant activity in log data. The author presented several key findings that may help curriculum designers in improving their courses. Also, he considered the effects of students shifting between device types (mobile and non-mobile) depending on the context and purpose. The overall results, as well as implications for education, were discussed, along with suggestions for possible future research.

Different applications and challenges of computational argumentation for modeling distinct aspects of learning processes are presented in Chap. 9 "Computational Argumentation for Supporting Learning Processes: Applications and Challenges" by Carlos Chesñevar, César A. Collazos and Ana Maguitman. The chapter is devoted to argument-based recommender systems for educational purposes; argument-based shared knowledge for computer-supported collaborative learning and argument-based opinion mining for eliciting students' knowledge based on information items corresponding to different topics of study. The current state-of-the-art in the domain is also briefly presented. It also gives a good starting point for researchers working on intelligent techniques for educational processes who are interested in incorporating argumentation as a metaphor for modelling intelligent decision making in Intelligent Tutoring Systems and Computer-Supported Collaborative Learning systems.

Chapter 10 "Revealing Latent Student Traits in Distance Learning through SNA and PCA" by Rozita Tsoni, Evangelos Sakkopoulos, and Vassilios S. Verykios considers significant issues in a distance learning postgraduate course. The authors proposed a novel approach based on learning analytics. The approach is based on a rich spectrum of metrics of Social Network Analysis that can capture complicated interaction of social students' behavior, along with academic performance indicators, in a process that aims to reveal the latent characteristics of students participating in the discussion fora.

Chapter 11 "Smart Technology in the Classroom: Systematic Review and Prospects for Algorithmic Accountability" by Maria Ovchinnikova, Daniel Ostnes, Arian Garshi, Malin Wist Jakobsen, Jørgen Nyborg-Christensen, and Marija Slavkovik brings a comprehensive review of the use of smart technologies in the classroom. The authors explored the state-of-the-art literature in several emergent subdisciplines: wearables, AI and education, school surveillance, accountability, and so on. Both positive and negative effects of using smart technologies are pointed out, and a framework to effectively identify accountability for smart technology in education is proposed.

Automated grading is the central topic of the Chap. 12 "Objective Tests in Automated Grading of Computer Science Courses: An Overview" by Marin Lujak, Marija Slavkovik, Alexis Lebis, Mathieu Vermeulen, and Arnaud Donie. Authors analyzed and mutually compared the most used objective tests in computer science courses in Moodle and MOOCs and outlined the advantages, technical limitations, and ethical challenges. Test feedback mechanisms that facilitate continuous learning for students as well as the identification and recognition of possible evaluation mistakes of the system of AI-supported methods for automating objective tests in programming are considered. Special attention is paid to the identification and mitigation of the context-specific ethical challenges and essential characteristics of tests.

Chapter 13 "Correlating Universal Design of Learning and the Performance in Science at Elementary School Level" by Munazza A. Mirza, Khawar Khurshid, Asma Hasan, Zawar Shah, and Faryal Shah is devoted to the essence of universal design of learning. The authors' study aims to investigate the impact on a learner's academic performance when a teacher uses the Universal Design of learning framework for planning science lessons. A framework based on the constructivist theory, built on cognitive neuroscience emphasizes engaging multiple brain networks by providing guidelines organized into three essential principles is presented. The experiments are conducted to discover the effectiveness of the UDL-based lesson implementation in science and a quasi-experimental pre-test and post-test design was used in the study. Authors found that elementary school pupils achieve better grades in science when taught using a universal design of learning approach in contrast to those who have been taught using traditional teaching method.

Next, the Chap. 14 "Facilitating Collaborative Learning with Virtual Reality Simulations, Gaming and Pair Programming" by Piia Näykki, Janne Fagerlund, Minna Silvennoinen, Mari Manu, Tuula Nousiainen, Merja Juntunen, and Mikko Vesisenaho brings to readers an interesting and emerging trend in educational settings. Authors presented socio-interactional functions that support collaborative learning through three case examples. The examples are based on the use of technology-enhanced simulation-based learning environments, Vive/Minecraft applying virtual and mixed reality and pair programming in a creative media project design with Scratch. These powerful experiential learning contexts provide engaging opportunities for collaborative learning.

"Gamification and the Internet of Things in Education" is the title of Chap. 15 authored by Georgios Pappas, Joshua Siegel, Ioannis N. Vogiatzakis, and Konstantinos Politopoulos. As gamification and the Internet of Things can impact education in a manner previously impossible, gamified tools built upon game engines can offer opportunities in the development of innovative virtual labs and other interactive experiences for students. The authors designed and developed a training gamified tool applied in the field of environmental studies. They showed how this is integrated with the Internet of Things to enable triggers in a virtual 3D space. Additionally, they also provided information on how this innovation has been used in a real distance-learning class for Master's degree students.

Chapter 16 "Communication-Driven Digital Learning Environments: 10 Years of Research and Development of the Campus Platform" by Luís Pedro and Carlos Santos underlines the Campus platform and the importance of communication concepts and affordances in the research and development of a digital learning environment. They argued the approach that values the social construction of knowledge, the importance of networks, collaboration, and sharing in educational processes. Apart from that, the evaluation study of the platform is presented, which allowed to characterize it as an open communication ecosystem for effective dialogue, participation, and engagement.

The last Chap. 17 “Educational Computer Games and Social Skills Training” by Margarita Stankova, Daniela Tuparova, Polina Mihova, Tsveta Kamenski, Georgi Tuparov, and Krista Mehandzhiyska considers the aspects of Autism spectrum disorders (ASD) in the context of technology-enhanced learning. The application of educational computer games aiming to improve the emotional understanding of children with ASD is presented. A specific game is modeled based on emotional intelligence and four focus areas: perceived emotions, use of emotions to facilitate thought, understanding emotions, and managing emotions. Additionally, the chapter discusses the principles of game development and presents data collected from the pilot testing with two groups of children: typically developing and children with ASD. The proposed approach would widen the opportunities for the children to establish and build relationships with peers, be better accepted in society, and reach an improved functional level.

This book would not have existed without the tremendous contribution of the authors and the reviewers. We remain grateful.

We owe thanks to the Springer-Verlag for their excellent support during the preparation of the manuscript.

Novi Sad, Serbia — Mirjana Ivanović
mira@dmi.uns.ac.rs

Novi Sad, Serbia — Aleksandra Klašnja-Milićević
akm@dmi.uns.ac.rs

Selby, UK — Lakhmi C. Jain

Contents

About the Editors

Mirjana Ivanović holds the position of Full Professor at Faculty of Sciences, University of Novi Sad, Serbia. She is a member of National Scientific Committee for Electronics, Telecommunication and Informatics within Ministry of Education, Science and Technological Development, Republic of Serbia. Prof. Ivanović is a member of Board of Directors of The Institute for Artificial Intelligence Research and Development of Serbia. She was a member of University Council for Informatics for more than 12 years. Prof. Ivanović is the author or co-author of 14 textbooks, several international monographs, and more than 450 research papers, most of which are published in international journals and conferences. Her research interests include agent technologies, intelligent techniques, applications of data mining and machine learning techniques in medical domains and technology-enhanced learning. She is a member of Program Committees of more than 350 international conferences, Program/General Chair of several international conferences, and leader of numerous international research projects. Mirjana Ivanović delivered several keynote speeches at international conferences and visited numerous academic institutions all over the world as visiting researcher (Germany, Slovenia, Australia, China, Korea). Currently, she is Editor-in-Chief of the Computer Science and Information Systems journal (e-mail: mira@dmi.uns.ac.rs).

As always, I am grateful to my precious Jakov, Tara, and Zoran for constant support in my life.

Aleksandra Klašnja-Milićević holds the position of Associate Professor at the Faculty of Sciences of the University of Novi Sad, Serbia. She joined the Computer Science graduate program at the Faculty of Science, Department of Mathematics and Informatics, University of Novi Sad in 2003, where she received her M.Sc. degree (2007) and Ph.D. degree (2013). Her research interests include e-learning and personalization, educational technology, learning analytics, technology-enhanced learning, and recommendation systems. Aleksandra has led or actively participates in national and international research projects to develop educational technology and investigate its impact on learning environments. She is a member of the editorial board of KES Journal and Frontiers of Artificial Intelligence. She is the author of a university textbook, a monograph, and more than 50 research articles published in high-level international journals or conferences. Aleksandra delivered several courses and managed an Adaptive Web-based System project at the Australian Institute of Higher Education in Sydney as a visiting researcher (e-mail: akm@dmi.uns.ac.rs).

Prof. Lakhmi C. Jain Ph.D., Dr. H.C., ME, BE(Hons), Fellow (Engineers Australia), is with the Liverpool Hope University and the University of Arad. He was formerly with the University of Technology Sydney, the University of Canberra and Bournemouth University. Professor Jain founded the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation, and teaming. Involving around 5,000 researchers drawn from universities and companies worldwide, KES facilitates international cooperation and generates synergy in teaching and research. KES regularly provides networking opportunities for professional community through one of the largest conferences of its kind in the area of KES. http://www.kesinternational.org/organisation.php.

His interests focus on the artificial intelligence paradigms and their applications in complex systems, security, e-education, e-healthcare, unmanned air vehicles, and intelligent agents.

Chapter 1
Current Trends in AI-Based Educational Processes—An Overview

Mirjana Ivanović, Aleksandra Klašnja-Milićević, Marcin Paprzycki, Maria Ganzha, Costin Bădică, Amelia Bădică, and Lakhmi C. Jain

Abstract Artificial intelligence (AI) is a rapidly developing research area, with immense influence on different areas of modern society and with numerous applications in real-life systems and environments. In this chapter we provide a brief overview of current state-of-the-art of developing intelligent educational systems. Particular attention is paid on the application of artificial intelligence methods in teaching and learning processes. Accordingly, we consider recent works that put light on different roles of AI in developing educational systems. Also, an overview of key educational domains that AI techniques influence, i.e.: adaptive personalization systems and intelligent tutoring systems, assessment and evaluation of students' outcomes and learning performances, and benefits and challenges of educational data mining and learning analytics in educational processes is presented.

Keywords Artificial intelligence in education · Personalized tutoring systems · Assessment and evaluation of students' knowledge · Educational data mining · Learning analytics

---

M. Ivanović (✉) · A. Klašnja-Milićević
Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia
e-mail: mira@dmi.uns.ac.rs

A. Klašnja-Milićević
e-mail: akm@dmi.uns.ac.rs

M. Paprzycki · M. Ganzha
Polish Academy of Sciences, Warszawa, Poland
e-mail: paprzyck@ibspan.waw.pl

M. Ganzha
e-mail: maria.ganzha@ibspan.waw.pl

C. Bădică · A. Bădică
University of Craiova, Craiova, Romania
e-mail: costin.badica@edu.ucv.ro

L. C. Jain
KES International, PO Box 243, Selby YO8 1DS, UK

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*,
Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_1

1.1 Introduction

Artificial Intelligence (AI) is recently becoming one of most rapidly evolving research areas, with numerous applications in different academic and industrial domains. Moreover, it is also present in a number of everyday activities of modern digital society. Among numerous application domain uses of AI techniques and methods, one of more appealing is its potential in education. Here, AI can be found in adaptive learning technologies, educational data mining (EDM) and learning analytics (LA), where contemporary and emerging AI-based approaches significantly influence (and support) educational processes and activities.

During the several decades long history of AI, diverse approaches to develop intelligent systems [1, 2] can be distinguished. A key driver of AI research in the 1950s was the focus on symbolic computation. Optimistic expectations were that simulation and programming of the generic logic of human reasoning will produce the systems that would behave "human intelligently". However, the main characteristic of such systems was the absence of domain-specific knowledge. Representational AI was founded in 1980s, and became known as "good-old-fashioned-AI". The essence of such approaches was in the manipulation of knowledge representations and implementation of specific class of intelligent systems, widely known as expert systems. Representational AI approach, used in educational processes, resulted in the development of so-called Intelligent Tutoring Systems (ITS) that included representations of domain knowledge and teaching material, learners' knowledge, and a pedagogic model [3]. However, most recent trend in applications of AI in educational domains is based on data-driven AI and it is oriented towards applications of educational data mining, learning analytics and use of artificial neural networks. This new, data-driven AI trend is a consequence of three key technical developments: appearance of the Internet, intensive use of smart phones in numerous activities and situations, and fast expansion of social media.

With further rapid development of Information and Communication Technology (ICT) and interrelated disciplines and technologies, educational systems offer to teachers and learners, a range of opportunities and challenges [4–6]. For example, there are several characteristic applications of AI in education.

- Important activities that are the usual component in education, like grading and assessment, can be automated by use of AI.
- Adaptation to learner's needs and learning preferences is important in education and by the use of AI it is relatively easy to point out to the learner specific topics and tasks that he/she needs to improve.
- Specially developed AI tutors can support teachers but also can offer additional support to learners and provide helpful feedback from educational process.
- AI crucially influences way of delivering education: who teaches students, where students learn, and how they acquire knowledge and skills. With constant design and development of AI-based educational systems they slowly become more and more able to offer a variety of innovative, tailored, and intelligent services to learners.

– Apart from direct support of core educational activities, AI can help in a majority of other educational activities, like AI-guided training that simplify the transition from college to high school.

However, in spite of the fact that AI has been well established area, with variety of educational applications, inclusion of such systems in day-to-day pedagogical processes is still challenging for educators [7–9]. Nevertheless, the pedagogical advantage is evident, as it can offer significant impact on educational processes and learning outcomes. In this context, this chapter will focus on providing a brief overview of current state-of-the-art of developing intelligent educational systems. We will focus on influences of AI methods and techniques and their applications in educational process, while avoiding discussion of AI support for administrative activities in educational institutions. This is because we believe that the latter does not belong to pedagogy, but to computer-supported administration, which is out of scope of current contribution.

The rest of the chapter is organized as follows. Section 1.2 presents different roles of AI in developing educational systems. An overview of several characteristic educational systems, based on AI techniques is presented in Sect. 1.3. Concluding remarks are given in the last section.

1.2 Different Roles and Applications of AI in Education

Rapid technological and ICT development facilitates changes that result in the fact that AI methods, approaches, and services are nowadays all around us, in majority of everyday activities. Education is definitively one of areas where AI can powerfully make significant changes. In the last decade we witnessed the development of a variety of tools and services that use computer intelligence to help both teachers and learners to get more out of the educational experience.

Usually, in contemporary research, AI and machine learning (ML) are often considered together as closely related approaches. In [10] ML is seen "as a subfield of artificial intelligence that includes software able to recognize patterns, make predictions, and apply newly discovered patterns to situations that were not included or covered by their initial design". Also, an important concept, used in contemporary intelligent personalized educational systems, is that of rational agents [11, 12]. Additionally, based on the current state-of-the-art in AI field it is possible to rise an ethical and philosophical question: will machines/robots/intelligent agents be able to develop consciousness and actual thinking in the future, or will they just simulate human thinking?

However, despite the fact that a lot of AI applications in educational environments already exist, some authors [8, 13] emphasized three categories of AI applications in education: (a) intelligent tutoring systems and systems that support collaborative learning, (b) personal tutors, and (c) intelligent virtual reality.

Intelligent tutoring systems (ITS) are specific systems that allow very important one-to-one personal tutoring. Based on several different components that are part of such systems, they can support: selection of suitable topic and teaching content for a particular student, or decisions about the learning path. They can also provide cognitive scaffolding. However, the drawback of such personal tutoring is a lack of collaboration and students' interaction with their peers, which is known to be an essential social part of the learning process. On the other hand, constant rapid development of different AI techniques offers new possibilities that also allows higher quality support and functionalities that such systems can considerably advance and contribute to collaborative learning as well.

Development and introduction of new AI technologies pushes their more advanced applications in educational settings. So, for example, virtual reality and augmented reality can tremendously increase quality of e-learning and guidance of students in very popular game-based learning environments. Virtual agents (i.e. chatbots), as a fast developing area, are interesting and useful facilitators of teachers and/or students' peers in virtual or remote labs [14]. According to [8], AI in education "includes everything from AI-driven, step-by-step personalized instructional and dialogue systems, through AI-supported exploratory learning, the analysis of student writing, intelligent agents in game-based environments, and student-support chatbots, to AI-facilitated student/tutor matching that puts students firmly in control of their own learning. It also includes students interacting one-to-one with computers, whole-school approaches, students using mobile phones outside the classroom, and much more besides."

Also, some other technological developments influence changes in educational processes in a slightly different way. One can take the advantage of existence of Big Data, which is collected during students' activities within e-learning environments and process and analyze it, to draw some useful conclusions about educational activities. Thus, educational data mining (EDM) and machine learning and learning analytics (LA) can provide just-in-time feedback and assessment of current student's achievement [15] but also can help them in selecting alternative learning paths that will improve their final learning outcomes. Recent applications of AI in educational environments are based on finding characteristic patterns in collected data and using them in different decision-making processes that can improve student's learning paths, improving teaching material, enhance offer of supplementary teaching material, and so on. Advantages of such applications of EDM and LA are that discovered correlations and patterns in collected data are not easily (if at all) understandable to (discoverable by) humans.

Another point of view on the use of AI in educational processes is presented in [4]. Authors considered educational AI tools from the system's/learner's/teacher's perspectives. System-facing tools provide information on the institutional level for administrators and managers. Learner-facing tools help students to learn particular subject/topic. Teacher-facing systems usually reduce tracers' workload by automating their different activities and tasks.

In the paper [16], authors showed deep systematic review of AI applications in higher education. Looking at more than 150 research papers they selected several crucial groups of systems: (1) adaptive systems and personalization, (2) intelligent tutoring systems, (3) assessment and evaluation, and (4) profiling and prediction. Later, authors made refinement and recognized specific applications in each of these groups:

– **Adaptive systems and personalization group**: teaching course content; recommending personalized content; supporting teachers and learning design; using academic data to monitor and guide students; representation of knowledge in concept maps;
– **Intelligent tutoring systems group**: teaching course content; diagnosing strengths and automated feedback; curating learning materials; facilitating collaboration; the teacher's perspective;
– **Assessment and evaluation group**: automated grading; obtaining feedback from learning sessions and processes; evaluation of student understanding, engagement, and academic integrity; evaluation of teaching;
– **Profiling and prediction group**: admissions decisions and course scheduling; drop-out and retention; student models and academic achievement.

In this section we presented different roles of AI in developing and using modern, sophisticated, and powerful educational systems recognized by different authors. Despite the fact that various views and opinions exists, it is evident that AI methods will significantly influence the further development of high quality educational ecosystems.

1.3 Some Characteristic Educational Systems Based on AI Techniques

Existing trend of interest and investments in AI, by world leading companies and research centers, democratization of higher education but also experiences with COVID-19 pandemic situation, in the last two years, resulted in significant financial pressure and challenges to propose proper solutions and resolve numerous problems in developing future, more intelligent, educational systems.

Consequently, it is logical to try to employ powerful AI methods to find adequate high-quality solutions [17]. Rather, newly established phenomena of "massive open online courses" (MOOC) allowed an enormous number of students, all over the world, to participate in a broad range of online courses. Apart from numerous advantages of such kind of education, a variety of problems appeared, especially for teachers. Having diverse students from different countries with different ways, habits, and characteristics of learning (pre-knowledge and skills for courses, rates of progress, …) raised emergent problems, such as: providing personalized feedback, assisting students to achieve satisfactory learning outcomes, implementing reliable assessment approaches and criteria [10]. On the other hand, we witness that different research and educational institutions have been developing a range of so-called intelligent, adaptive, or personalized educational systems for different courses [5, 7]. However, it is evident that in majority of cases, these systems are usually part of research projects, realized as proof-of-concept, and are used in real learning environments only for several years, i.e. until the projects end.

Fortunately, there are also positive cases when development and improvements of some systems are part of long lasting research and educational activities in different institutions and countries and they are used in real educational processes and during the years they are constantly evolving while becoming enhanced with additional functionalities [20–22]. Nowadays, such systems gather huge amount of learners' data, and analyze it. As a result, they can significantly impact and influence learners' and teachers' activities.

Rapid development of software, hardware, and data processing strongly influenced the new renaissance era of AI that together with EDM and LA, as well as with sentic computing (including face and emotion recognition), plays an essential role in developing a wider range of applications in sophisticated educational ecosystems. In the rest of this section, we will briefly present several groups of characteristic AI-based educational systems and their essential functionalities.

1.3.1 Adaptive Personalization Systems and Intelligent Tutoring Systems

Development of adaptive and personalized educational systems is highly influenced by learners' learning characteristics, preferences, and styles. Developmental efforts are generally oriented towards achieving the best learning curve, learning effectiveness and efficiency for individual learner. Accomplishment of these functionalities is not an easy task. It requires extra knowledge, and it forces and represents one of the key issues in realization of reliable personalized educational systems. Several examples of such systems will be briefly presented below.

As a result of a large project, the multifunctional educational system—StuDiAsE [23] had been developed. The system supports numerous functionalities based on AI methods like: Learner Diagnosis, Assistance, and Evaluation. It can monitor the comprehension of the learner based on text comprehension theory [24], and it can assess learner's pre-knowledge based on his/her profile, to obtain personalized scaffolding. Additionally, the system can evaluate learning performance and control several factors that influence the learner's motivation. Finally, interaction with the system is based on dialogue theory [25].

Among variety of AI supported educational systems, intelligent tutoring systems (ITS) are probably the most important and dominant [8]. Usually, they support step by step tutorials adjusted to learner's individual style of learning, especially when subjects are presented in the system in well-defined manner. High quality ITSs should generate guidance and adequate hints to learners but also should adjust the level of difficulty of available teaching material and subjects. Typical architecture of an ITS includes three key AI models: domain model, pedagogical model, and learner model. Based on available data from these models, AI algorithms can support adaptation and propose individual/personalized sequences of learning activities and topics.

An interesting web-based ITS is focused on learners' cognitive styles [26]. Cognitive styles of learners in such systems influence teaching material organization and their efficiency and success of learning. Instead of using questionnaires to identify learning styles, an innovative approach is based on a multi-layer feed-forward neural network used to observe learner's browsing behavior.

A personalized intelligent web-based tutoring system is presented in [27]. Apart from support of personalization, the system includes elements of recommendations and collaborative tagging techniques that are based on pedagogical aspects of learning. Employment of collaborative tagging allows increasing of learners' motivation and their better comprehension of the learning content. Selected tag-based recommendation increases the system's capability as it offers an additional functionality to quickly identify supplementary material suitable for learner to improve his/her knowledge. Personalized recommendations in the system should be consistent with the previously acquired knowledge of the learner.

1.3.2 Assessment and Evaluation

With existing intense interest in the applications of AI in education [2, 28], there is also a significant interest in the applications for educational assessment. Recent developments in AI-based educational assessment are increasingly focused on means of improving assessment efficacy and validity. To achieve appropriate results, the primary activity is the analysis of the large volumes of process data, collected from assessment contexts.

In general, AI-based educational tools devoted to learning and teaching usually support some kind of assessment or evaluation of students' knowledge acquisition [29]. However, in the majority of such tools, the pedagogy underlying the educational action is not considered. In this overview paper, different systems based on AI are briefly presented and some characteristic ones are mentioned in the rest of this section. Janpla and Piriyasurawong [30] develop an AI-based software to produce e-learning tests by selecting questions for online examinations. Already mentioned Samarakou et al. [31], proposed StuDiAsE system, which is focused on continuous monitoring and assessment and also includes different aspects of assessment of students' gained knowledge. Applied AI approach proved useful to support personalized feedback and to evaluate performance of engineering students.

An adaptive learning system with self-assessment that also targets students with disabilities, is presented in [32]: "In the next future, we can expect that, within adaptive e-learning systems, both automatic and manual procedures will interoperate to elicit users' interaction needs for ensuring accessibility". Presented "results indicate that the procedure allows students, both disabled and non-disabled, to self-assess and report adequately their preferences to access electronic learning materials".

Completely different approach can be found in [33], where authors focused on simulation-based training in medicine supported by AI. A Virtual Operative Assistant has been developed to provide automatic feedback to students using metrics of performance. In this system, virtual reality and AI were integrated in order to classify students according to their proficiency performance and to support them with adequate feedback to help them to improve their knowledge and skills.

Another system that combines VR and AI, to achieve the assessment of competence in different dental tasks is presented in [34]. Automatically assessing and grading medical students' collection of patient information is presented in [35]. Further, in the paper [36], authors proposed automatic assessment of different kinds of collaboration-based activities built on active learning methods. In the system presented in [37], students automatically receive grades and have possibility to visualize their results as an adequate feedback. The system was used within an AI-based course for teaching AI. Use of intelligent grading systems is frequent used in teaching programming and evaluating students' performance. For instance, automatic assignment of a grade for the task a student performed in programming is described in [7].

An example of different directions in using AI for students' assessment is the ability to automatically evaluate students' essays in English. Liu et al. [13] proposed an AI-based system able to evaluate students' engineering essays in English. Another AI system for formative assessment performs an automatic grading of learners to give feedback and to adapt the specified tasks accordingly.

Effects of the use of e-assessment can also negatively influence students' knowledge evaluation, as reported in [38]. To minimize negative effects, a lot of innovative e-learning platforms have been developed, with range of possible tasks and functionalities, starting from different types of questions but also solving relatively complex programming tasks. Nowadays, some available e- learning platforms support multimodal presentation of teaching materials and collecting students' responses: in-video quizzes or, for example, in [39] authors used specially developed system for "easy authoring, recording, and reviewing interactive multimedia exercises embedded in lecture videos". Students' can make audio/video recordings of their responses and teachers can immediately review these responses.

It is clear that technology enhanced systems based on AI can make learning and assessment more attractive and productive. Very interesting system is presented in [40]. It is a distributed event collection and analysis architecture that enables students to solve practical programming questions during lectures. Students' interactions with the system generate a lot of information about specific tasks/questions. The results of processing of information are visually presented to the teacher during the class. Hence, the teacher can properly react and change style and dynamics of teaching. In this platform the social dimension of teaching and students' results is not considered. Summary of group results of all students for particular question are important, as students can personally assess their position and learning performance comparing to their classmates. Such approach, realized in privacy-preserving way, is offered by MasteryGrids OSSM (Open Social Student Modeling) interface [41]. Personal performances and progress of a student are compared and visually presented with the progress of the class. So, students can see their position within the class and can try more tasks and questions in order to achieve better results.

1.3.3 Intelligent Interfaces in Educational Systems

Human–Computer interfaces (HCI) play important role in communication between user and computer/software application. Through the history of development of ICT technologies, computer hardware and software, wide range of different HCI techniques have been developed. The recent trend is a consequence of rapid development of different forms of personal digital assistants. One of the very popular AI approaches that supports educational processes is using a chatbot [42]. Typical example of such assistant, usually mentioned in the literature, is Apple's Siri [43, 13]. Siri uses advantages of ML and natural speech to answer questions, to return relevant search information, and perform appropriate actions or some other activities. Despite the fact that Siri has a rather simple voice-controlled interface, this project has significant effects on further development of nowadays more complex solutions.

Intelligent software agents and numerous forms of their visualization represent a keystone in the new era of HCI in different areas including educational systems. Various educational systems usually contain a component that facilitate HCI. Modern HCIs enabled communication between the system and user (student and teacher) in more user-friendly and higher in quality. Teacherbots, strongly based on AI methods and techniques for personalized education, provide tailored teaching material, guidance, help, and hints during learning. They also can be seen in another role i.e., as teachers' assistants in organizing teaching material and in providing fast reactions/answers to student's questions.

Another characteristic example is "Jill Watson" (teacherbot based on IBM's Watson platform [44, 15]). It represents affordable, personalized, and intelligent solution for traditional user interfaces, where learners are usually passive consumers of presented teaching material.

While delivering a massive open online course, Georgia Institute of Technology, having a great number of students would like to provide high-quality learning and tailored assistance to them. Without personalized assistance students drop out rate was increasing so they attempted to find a solution to provide personal attention and decided to incorporate in their courses a virtual teaching assistant who will try to reply to a variety of predictable students' questions. To fulfill this task Jill was trained on a comprehensive database containing the students' questions.

In educational field most studies that consider chatbots are focused on individual users. However, another important pedagogical aspect of teaching is students' collaboration and teamwork. To address the collaborative group settings some authors considered alternative approaches [5]. The focus is shifted on how chatbot-mediated learning can improve learning outcomes of students in team-based assignments. For example, David et al. [5] used chatbots to support the teacher, as teaching assistants, in group settings for classroom orchestration improvement. In the paper [9], author presented effects of use of chatbots to facilitate team-based projects. The important conclusion drawn is that chatbots can improve learning performance and a higher quality of collaboration through teamwork. Also, some quality indicators of educational chatbots are proposed which are based on intense research, and they pointed some important aspects such as Pedagogy, Reliability, Usability, and Interactivity.

1.3.4 EDM and LA: The Benefits and the Challenges in Educational Processes

Emergent development and applications of ML techniques opens a new era, and brings many possibilities and challenges for higher education. Educational data mining and learning analytics definitively offer immense benefits and advancements in developing intelligent educational settings.

Siemens and Gasevic [45] defined Learning Analytics (LA) as “the measurement, collection, analysis and reporting of data about learners and their contexts for the purposes of understanding and optimizing learning and the environments in which it occurs”.

Recent research in educational LA is focused on finding an answer for very complex and important questions: what knowledge and skills did student gain (is gaining) and whether and how deeply a student was (is) engaged in the learning process. New methods, approaches and techniques should help in predicting student’s learning outcomes in e-learning environments. LA based on educational data analysis can help teachers, and a range of educational experts to look for students’ online information connected to the learning processes. The goal of LA in online educational settings and computer-supported instruction is to improve the learning experience and the whole learning process.

Apart from analyzing educational data related to teachers and learners, LA methods are used to discover characteristic patterns of learning behavior, in order to improve learning performance and quality. Additionally, interpretation of obtained results and gaining new understandings can offer the educational stakeholders’ new insights to support their decisions and actions directed towards improvements in teaching, learning, and organizational effectiveness [10].

From the point of view of teaching and learning effects, LA helps monitoring and predicting student’s academic performance. It provides opportunity to immediately identify topics in which students might be facing problems and accordingly, to facilitate immediate reactions and interventions that can help preventing poor learning performance [46].

El Alfy et al. [6] analyzed large number of recent papers and pointed out to the potential benefits and challenges that LA can provide for different educational stakeholders. Based on their analysis, numerous benefits and challenges are presented. Identified challenges and benefits of LA are separated into two groups: Management related and Teaching and learning related.

Management related challenges are enlisted in [6]: Lack of staff and technology available to learning analytics projects; Need for custom-made analytics initiatives that is context specific requiring human and structural capacity building; Learning analytics frameworks need to be sensitive to idiosyncrasies of the educational institution and its stakeholders; and Need to foster organizational adoption & cultural change.

Teaching and learning related challenges are enlisted in [6]: Limitation of results of learning analytics is derived from values of aggregate data such as marks in summative assessments.

Management related benefits are enlisted in [6]: Data mining supports decision makers in HEIs to frame norms to improve student enrolment; Learning analytics is highly responsive to real-time learning processes; Learning analytics capability to link library services with institutional objectives and outcomes; Big data and analytics could be used to improve selection of staff and training interventions, cut costs, improve retention, and performance. as well as meet strategic goals.

Teaching and learning related benefits are [6]: Learning analytics overcome key measurement challenges in educational assessments; Developing automated tools that promote accountability and academic integrity in the e-learning environment by analyzing patterns in the student-generated content; Detect which students are lagging behind and the reason of their low levels of engagement in online learning; Aggregate data from multiple courses to detect patterns for remedial actions for students performance; Monitoring students' performance and progress individually as well as in comparison with peers; Provide real time feedback to students about their progress and class engagement through SMS notification; Identify most effective intervention strategies in helping academically at-risk students succeed; Develop predictive models of students' academic performance; Predictors of individual performance in a teamwork context; The ability to demonstrate how the instructor's course preparation and assistance activities affect different dimensions of student engagement activities; Determining student behavior model, prediction of performance, increase self-awareness amongst students, improve feedback on assessment, recommend resources.

1.4 Concluding Remarks

Several important educational domains, where AI methods and approaches are very promising in overcoming current limitations, are pointed out in [3].

– Educational programs supported by AI methods can give learners and teachers a constructive feedback, based on observed learners' progress during learning. They can also notify teachers about learning performance. Scaffolding is frequently part of such systems and can help teachers to improve crucial parts of teaching material and subjects.

– AI tutors can deliver additional support to students—they provide, for both learners and teachers, significant feedback about the success of the learning process. They are especially useful for courses in which exist limitations in teaching high-order creativity and critical thinking.
– Teachers can be supported by AI tutors and can integrate AI teaching material as supplementary, to help weak learners' hands-on experiences in the form similar to human interaction.
– Automation of grading—recent AI techniques cannot truly replace teachers in grading even simple tests or students' homework. Particularly, essay grading is still in preliminary phase but with great tendency to be substantially improved in the future.
– In spite of the fact that still there are limitations in more qualitative online grading, actual grading is performed instantly thus giving teachers access to data immediately.
– AI also allows tailored and personalized teaching. AI powered educational systems can deliver customized lectures to groups of students, freeing teachers to work one-on-one with students who need it the most.

Apart from mentioned benefits of intelligent e-learning environments there are some limitations as well:

– Learning is an inherently cultural process and computers cannot replace the cultural flavor of learning.
– Learning is not only the process of downloading knowledge or passing an examination. Developing a sense of purpose is crucial to self-directed learning and instilling it in others is an absolutely human activity.

Acknowledgements This work has been supported by the joint research project "Agent Technologies in Dynamics Environments" under the agreement on scientific cooperation between University of Novi Sad, University of Craiova, SRI PAS and Warsaw University of Technology, as well as Mirjana Ivanović and Aleksandra Klašnja-Milićević acknowledge financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-68/2022-14/200125).

References

1. DFKI, Intelligent Solutions for the Knowledge Society. The German Research Center for Artificial Intelligence (2015). http://www/dfki.de/web?set_language=en&cl=en. Accessed 30 Oct 2016
2. S. Somyürek, P. Brusilovsky, J. Guerra, Supporting knowledge monitoring ability: open learner modeling vs. open social learner modeling. Res. Pract. Technol. Enhanc. Learn. **15**(1), 17 (2020)
3. M. Fahimirad, S.S. Kotamjani, A review on application of artificial intelligence in teaching and learning in educational contexts. Int. J. Learn. Dev. **8**, 106–118 (2018)
4. T. Baker, L. Smith, Educ-AI-tion rebooted? Exploring the future of artificial intelligence in schools and colleges (2019). Accessed from Nesta Foundation website: https://media.nesta.org.uk/documents/Future_of_AI_and_education_v5_WEB.pdf

5. B. David, R. Chalon, B. Zhang, C. Yin, Design of a collaborative learning environment integrating emotions and virtual assistants (chatbots). In: *2019 IEEE 23rd International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (IEEE, 2019), pp. 51–56. https://doi.org/10.1109/CSCWD.2019.8791893
6. S. El Alfy, G.J. Marx, A. Dani, Exploring the benefits and challenges of learning analytics in higher education institutions: a systematic literature review. Inf Discov Delivery (2019). https://doi.org/10.1108/IDD-06-2018-0018
7. F. Grivokostopoulou, I. Perikos, I. Hatzilygeroudis, An educational system for learning search algorithms and automatically assessing student performance. Int. J. Artif. Intell. Educ. **27**, 207–240 (2017). https://doi.org/10.1007/s40593-016-0116-x
8. W. Holmes, M. Bialik, C. Fadel, *Artificial Intelligence, in Education: Promises and Implications for Teaching and Learning* (Center for Curriculum Redesign, Boston, 2019)
9. J.A. Kumar, Educational chatbots for project-based learning: investigating learning outcomes for a team-based design course. Int. J. Educ. Technol. High. Educ. **18**(1), 1–28 (2021). https://doi.org/10.1186/s41239-021-00302-w
10. O.P. Pardo, R. Martinez-Maldonado, S. Dawson, Provision of data-driven student feedback in LA&EDM. Handb. Learn. Anal. 163–174 (2017). https://doi.org/10.18608/hla17.014
11. W.H. Dai, S. Huang, X. Zhou, X.E. Yu, M. Ivanovic, D.R. Xu, Emotional intelligence system for ubiquitous smart foreign language education based on neural mechanism. J. Inf. Technol. Appl. Manage. **21**(3), 65–77 (2014). http://www.dbpia.co.kr/Journal/ArticleList/159833
12. M. Ivanović, D. Mitrović, Z. Budimac, L. Jerinić, C. Bădică, HAPA: harvester and pedagogical agents in e-learning environments. Int. J. Comput. Commun. Control **10**(2), 200–210 (2015). ISSN 1841-9836
13. M. Liu, Y. Wang, W. Xu, L. Liu, Automated scoring of Chinese engineering students' English essays. Int. J. Distance Educ. Technol. **15**, 52–68 (2017). https://doi.org/10.4018/IJDET.2017010104
14. C.W. Okonkwo, A. Ade-Ibijola, Chatbots applications in education: a systematic review. Comput. Educ.: Artif. Intell. **2**, 100033 (2021). https://doi.org/10.1016/j.caeai.2021.100033
15. R. Luckin, W. Holmes, M. Griffiths, L.B. Forcier, Intelligence unleashed - an argument for AI in education (2016). Accessed from http://discovery.ucl.ac.uk/1475756/
16. I. Tuomi, M. Cabrera Giraldez, R. Vuorikari, Y. Punie, *The Impact of Artificial Intelligence on Learning, Teaching, and Education* (Publications Office of the European Union, 2018). https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/impact-artificial-intelligence-learning-teaching-and-education
17. J. Grove, TeachHigher "disbanded" ahead of campus protest. Times Higher Education, 2 June 2015. http://www.timeshighereducation.com/news/teachhigher-disbanded-ahead-campus-protest. Accessed 28 Apr 2017
18. A. Klasnja-Milicevic, B. Vesin, M. Ivanovic, Z. Budimac, L.C. Jain, *E-Learning Systems - Intelligent Techniques for Personalization.* Intelligent Systems Reference Library vol. 112 (Springer, 2017), pp. 3–294. ISBN 978-3-319-41161-3
19. A. Klašnja-Milićevic, M. Ivanović, E-learning personalization systems and sustainable education. Sustainability **021**(13), 6713 (2022). https://doi.org/10.3390/su13126713
20. J. Barria-Pineda, K. Akhuseyinoglu, S. Zelem-Celap, P. Brusilovsky, A. Klasnja-Milicevic, M. Ivanovic, Explainable recommendations in a personalized programming practice system, in *Artificial Intelligence in Education - 22nd International Conference, AIED 2021, Utrecht, The Netherlands, June 14–18, 2021, Proceedings, Part I*. LNCS, vol 12748. (Springer, 2021), pp. 64–76. ISBN 978-3-030-78291-7
21. M.J. Laakso, E. Kaila, T. Rajala, ViLLE - collaborative education tool: designing and utilizing an exercise-based learning environment. Educ. Inf. Technol. 23(4), 1655–1676 (2018)
22. A. Rodriguez-Ascaso, J.G. Boticario, C. Finat, H. Petrie, Setting accessibility preferences about learning objects within adaptive elearning systems: user experience and organizational aspects. Expert Syst. **34**, e12187 (2017). https://doi.org/10.1111/exsy.12187
23. A.T. Quadri, N.A. Shukor, The benefits of learning analytics to higher education institutions: a scoping review. Int. J. Emerg. Technol. Learn. (iJET) **16**(23), 4–15 (2021). https://doi.org/10.3991/ijet.v16i23.27471

24. G. Denhiere, S. Baudet, *Lecture, Comprehension de Texte et Science Cognitive* (Presses Universitariesde France, 1992)
25. A. Collins, B. Beranek, *A Sample Dialogue Based on a Theory on Inquiry Teaching*, University of Illionosi at Urbana- Cpampaign (1986)
26. L. Jia-Jiunn, C. Ya-Chen, Y. Shiou-Wen, Designing an adaptive web-based learning system based on students' cognitive styles identified online. Comput. Educ. **58**(1), 209–222 (2012)
27. A. Klasnja-Milicevic, M. Ivanovic, B. Vesin, Z. Budimac, Enhancing e-learning systems with personalized recommendation based on collaborative tagging techniques. Appl. Intell. **48**(6), 1519–1535 (2018)
28. G. Siemens, D. Gasevic, "Guest editorial-learning and knowledge analytics. Educ. Technol. Soc. **15**(3), 1–2 (2012)
29. V. González-Calatayud, P. Prendes-Espinosa, R. Roig-Vila, Artificial intelligence for student assessment: a systematic review. Appl. Sci. **11**, 5467 (2021) https://doi.org/10.3390/app11125467
30. S. Janpla, P. Piriyasurawong, The development of an intelligent multilevel item bank model for the national evaluation of undergraduates. Univers. J. Educ. Res. **8**, 4163–4172 (2020). https://doi.org/10.13189/ujer.2020.080942
31. P. Rhienmora, P. Haddawy, S. Suebnukarn, M.N. Dailey, Intelligent dental training simulator with objective skill assessment and feedback. Artif. Intell. Med. **2011**(52), 115–121 (2011). https://doi.org/10.1016/j.artmed.2011.04.003
32. S. Popenici, S. Kerr, Exploring the impact of artificial intelligence on teaching and learning in higher education. Res. Pract. Technol. Enhanc. Learn. (2017). https://doi.org/10.1186/s41039-017-0062-8
33. J. Maderer, *Artificial Intelligence Course Creates AI Teaching Assistant*, Georgia Tech News Center, 9 May 2016 (2016). https://news.gatech.edu/news/2016/05/09/artificial-intelligence-course-creates-ai-teaching-assistant, Accessed 10 Aug 2021
34. M. Pérez-Sanagustín, I. Hilliger, C. Alario-Hoyos, C.D. Kloos, S. Rayyan, H-MOOC framework: reusing MOOCs for hybrid education. J. Comput. High. Educ. **29**(1), 47–64 (2017)
35. R. Luckin, Towards artificial intelligence-based assessment system, Nat. Human Behav. **1**(0028) (2017)
36. E. Kaila, E. Kurvinen, E. Lokkila, M.-J. Laakso, Redesigning an object-oriented programming course. ACM Trans. Comput. Educ. **16**, 1–21 (2016). https://doi.org/10.1145/2906362
37. A.K. Goel, D.A. Joyner, Using AI to teach AI: lessons from an online AI class. AI Mag. **38**, 48–59 (2017). https://doi.org/10.1609/aimag.v38i2.2732
38. V. Triglianos, M. Labaj, R. Moro, J. Simko, M. Hucko, J. Tvarozek, C. Pautasso, M. Bielikova, Experiences using an interactive presentation platform in a functional and logic programming course, in *Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization* (ACM, New York, 2017), pp. 311–316
39. J. Kim, E.L. Glassman, A. Monroy-Hernández, M.R. Morris, Rimes: embedding interactive multimedia exercises in lecture videos, in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (ACM, New York, 2015), pp. 1535–1544
40. M. Samarakou, E.D. Fylladitakis, D. Karolidis, W.-G. Früh, A. Hatziapostolou, S.S. Athinaios, M. Grigoriadou, Evaluation of an intelligent open learning system for engineering education. Knowl. Manag. E-Learn. An Int. J. **2016**(8), 496–513 (2016). https://doi.org/10.34105/j.kmel.2016.08.031
41. P. Brusilovsky, S. Somyürek, J. Guerra, R. Hosseini, V. Zadorozhny, The value of social: Comparing open student modeling and open social student modeling, in *International Conference on User Modeling, Adaptation, and Personalization* (Springer, Cham, 2015), pp. 44–55
42. K.R. Maicher, L. Zimmerman, B. Wilcox, B. Liston, H. Cronau, A. Macerollo, L. Jin, E. Jaffe, M. White, E. Fosler-Lussier et al., Using virtual standardized patients to accurately assess information gathering skills in medical students. Med. Teach. **41**, 1053–1059 (2019). https://doi.org/10.1080/0142159X.2019.1616683

43. N. Bostrom, E. Yudkowsky, The ethics of artificial intelligence, in *Cambridge handbook of artificial intelligence*. ed. by K. Frankish, W.M. Ransey (Cambridge University Press, 2011), pp. 316–334
44. Deakin University, IBM Watson now powering Deakin. A new partnership that aim to exceed students' needs (2016). http://archive.li/kEnXm. Accessed 30 Oct 2016
45. M. Samarakou, E.D. Fylladitakis, W.G. Früh, A. Hatziapostolou, J.J. Gelegenis, An advanced elearning environment developed for engineering learners. iJET **10**(3), 22–33 (2015)
46. N. Mirchi, V. Bissonnette, R. Yilmaz, N. Ledwos, A. Winkler-Schwartz, R.F. Del Maestro, The virtual operative assistant: an explainable artificial intelligence tool for simulation-based training in surgery and medicine. PLoS One **15**, e0229596 (2020).https://doi.org/10.1371/journal.pone.0229596
47. I. Tuomi, The use of Artificial Intelligence (AI) in education, May 2020 (2020). https://bit.ly/3lCMotK, Accessed July 15
48. E. Wood, L. Zivcakova, P. Gentile, K. Archer, D. De Pasquale, A. Nosko, Examining the impact of off-task multi-tasking with technology on real-time classroom learning. Comput. Educ. **58**(1), 365–374 (2012)
49. O. Zawacki-Richter, V.I. Marín, M. Bond, F. Gouverneur, Systematic review of research on artificial intelligence applications in higher education–where are the educators? Int. J. Educ. Technol. High. Educ. **16**(1), 1–27 (2019)

Recommended for Further Reading

50. U.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2021* (Springer, Germany, 2021)
51. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2020* (Springer, Germany, 2020)
52. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2019* (Springer, Germany, 2019)
53. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2018* (Springer, Germany, 2018)
54. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2017* (Springer, Germany, 2017)
55. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2016* (Springer, Germany, 2016)
56. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2015* (Springer, Germany, 2015)
57. M. Ivanovic, L.C. Jain, (eds.), *E-Learning Paradigms and Applications* (Springer, Germany, 2014)
58. L.C. Jain et al. (eds.), *Evolution of Teaching and Learning Paradigms in Intelligent environment* (Springer, Germany, 2007)
59. C. Ghaoui et al. (eds.), *Knowledge-Based Virtual Education* (Springer, Germany, 2005)
60. L.C. Jain et al. (eds.), *Virtual Environments for Teaching and Learning* (World Scientific Publishing Company Singapore, 2002)
61. L.C. Jain (ed.), *Innovations in Teaching and Learning* (Springer, Germany, 2000)

Chapter 2
Digitalization of Education

Đorđe Nadrljanski, Mila Nadrljanski, and Mira Pavlinović

Abstract This paper discusses features and diversity of concepts and initiatives for digitalization in education. It also briefly discusses the advantages and challenges related to development of digitalized environments in education, as well as greater need for professional development of people working in digitalization. In addition, they encourage and promote innovation in many different spheres of life. The innovative capacity of technology is highly conditioned by the levels of digital skills of the population. It is not surprising that there is a very strong link between education and skills needed to utilize digital technologies in different spheres of life. An efficient, diverse, and strong higher education sector and research system will help the higher education sector to achieve this goal in the best possible way. Universities and faculties manage a significant portion of community resources and must use those resources effectively and for the benefit of society. Institutions will develop their positions according to their strengths and individuality and will contribute to higher quality and to other sectors of society. Furthermore, they will meet the needs of society in various fields and help each country to internationally affirm itself as an outstanding knowledge society. Digitalization is a tool for making fundamental changes in the processes, content, and various forms of work, which can put the education sector in a better position to achieve the goals of education and research, to increase quality and relevance in the approach to education for all. The time when experts talked about education technology in terms of audio, visual and experiential technology has passed. They also talked about hardware technology, software technology and a system based on technology. These are expressions from the past, as

Đ. Nadrljanski (✉) · M. Nadrljanski
College of Inspection and Personnel Management of Maritime Studies, 209 Zrinsko Frankopanska, 21000 Split, Croatia
e-mail: dekan@vsikmp.hr

M. Nadrljanski
e-mail: mila@pfst.hr

M. Pavlinović
Faculty of Maritime Studies, University of Split, 37 Ruđera Boškovića, 21000 Split, Croatia
e-mail: mira.pavlinovic@pfst.hr

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_2

the old concepts in the field of educational technology or EdTech have been outdated during the last decade.

Keywords Digitalization · Digital skills · Higher education · Educational technology

2.1 Introduction

In everyday life, the Internet, mobile technologies, and online communities have significantly reshaped the way we educate ourselves, which is the key to the efficiency. Thus, for technologies such as robotics, connectivity, and machine learning to be sustained, organizations must be able to develop a digital culture that supports digital transformation. Many technologies are still at the beginning of their development and much more needs to be done to ensure that they are used in the most responsible and positive way for a healthy development of students. This development will continue to be monitored and an insight and recommendations on how best to incorporate digital (connected) tools into schools will be provided.

The aim of this paper is to distinguish between the research field of digitalization and the role of educational technology as an interdisciplinary field used for digitalization, and to provide an answer for the research questions what makes good educational software. This paper also analyses educational software, software programs that serve to support teachers and improve learning outcomes. The aim is to distinguish the field of research on digitalization and educational technology as an interdisciplinary field and to show some of the methods used for research questions arising from the concept of what makes good educational software.

2.2 Digitalization of Education

The modern scientific and technological revolution is radically changing all spheres of society. Informatization, as a civilizational process, is changing especially quickly and has affected all segments of people's lives and work, including education systems. Modern education, according to many scientists, is oriented towards the achievements of complete and overall digitalization. People will need to have the right digital education in the near future (already today) to be successful in their future workplace. They can get this type of education at school, university or at work.

The ongoing digital transformation[1] is making information technology education increasingly important on a daily basis. One important reason for this is that digital media provides new opportunities for digital learning. Digital education will allow everyone to continue participating in the real world in a certain way in the future.

[1] Many mistakenly confuse digital transformation with other applications of information technology in work and personal life.

Modern software will also enable the progress in terms of which educational content has been mastered and which areas still need further education. The advantage of new technologies and methods of work can be personalized, focusing on the development of the potential of each individual. Despite all the changes that occur after the digital transformation, the function of education remains unchanged: it should be possible for people to develop as individuals and allow them to participate responsibly in social, political, and economic life. Therefore education, that is developed on the basis of the latest technology is needed. In order for digital education to achieve the set tasks, the teaching staff at all levels must be educated and modernized. Digital education requires well-trained staff who are able to use digital media to convey relevant information to pupils, students, and trainees.

It is important that these efforts are practical, with an emphasis on the needs of reality. Many of the recent educational research has focused on teaching and learning within classroom conversations. This raises questions of the role of digitalization in supporting such conversations. The main hypothesis of this paper is that the nature of computers is dual– they are machines that can act as human beings (subjects), and this allows them to play a potentially recognizable and valuable role in educational conversations. In the world, the digitalization of education is closely linked to the changed way of life and work in the digital environment and the emergence of generations who were born and study in this particular environment. The authors plan to conduct scientific and professional research on digital education that will facilitate the education of the next generations, which would achieve an optimal potential and develop a culture of lifelong learning. This would prepare individuals to work to meet global challenges and achieve a more inclusive and contemporary society. It is expected that the planned research will, at the global level, enable effective approaches to digital education to support individual's educational ambitions. This will be achieved in the next period over the next three years through the implementation of the following activities contained in the planned development strategy:

- Investigate the impact of changes in the field of digitalization on national and international education policies in particular digital education;
- Plan recognised research methods focused on the higher education sectors as well as learning on a workplace;
- Apply a portfolio of recognizable interdisciplinary research, aligned with major university challenges, that reflects the underlying reality;
- Collaborate with leading domestic and international researchers on digital education;
- Increase the effectiveness and efficiency of digital education practices, taking into account the perspectives of all stakeholders;
- Develop outstanding graduates and scientists at the forefront of research and innovation in digital education.

The digitalization of education is a science-based trend towards reforming and modernising global education system. Digitalization means the transformation of all types of information (texts, sounds, visual materials, video, and other data from various sources) into digital language.

Digital transformation is a long process of creating a "digital university organization" in which most processes are performed without any human participation. The specifics of the functioning of the university in the context of digital transformation are as follows:

- Creation of special units related to digital technologies within the management structure of the university.
- Conducting an online university survey with students on the use of distance education technology.
- Exploring the possibilities of using mobile digital devices to access electronic databases of university employees, students, and professors.
- Analysing the strategies and methodologies on the use of digital resources for the implementation, regulation, and control of educational processes.
- Observing the speed of interaction between teaching staff and students and other users of educational services using digital technology.
- Realization of new possibilities for organizational and social interactions between university staff and students of educational process.
- Identifying positive activities, aspects, and problems of the use of digital technology in university education.
- Examining the mastery of modern digital devices and software, as well as the ability to apply digital technologies in practice management, are mandatory competencies for all participants in the educational process [7].

Many universities have been using digital technologies for more than 10 years, such as electronic timetables, electronic library system, electronic educational resources (portals). On one hand, this facilitates the process of interaction between students and teachers [11]. Today's students, as digital users of educational services, see the following advantages of using digital technologies: the ability to listen to lectures by leading scientists and practitioners from other universities and countries, save time for education and training, learn in an easier and more understandable way, learn anywhere in the world, receive the most relevant knowledge all day long, anywhere in the world. They believe that continuous learning is much more interesting and enables the acquisition of competitive specialist skills.[2] However, the use of distance learning education technologies does not guarantee the participation of students in the learning process [12] and/or the achievement of high results [10], while changes do not occur only by establishing contact [5]. The factors that have an influence on forming the prestige and competitiveness of a university are dependent on the loyalty of students, which is reflected in their information about the provision of educational services and students' recommendations to their friends and acquaintances.

Digital innovations have opened up new opportunities for innovations in all spheres of life and work, especially as opportunities that enable entirely new forms

[2] Ibidem op. citatum.

of interaction. Digitalization differs from previous paths of technological innovations, with internal and external collaboration, and innovation platforms forming best practice management mechanisms. Digital transformation is penetrating the industry, many social organizations, and education is no exception. The goal for accomplishing this is to meet the expectations and new learning needs of today's students. They play a key role in the digital transformation of education service providers.

All over the world, digitalization in education is closely linked to the new way of life in the digital environment and to the emergence of new generations born and studying in a particular environment. To be successful in the workplace in the future, students will need to have the right digital education. Whether at school, university, or work—the ongoing digital transformation is making IT skills more and more important. The methodological transformation of the educational process itself, as an integral part of the digital transformation, should not be neglected. We are confident that the education system will be able to respond to the challenges of digitalization and seize the opportunities it provides, but a new comprehensive approach is needed. New possibilities for rapid data assessment enable the adaptation of learning content and methods to the individual needs of pupils and students. Intelligent software can guide their progress and identify which educational content is mastered and which areas still need traditional teaching. In this way, educational processes can be personalized, focusing on developing the potential of individual students. The condition for change is not only what is taught, but also methods of how to learn.

Whether digital platforms, virtual or augmented reality, online libraries or webinars are involved, the fact is that digital media enable many new and innovative forms of teaching and learning in schools, vocational institutions, and universities, as well as in corporate training and development programs for already employed. We believe that digital learning means more than the digitalization of existing educational materials. Digitalization in education will enable transformed forms and contents of communication, cooperation, and networking. As digital teaching is not tied either to time or place, it is more flexible, individualized and more mobile than previous forms and ways of learning. This means that in digitalization, learning content is created, shared with others, and developed together in the cloud or in the fog. With digital education, students accept greater personal responsibility at an early age, and at the same time improve communication and teamwork. Modern technology affects societies around the world and creates new opportunities and challenges, and its role in education is becoming increasingly important. Digitalization differs from previous technological innovation solutions, with internal and external collaboration and innovation platforms that form best practice management mechanisms. Digitalization in education in addition to the technological component has a crucial role in transforming the educational process. Digitalization in education is a great opportunity, but also a challenge in terms of proper use, which implies critical thinking, and by no means superficiality and mere consumerism.

The paper also deals with pedagogical possibilities and effects of education in the electronic environment. A variety of applications is found in digital media in education: from curricula and learning and training programs, databases and tools, through learning games, experiments and simulations to complex communication and cooperation environments. Special attention is paid to the following topics: work with young people; vocational education; training; adult education (lifelong learning); pupils and students; teachers; school management; parents; use of the Internet and educational platforms; digital media in teaching; using digital media at home; computer use and professional successes; methodological problems.

Media characteristics, learning prerequisites, didactic design and learning culture.

Mastering the media is not relevant during the school period, but is especially important in the early childhood development phase. From the initial observation of the media as auditory and visual sources of challenges, through the development of media desires and preferences as well as the first forms of independent media management to active work with the media, different stages of children's media use can be monitored. The first contacts are in the parental home, and they largely depend on the level of parents' education. There, children should be trained to use the media as places of non-formal learning, as a means of mastering the world and as a subject of critical assessment, from which they will benefit in organizing their own lives. This requires, structurally, the improvement of media and pedagogical education of educators, as well as the close connection of family media education and professional improvement of media competence in pedagogical institutions. The amount of time children and teens spend on digital technology inside and outside of school has a significant impact on their learning in the classroom and on their physical and mental well-being. In youth, this leads to various forms of media use, which in turn is conditioned by the level of education. For teenagers, the media represent places of non-formal learning outside of institutionalized learning processes. They use media for orientation in the development of their personality, as a source of information and knowledge and for developing media competence. The disproportionate ability of young people to use information and knowledge or to be actively and creatively introduced into some youth cultures certainly contribute to the widening of the knowledge gap between educated and less educated young people. An important task of young people's extracurricular activities is therefore to prepare the conditions and opportunities for young people to gain experience related to the media and to try out different opportunities that media offer. The work in the media proved to be particularly successful. For professional education, a special task is set to analyse and think about the penetration of digitalization into the systems of work and the change of tasks that arise from it. This penetration is increasingly affecting the disappearance of the boundaries between work and learning. The focus is no longer on mastering a work system, but on developing the ability to solve problems in the work process with the help of digital technologies. Training processes are subject to special conditions, e.g. in the organization as part-time studies, as part-time learning, or leisure training. It is understandable that the possibilities of digital media are used here, especially the Internet and specialized platforms to provide support in such learning processes. In addition to training, there is a need in adult education to, for example in social, cultural, primary and language education, improve the involvement of digital media as a cultural technique and as a prerequisite for social engagement. In particular, those adults who are not involved in professional development must be given a wide opportunity to acquire competencies that will enable them to actively participate in social life and have independent access to educational tools. Until now, these issues have not been sufficiently clarified, starting from the development of specific didactics suitable for encouraging and improving the development of competence in network-based learning processes, through the proportional preparation of standard training topics to the educational profiles of relevant trainees. An important although not a sufficient prerequisite for a successful work with digital media in education is a positive basic attitude towards new media. One such attitude can be understood by indicators of subjective opinion about the importance of working on a computer, interest in the computer, the social significance of the computer for everyday and professional life and possible positive or negative influences.

Many studies show that students in most countries have a very positive basic attitude towards digital media. This is true in international comparison, where there are certainly clear differences between boys and girls, in favour of boys. In addition to the growing social relevance of computers and the necessity to use them competently, for students the hope of improving teaching, i.e. learning and possible professional needs are important aspects, that affect both the importance of digital media and the open basic attitude towards them. If we look at students and their attitudes towards digitalization, then we notice that they assess the intermediary function of digital media as absolutely useful, this is especially true of learning programs, but they are more suspicious about improving motivation and individualization. However, their attitude, as in other groups, depends on their own experience. This partially restrained assessment of students may be an expression of the not yet fully proven use of digital media in teaching in colleges. To sum up, we can conclude that the actors participating in education in the world show a very positive basic attitude and basic mood regarding the social importance of digitalization and its application in teaching.

Parents on a broader level see digitalization as an opportunity and a benefit for the didactic area to support learning processes, but they are particularly critical and concerned about the Internet in terms of media education. However, parents generally, as can be read in various studies, give great importance to digital media for everyday life and profession, and believe that the school must also train children to work on a computer. In recent years, the number of parents who have set this task as an obligation has been growing.

Regarding the use of computers and the Internet in teaching, if everything is taken into account, it is not yet possible to talk about the evident integration of digital media in teaching, although the indicators of use in recent years are on the rise. In primary schools, the use of computers is more common, primarily in language and mathematics teaching, as well as in extracurricular activities, where teaching software and multimedia lexicons are used. In upper grades, digital media are more often used in the teaching of informatics, in extracurricular activities, in teaching of technical subjects, natural science subjects and economic subjects. As far as software is concerned, tools, presentation programs and programming languages are primarily used. In vocational schools, a special role in frequent use play the crafts, technical subjects, and informatics, and accordingly, the software specific to the appropriate

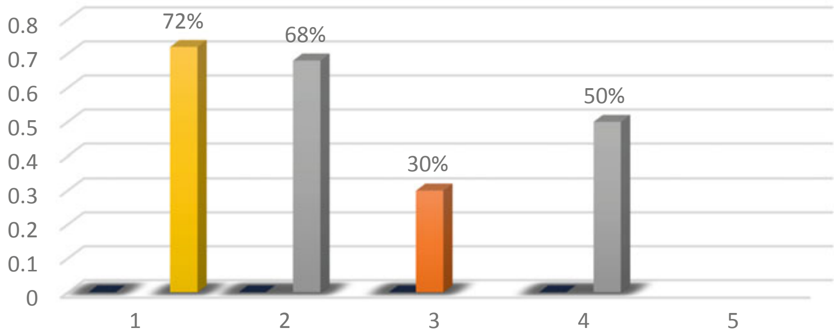


Fig. 2.1 Empirical data on the usage of the computer depending on the type of educational institution

profession is used. Compared to other types of schools, there are more available software packages. In 2018, half of the teaching staff often or occasionally use the computer in teaching, one third of the teachers frequently or occasionally use the Internet in general education schools.[3] The teachers, however, state that they want to use the media more in the future. Despite the fact that 72% of them want to use the Internet more often, and 68% want to work with a computer more often, still about 50% of them have not used digital media in teaching at all. The empirical data show that, depending on the type of educational institution, a group of 10 to 30% of teachers regularly use digital media in teaching. This group also represents the main user of online tolls for teachers. Over 90% of them use the computer due to the advantages it provides every day or several times a week for the preparation of classes and for after-school work, and more than half of them use a computer daily or several times a week in class. A graphical illustration to show the application of the computer is given in Fig. 2.1.

In contrast to the still relatively insufficient use of digital media in teaching, children and young people at home often use a computer. In 2018, it was found that 38% of children between the ages of 6 and 13 regularly use a computer (at least once a week) at school, and 86% of them use a computer regularly at home. Thus, 32% of young people use a computer every day or several times a week at school, and 76% used the computer at home with the same frequency.[4] Home use is not, however, limited to extracurricular activities, but also includes learning activities for school. The data from national research are also confirmed by international research in which the Republic of Croatia also takes part. If regular school usage (i.e. mostly every day or several times a week) is taken as a criterion, then Croatia, in the case of 15-year-old pupils, ranks last in comparison to the OECD member states.

Compared to other OECD member states, with above-average frequent home use, Croatia shows a great difference between school and home use of digital media. In

[3] The research was conducted by the authors in the area of Split, the Republic of Croatia.

[4] The study was carried out by the authors on a sample of primary school pupils in Split, the Republic of Croatia.

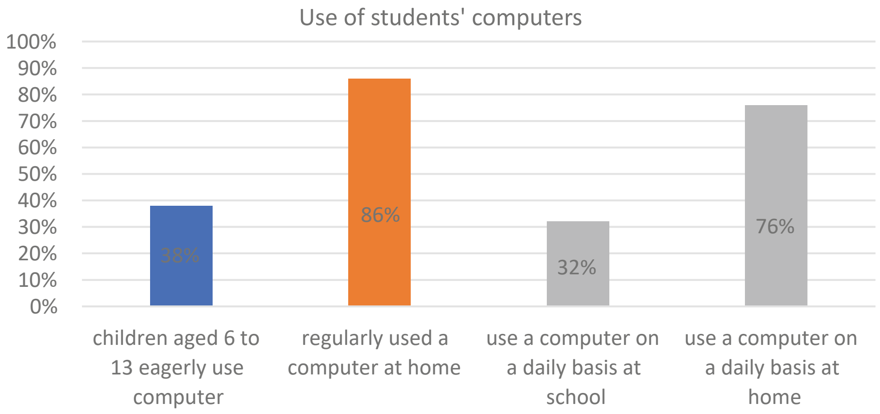


Fig. 2.2 Computer usage of primary school pupils in Split

addition to high expectations regarding the potential of digital media that enhance learning, the question of their effects also arises. At the same time, various levels can be noticed in which these influences are reflected: successes in the profession, professional competencies, changes in the teaching culture and aspects of school development. All data require a careful approach in two ways: on the one hand, correlations do not yet show anything about causal relationships, and, on the other hand, the research-methodological problem is that only bivariate relationships are often observed, which can be presented differently if influencing factors are considered to be control variables. Which models of analysis are finally appropriate is a question that needs to be clarified by research and methodology of research. Now, in any case, the cognitive hypotheses of research can be formulated on the basis of the mentioned connections (Fig. 2.2).

Much more detailed insight into the teaching processes of digital media is allowed by scientific studies of a typical individual case, in which not only the outcome but also the learning processes themselves are the subject of research. Such way of gaining information undermines the representativeness. Namely, such individual case studies show that digital media do not exacerbate the success of students in the profession, as it can be improved in some parts of certain areas. This can be applied to partial competencies in mathematics or to various aspects of success in system writing. Particularly high-quality studies indicate that the question of success in learning does not depend in large part on the extent of the characteristics of the used media, the prerequisites for student learning and the didactic design of teaching. The results of such studies, which tend to report negative impacts on learning success, show in the analysis of teaching activities that partial artifacts can arise, e.g. by shortening the explanation of professional content in favour of dealing with media-specific interests, and lead to misconceptions.

New media are demanding and accelerating the change of teaching. Many studies point in particular to a change in understanding of the role of the teacher. Instead

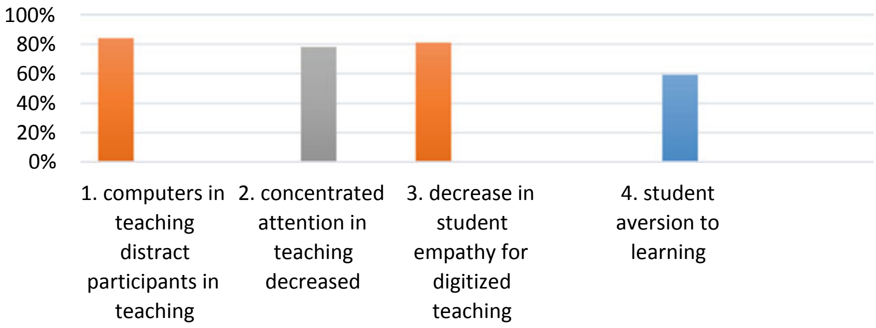


Fig. 2.3 Evaluation of computer application in teaching

of the role of transmitter of teaching messages, the teacher gets the function of an advisor and a moderator. In this regard, changes in teaching patterns are described. In a narrower sense, such models refer primarily to typical teaching activities with digital media, e.g. the application of training and checking software, the use of the Internet for search or cooperation, etc. But in a broader sense, these forms of work relate to how teachers in principle understand the design and delivery of teaching.[5] Thus, case studies of individual cases, such as those related to learning with a laptop (tablet), show that changes in the teaching culture are closely related to routine models of teaching procedures in practice. Those teachers who perform student-centred teaching using a laptop, notice fewer changes than those who hold fast to the teaching process in whose centre the teacher is. Efficient integration of new media succeeds mostly for teachers who contribute to the interaction of media content, learning predispositions and social forms with their teaching style. During the interviews, the respondents were asked to describe the key aspects needed to achieve the goal of digitalization in their school. At the school leadership level, the core of digitalization was linked to changes and transformations in teaching and learning. As shown in the following research (Fig. 2.3) and practice, digitalization processes are limited to the application of digital technologies without pedagogical and organisational changes. This paper provides an overview of the evidence of the authors from the research and evaluation studies related to digitalization, but also to broader higher education practices. It is argued that the use of ICT alone does not result in improved educational outcomes and ways of teaching:

1. computers in teaching distract participants in teaching 84%
2. concentrated attention in teaching decreased 78%
3. decrease in student empathy for digitalized teaching 81%
4. student aversion towards learning 59%

Little has been written and researched about specific teaching methods and/or challenges in teaching twenty-first century competencies. With the entry of digitalization into the field of education, it is not clear whether technology has helped

[5] The study was carried out by the authors on a sample of primary school pupils in Split, the Republic of Croatia.

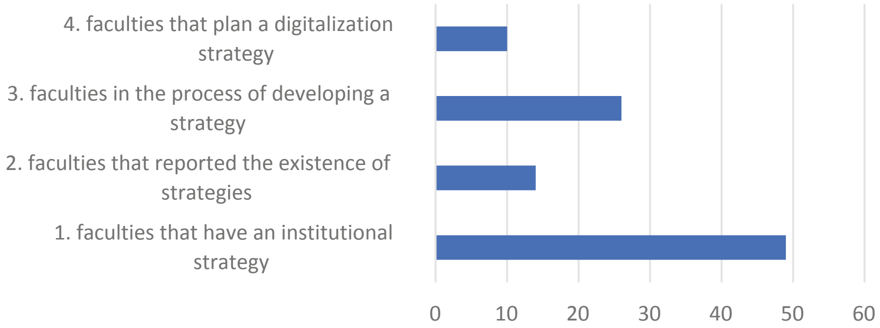


Fig. 2.4 An example of institutions having a digitalization strategy

to remove, or the removal of barriers has itself become another obstacle in integrating competencies. Gaining a teacher perspective is key to understanding barriers as well as solutions to mitigate barriers through innovative teaching methods applied worldwide through digital or non-digital platforms. The need for genuine teacher contributions exists in this area as an obstacle to the twenty-first century education and the role of digitalization. Digitalization is only successful when we have changed the way we teach (Fig. 2.4).

Gaining a teacher perspective is key to understanding barriers, as well as solutions to alleviate barriers through innovative teaching methods that emphasize the importance of the science-teaching process and the importance of placing students at the centre of all activities. The mission of the teacher changes from a mere transmitter of information to a conductor and organizer of a learning situation. To achieve this, several methods must be combined, which require a balance between theoretical and practical teaching. They can also be used to perform complementary activities. A pilot research on how digitalization is evolving, as a potential factor in colleges, reinforces the idea that digitization is directed towards technical development, often characterized by the first steps of change and development towards digitalization of education. Almost half of the institutions stated that they have an institutional strategy (49%), while only 14% reported the existence of strategies at the faculties. Just over a quarter (26%) said they were in the process developing a strategy. 10% of the faculties have a plan to develop digitalization strategy.

The digitalization of education includes various aspects of quality, from organizational issues, technological infrastructure to pedagogical approaches. Digital learning and education are just as important as formal education, although a much larger amount of information is available through digital learning. In addition, as digitalization moves forward as a key concept in higher education institutions, it also encompasses quality issues in many ways.

The essence of this part of the project is mapping and discussion on digitalization in teaching and learning in higher education institutions, which is understood as an external and internal process.

Digitalization initiatives have problems in achieving sustainability in schools, and the application and the use of technology largely supports previous practices and do not lead towards the change and development. The research based on evidence of digital transformation in teaching practices is often small-scale, and processes are often led and dependent on individual enthusiasts.

Education should not only be based on theory, as it is easier for educators when working with a larger number of students, but it must also be in line with the balance of practical knowledge and skills needed to start a profession. In the context of education and digitalization, transformations could be shaped as new knowledge and practices of teaching, learning, communicating, and organizing work in schools and at universities.

The concept of transformation in this paper is broken down into smaller analytical units. In short, the conceptualization of digitalization that emerges through smaller steps allows the analysis of gradual digitalization, although it may not result in a complete transformation in education. The analytical focus in this paper is how teachers, education leaders and educational technologists understand the object of digitalization, how educational institutions implement digital and educational changes, and how new practices and infrastructures emerge as a part of digital transformation in education. This, in turn, is expected to contribute to solutions at different levels of learning, and thus to transformation steps in school.

According to current research, changes should happen every 5 years because they are already permanent and rapid. They should then be applied in education, in line with future labour market needs, through communication with employers and companies that are a part of the labour market for future professionals. As discussed in the research, digitalization processes are often limited to the application of digital technologies, without interfering with teaching and learning practices or organizational infrastructures to support digitalization [4].

The need for research is in line with occupations that will disappear in the near future. Students will not be educated for occupations that will not be needed in the society in the future, according to the development of digitalization. Professors will not lose their jobs as they will shift to new subjects to teach or improve certain profiles in line with the development of digitalization. This fact has an influence of the application of digitalization of adult education. This means that those who have to retrain must master the process of digitalization of education, and later apply it to their jobs. Digitalization and the use of tools facilitate learning and presentation, speeding up the process of solving tasks that can be solved by more students at the same time. It also facilitates the process of examining tasks, and it is possible to show a video of many phenomena and processes. In doing so, projects and internships must be an integral part of 4, 5 or 6 years of education in cooperation with companies or institutions, depending on the profession for which the students are prepared. Upon completion of their education, students will undergo training, acquire the necessary skills and are ready for the labour market. Software in the field of education is an intellectual technology and is called educational software, it includes programming languages and accessories and the organization of teaching and learning, which is based on logic and pedagogy. Thus, the term educational software means both ready-made computer programs, which can be used in teaching, and programs that help and guide the individual phase of learning. The educational software contains various curricula intended for users. The development of educational technology began when schools and colleges began transforming traditional classrooms into virtual classrooms by investing in educational software applications. The main goal of educational software today is to make learning exciting. Educational software provides adequate support to take advantage of developed and customized applications. The authors of the article formulated the hypothesis that, in general, universities are ready for long distance learning. There are also positive aspects and problems that are an encouragement to improve educational processes in the context of digitalization. The purpose of the study is to analyse the readiness of universities to develop digitalization at universities using educational software and computers.

Although, this certainly applies to all stages of the educational process; however, in higher education the development of new competencies has a certain need: higher education prepares students for a professional career in which they will move through challenges and decision-making based on (reflective) competencies that are especially developed during higher education. In this regard, higher education plays a crucial role in enabling students to become educated professionals, including competence in problem-solving, information and conflict resolution [3]. The respondents were asked about the subject of digitization in their faculty and their specific role/practice, how the subject (including digital, educational, and organizational needs) was discussed and developed now and over the years (individual and collective levels), how their faculties dealt with digital solutions and what support was available. The respondents were also asked to describe the problems and difficulties in trying to integrate digital technologies at different organizational levels, the examples of changes in colleges and their practice, and what was important to bring about such changes. Ongoing project, the first results of the analysis show that the form, quality, and dimensions of the students' thinking process differ significantly. This is partly based on external conditions such as motivation to study, building an identity before and during studies, study conditions, and so on, which then interact with the ways students use technology, interact with teachers and their educational software. The first findings allow a detailed assessment of individual solutions and styles when incorporating educational technologies for students. This can develop a discussion of why the use of technology is still ambiguous in higher education, both on the student side and on the teacher/leader [9] side and form the basis for recommendations for actively fitting individualized and iterative process facilitations into the pedagogical repertoire of higher education technology courses [9]. From the perspective of university teachers, digitalization has been specifically described as a tool for enhanced control of tasks, materials, and communication with students; for example, less work, administration, and better teaching and communication opportunities: "I saw the benefits of digital technologies pretty quickly; it was not an increased workload, but a relief in everyday life "and" to organize everything was the initial argument [2]."

The aim is to distinguish the field of educational technology research as an interdisciplinary field and to show some of the methods used to approach many research questions that arise from asking what makes a good educational software. Educational solutions offer an alternative and innovative approach to conventional or traditional classroom learning methods. Therefore, it is needed to consistently develop educational software that transforms learning from conventional to innovative, focusing on powerful management systems, automated data synchronization, integration with customized mobile payments, and secure systems for communication and engagement of teachers and students. Qualitative findings show that learning occurs in the conversation of students working on the computer, and quantitative findings suggest that this approach can bring significant benefits in learning within the normal curriculum. Supporting the development of students' digital competence, according to teachers and educational technologists, is an opportunity for students to contribute to alternative ways of teaching, learning, communication and collaboration inside and outside the physical classroom. Accordingly, during the year, students were offered digital course modules (including security, integrity, seeking knowledge and information, developing critical thinking, and creating digital information) and digital support for educational assignments (for making digital presentations, movies, etc.).

Qualitative findings show that learning occurs in the conversation of students working on the computer, and quantitative findings suggest that this approach can bring significant benefits in learning within the regular curriculum. Supporting the development of students' digital competence, according to teachers and educational technologists, is an opportunity for students to contribute to alternative ways of teaching, learning, communication and collaboration inside and outside the physical classroom. Accordingly, during the year students were offered digital course modules (including security, integrity, seeking knowledge and information, developing critical thinking, and creating digital information) and digital support for educational assignments (for making digital presentations, films, etc.).

From a teacher's perspective, changes in teaching and learning practices are generally described as improved opportunities for individualized teaching, information distribution, and are more involved in student learning. "Students can just ask us and read, and they can do it directly on the computer. That way the classes become so lively, instead of handing in papers and waiting for comments for two weeks." There were also statements that "I now have my own reusable digital material" and "I should not take unnecessary time away from lectures due to lost work. However, as teachers put it, these aspects require digital systems and organizational support. In doing so, university teachers stated that digitization is seen as a tool to reduce administrative burden, which in turn allows teachers to develop digitally in the teaching process. Also one dean of a faculty said, "Most people are driven, curious and competent." For that, they need peace, quiet and protection from the administrative burden. In addition to the technological dimensions of digitalization, support is focused on the development of new teaching and learning designs, new ways of communication within the organization, new ways of planning and organizing schooling in rural areas and new ways of organizing administrative work. This also means that the digitalization budget must contain more than a technical infusion.

The modern scientific and technological revolution is radically changing all spheres of society. Informatization is changing especially fast as a civilizational process that has affected all segments of people's lives and work, including education systems. Modern education, according to many scientists, focuses on the achievements and achievements of information and communication technologies (ICT). The development of modern science in the field of ICT in education requires the introduction of new approaches to the education system. Systematic thinking about the needs that lead to changes in established ways of teaching, and which are caused by the application of information technology in the process of learning and teaching, is one of the ways of thinking about modern tendencies in education. Today, education leaders face great challenges and opportunities, from ensuring that every student has support for successful graduation, to balancing budgets and encouraging transformation to develop their systems into the largest educational institutions of the twenty-first century. Lectures over the past year have been remote, hybrid or personal—it has introduced many challenges and opportunities for teachers and students. One of these opportunities is finding new ways to create systems in which students of all learning abilities can access learning from anywhere. The application of information and communication technologies (ICT) is changing education systems.

With the use of new technologies, education becomes available to a larger number of people regardless of spatial distance, time constraints, age, or special needs. With the help of new technologies, even less economically developed countries can become involved in the information society. Modern students, after all, have come to know the world through technology and accept all its forms. Not only that, but students quickly understand and make full use of it, so investing in educational software can have long-term and immediate benefits. Implementing new technology at a college or university requires more than just buying new computers and setting up a website. The successful use of technology for teaching and learning also requires major changes in teaching and organizational culture. In managing technological change, Tony Bates [1]—a world-renowned expert on the use of technology in university teaching—discovers how to create a new, technologically competitive academic organization. He conducted research from recent available papers and best practice cases—as well as from his thirty years of experience in using teaching technology—to provide practical change management strategies to ensure the successful use of technology.

The authors suggest how to win faculty support for teaching using technology and offer suggestions on appropriate decision-making structures and how to apply them. In doing so, they cover topics vital to all involved in technology or technology-based learning, as well as the topics that involve change of management in order to ensure the successful use of technology in higher education. Moving to the leading role of digitalization in higher education means taking on additional responsibility for strategic planning. Strategies to gain faculty support for technology teaching, appropriate reward systems, funding innovation, and regular technology-based teaching, workload and cost management, copyright issues, and helping the faculty develop a vision for teaching and learning with technology are all described, and advice is given on appropriate decision-making and reporting structures [1].

The digital transformation is causing major changes in higher education and research. These current changes impose the feeling that the combination of powerful new communication technology, big data, profitable digital companies, new relationship of citizens with information and knowledge and the global state of the environment will bring either highly desirable or terribly harmful outcomes. The digital transformation has come into classroom because colleges want to use digital teaching materials. Digital versions of materials are much easier to modify and distribute, and can be incorporated with additional features that help students learn. These materials include assessments, which are based on student AI and can be assessed and analysed, while saving teachers valuable time.

The perception of permanent acceleration creates both extravagant and plausible images of the future. Within this confusing landscape, public higher education institutions and research institutions (referred to herein as “HER”) need tools to anticipate change and develop appropriate strategies. Explaining how HER could evolve to meet digital transformation is complex and multi-layered. The rapid rate at which technology affects practices and organizations creates a high level of uncertainty. Digital implications that extend far into scientific disciplines, economic sectors, and civil society generate interdependence and nonlinear change. Educational software is a very complex product of intellectual, creative and teamwork, created for functions in educational processes. Students use educational software in several categories to cover and master curricular content and lesson plans, taking exams and learning. The efficiency of teaching and learning in modern conditions depends, among other things, on the quality of the applied educational software. The quality of educational software is determined by a whole set of relevant factors that are built into it, ranging from creation to adequate application in a specific educational situation. In the field of educational software, the terms “software review” and “software evaluation” are often used, and some authors do not differentiate between them when it comes to its evaluation or assessment. Of course, it is about the use of these terms in the English-speaking area, so it is necessary to interpret them in more detail.

The word “evaluation” is interpreted as the process of collecting, processing data, and using information to assess and decide on the value of educational software. The term “review” is used in the sense of a critical assessment of educational software, but without a thorough study and testing of that software product. This term is often used for superficial judgment or personal (subjective) impression. Educational software is a complex intellectual, IT, aesthetic, educational and technical product that must be evaluated as a complex whole. Evaluation of educational software is performed from different aspects, known as: formative evaluation, summary (complex) evaluation, technical evaluation and educational (educational) evaluation. **Formative** (preliminary) evaluation of educational software refers to the phase of its creation and development, and is based on the evaluation of the documentation of each part of the development process of educational software. **Summative** evaluation of educational software can be done through extensive testing by the method of parallel groups, observation, etc. The goal of summative evaluation of educational software is to determine whether the set goals and objectives are achieved and how. **Technical** evaluation of educational software is performed in order to check its technical characteristics in terms of: robustness (reliability on error), screen design, quality of equipment, etc. Information on the quality of educational software can be obtained through assessment and evaluation. Based on the experience of specialized identification institutions. The methods, techniques, and instruments for quality evaluation in educational software (EPIE,[6] MicroSIFT,[7] Alberta Education[8]), for obtaining the basis for "measuring" the quality of educational software are used: description and catalogue records, careful reviews (assessments), systematic evaluation, data on non-recommended educational software in which basic shortcomings have been identified.

The paper gives in detail all important concepts around educational software, from its definition to the latest trends in educational software. Today, many universities and colleges have embraced the latest technologies to educate students for the future. From science and informatics courses to practice, cabinets are technology-based, using online educational software, which is now a reality. Educational software usually has different features based on its use, goals, and target users. However, the best educational software has some common features, listed below. Each student has a different pace of learning for different curricula. Therefore, it is crucial for a quality educational software solution to enable individualization in these areas. Students should be able to structure and manage their learning speed and save their work so that they can use it again later for joint courses. Students who may not like to sit in class and listen to a lecture or solve assignments may be thrilled with an educational game designed to teach math using sound and graphics. Educational software is applied in the following educational areas such as distance learning, networking, training, and more specific programs such as equipment training and support. Education and training software can be online (web-based) software, software that is downloaded and run on a local computer system, or software that is purchased and distributed through networked education systems for a large number of users. The basic function of most educational software programs, whether intended for college or for home use, is to improve the teaching process. Professors can use educational software in a variety of ways to achieve better success. Educational software allows students to monitor what they learn and to demonstrate their knowledge.

For example, free Microsoft Office software allows teachers to create concept maps, charts, and graphs, as well as enter test data. Teachers can also import data from e-books, websites, and blogs in an introduction to PowerPoint. This type of educational software provides teachers with excellent current details and interaction with students in an easy way [13].

---

[6] The Department of Educational Programs and Institutional Effectiveness (EPIE) provides leadership and coordination of education and service initiatives across the United States, course and program approval, accreditation, strategic planning, class attendance, and institutional research.

[7] Students and teachers at eligible institutions can apply for Office 365 Education free of charge, including Word, Excel, PowerPoint, and now Microsoft Teams, plus additional tools in the classroom. Also cloud services to create a modern classroom. Microsoft Corporation is an American multinational technology company based in Redmond. The company's core business includes the development, production, licensing, support, and sale of computer software.

[8] The Education Capital Planning Division in Alberta is responsible for developing and implementing policies, plans and strategies to support infrastructure and capital planning and investment in the education system.

Another popular tool for cloud-based[9] colleges and professors is the online project management portal. Tools like Basecamp allow entire departments to be on the same page as they write a new test, develop new worksheets, or adopt a new textbook that is better in line with educational standards. These collaboration tools can be accessed anywhere with an Internet connection, which facilitates collaboration from home and uses school planning time more effectively to meet students' needs.

The types of educational software are classified in this paper according to the degree of user independence in managing the process of education, i.e. learning. Less independent work of the user is more defined by the educational software program, and more independent work is the one in which the software allows the user to manage and structure the process of his learning and work.

- Educational software that completely guides the user through the learning process and in which the user's independence is directed by the program is called management educational software. This type of software, in addition to the elements of educational content, also has instructions for use. The instruction gives the user a suggestion when to stop using the computer and to continue learning from the textbook or to make an experiment, i.e. to look for some data in other sources and/or to consult the teacher.
- Tutor educational software is intended for learning those educational contents that are learned in the form of programmed exercises and which the user must master in the same order (learning by mechanical memorization). It is software that has very rigid control algorithms built into it, which the software user can have little influence on.
- Diagnostic educational software is used to test the knowledge, abilities and skills of users for some educational content. This type of software provides the user with information of the feedback type, on the basis of which he can make management decisions about further learning or education flows.
- Educational training software is used exclusively to determine knowledge or build skills. The user manages his education and determines the difficulty of the task that the software contains and based on the achieved results, the user determines the tasks to be mastered.
- Educational software of the database type (knowledge) is designed in the form of a specialized encyclopaedia of knowledge. This means that the user can only get the information that is in some way of organization and content of the interpretation stored in the data bank. Based on his educational goals and tasks, the user structures the learning process using knowledge from the data bank.
- Educational software of the experimental type is used for experiments in laboratories and practical classes for measuring and controlling processes, apparatus and machines. There is also the use of additional hardware with the computer.

[9] Simply explained, cloud computing is the delivery of computing services — including servers, storage, databases, networking, software, analytics, and intelligence — over the Internet (the "cloud") to deliver faster innovation, flexible resources, and economies of scale. Usually, only the cloud services used are paid for, which helps reducing operating costs, run infrastructure more efficiently, and adapt to education needs.

With the help of a computer and specific software, the user manages the learning process with empirical methods.

- Educational simulation software allows some real systems to be represented using models on a computer and to simulate the processes of those systems on it. Also, with the help of simulation, it is possible to discover the functional and structural features of the system being studied. Depending on the previous knowledge, the user can program his own learning and education using simulation models given to him or construct them himself. In the application of simulation software, individual knowledge about the management of learning and education processes comes is demonstrated.
- Software tools are programs designed for users to design educational content that they master themselves. This primarily refers to tools for word processing, database formation, various calculations, graphics, etc. These software products provide great opportunities for complete self-management, knowledge acquisition, skill building and habit building.
- Graphic software has a great application for students and teachers. Thanks to this software, they can not only record and modify, but also create images present online or in the program. It also allows you to create elegant online presentations.
- Digital media—educational software. Educational software has turned a traditional classroom into a digital one. In the era of smart technologies, educational content has also become smart. Such software encompasses a variety of technologies, including artificial intelligence and machine learning, so that its digital content effortlessly adapts to different user needs and knowledge base. Moreover, smart content contains built-in grades so teachers can track and test students effortlessly.
- Intelligent tutoring systems are the highest level of quality educational software and are based on achievements in the field of artificial intelligence. Intelligent tutoring systems are dialogue-oriented systems, which, based on communication with the user, provide the necessary knowledge and advice that they explain in an adequate way. Such knowledge comes from experts and differs from textbooks. For now, the programs are still in research and development and are used in teaching and learning. Intelligent tutoring systems from the point of view of user management represent the highest level of independence [6].

The rapid development of technology has conditioned that education also becomes digital like many other industries. There are many educational software available on the market today [13].

- The authoring system allows teachers to create educational software. With this, they can easily design electronic cards or index cards on specific topics. They can also create tutorials, lessons for multimedia content. There is also an online authoring system that helps teachers in this regard.
- Desktop Publishing Leaflets, brochures and newsletters are created and designed using desktop publishing software. Using this, teachers inform students about faculty activities in an attractive way. It is a necessary skill for new graduates. Many colleges focus on desktop publishing packages, such as Microsoft Office

and Adobe Creative Suite. There are many paid courses and videos available on YouTube for learning.

- Graphic software, this type of educational software is especially used in making presentations. Using this software, students can capture, create and modify images available on the Internet. Adobe Photoshop, CorelDraw, Microsoft paint, Canva and Picasa are examples of graphics software.
- Reference software. The name shows its purpose. This software provides additional assistance when searching for research projects. Encyclopaedias, thesauri, atlases, and dictionaries are typical examples of reference software.
- Software evaluation. Such software is designed for student assessment. The test or exam ends on a networked computer. After that, this software scores each test of each student and provides the result as an output. This software can also help prepare students for exams. Many types of software are used to update, submit, assess and grade. Moodle, Google Classroom, Grading Master, and Blackboard Learn are the best examples of grading software.
- Tutorials software. This type of educational software offers students a platform on which they can learn on their own. Such software provides information on a particular topic, gives them time to practice, and ultimately examines their performance. Courser, Alison and Udemy are examples of software tutorials.
- Educational games. Some games are designed for educational purposes. Education and games in one place make the learning environment existing. Also, these games improve the motivation to learn. Charades, Hangman, Bingo, Pictionary and QuizAlize are the best examples of educational games.
- Demonstration software. This type of educational software is used for experimental purposes in the fields of biology, physics, chemistry. Sometimes the device is expensive to buy, or it is unsafe to work physically. Thus, this software assisted in the simulation and observation of the experiment. There is a lot of demonstration software such as Wolfram Demonstration Projects, MyPhysicsLab and PhET Interactive Simulation.
- Special needs software. Special needs educational software is designed for the needs of special students. Basically, this software, combined with the auxiliary software, provides an effective platform for learning for students with special needs. Computer text reading aloud, speech synthesizers, and multimedia software are examples of such software.
- Software for solving mathematical problems. This software helps teachers, especially mathematics, to develop student' problem-solving skills. Science teachers can also use this kind of software to conduct the results of experiments.
- Utility, educational software is a utility for teachers. It helps them to create tests and quizzes. It can be said that it functions as a grading book for teachers.

Through video conferencing, a student can acquire their education online. Students and teachers communicate and lead their discussions in virtual rooms. In this case, universities are also developing more programs, using distance learning models. They offer foreign students online courses without having to leave their country.

The paper argues that rapid digital disruption implies a method by which business technology is treated as an element of a strategy that would change. The advent of the Internet and the World Wide Web has changed and strengthened the role of technology in enabling new ways of doing business, and companies have begun to develop business and technology strategies in parallel. Now is the time of digitalization when technology has the potential to fundamentally change the nature of business and the way it does business. For this reason, it is necessary that all companies need to establish a technology-driven strategy. One that never stays intact, but is dynamic and capable will adapt quickly to change with the advent of new technologies. Successful companies will see technology as an opportunity for progress, not as something they just have to "deal with". Business success will be inextricably linked to the way modern digital technologies are used in all aspects. Future business success is likely to be characterized by companies that accept only digital disruptions.

The concepts of digital and digitalization of the company have existed for many years, however they still remain abstract. This lack of a common and concrete definition leads to a certain ambiguity already when it comes to the basic task of DMM: measuring the level of digitalization of a company. In this context, questions such as: What are the relevant variables for measuring digitization? How can they be quantified? How can a certain comparability between companies be ensured? How can one investigate whether a certain level of digitization affects a company's performance? In this regard, emphasis is placed on the need for further scientific research on digital maturity, in order to contribute to a deeper understanding of the current sociotechnical phenomenon of digital transformation. Recently, in the context of digitalization, researchers and practitioners have set out to assess the digital maturity of organizations. The proposed models based on the development and application of the maturity model still have a number of shortcomings. As for the maturity model measurement procedures, the existing academic literature does not yet offer specific quality criteria. As already pointed out, the target area of interest in terms of digitalization of companies is very wide and a significant research venture and consensus in its application and comparative analysis measurement of achievements is still ahead.

2.3 Conclusions

The paper argues that rapid digital disruption implies a method by which business technology is treated as an element of a strategy that would change. The advent of the Internet and the World Wide Web has changed and strengthened the role of technology in enabling new ways of doing business, and companies have begun to develop business and technology strategies in parallel. Now is the time of digitalization when technology has the potential to fundamentally change the nature of business and the way it does business. For this reason, it is necessary that all companies need to establish a technology-driven strategy. One that never stays intact, but is dynamic and capable will adapt quickly to change with the advent of new technologies. Successful companies will see technology as an opportunity for progress, not as something they

just have to "deal with". Business success will be inextricably linked to the way modern digital technologies are used in all aspects. Future business success is likely to be characterized by companies that accept only digital disruptions.

The concepts of digital and digitalization of the company have existed for many years, however they still remain abstract. This lack of a common and concrete definition leads to a certain ambiguity already when it comes to the basic task of DMM: measuring the level of digitalization of a company. In this context, questions such as: What are the relevant variables for measuring digitization? How can they be quantified? How can a certain comparability between companies be ensured? How can one investigate whether a certain level of digitization affects a company's performance? In this regard, emphasis is placed on the need for further scientific research on digital maturity, in order to contribute to a deeper understanding of the current sociotechnical phenomenon of digital transformation. Recently, in the context of digitalization, researchers and practitioners have set out to assess the digital maturity of organizations. The proposed models based on the development and application of the maturity model still have a number of shortcomings. As for the maturity model measurement procedures, the existing academic literature does not yet offer specific quality criteria. As already pointed out, the target area of interest in terms of digitalization of companies is very wide and a significant research venture and consensus in its application and comparative analysis measurement of achievements is still ahead.

References

1. A.W.T. Bates, Upravljanje tehnološkim promjenama: strategije za vođe fakulteta i sveučilišta. Jossey-Bassova serija visokog obrazovanja i obrazovanja odraslih; Publishers Jossey-Bass, 350 Sansome St., San Francisco, CA 94104 (2014)
2. T. de Lange, *Tehnologija i pedagogija: Analiza digitalnih praksi u medijskom obrazovanju* (AIT Oslo AS, Oslo, 2010)
3. D.M. Griffioen, U. de Jong, Implementing research in professional higher education: factors that influence lecturers' perceptions. Educ. Manage. Administr. Lead. (2014). https://doi.org/10.1177/1741143214523008
4. M. Håkansson-Lindqvist, F. Pettersson, Digitalizacija i školsko vodstvo: o složenosti vođenja digitalizacije u školi. Međunarodni časopis za informacijske i obrazovne tehnologije **36**(3), 218–230 (2019)
5. C. Marcelo-García, C. Yot-Domínguez, C. Mayor Ruiz, University teaching with digital technologies. Comunicar **23**(45), 117–124 (2015). https://doi.org/10.3916/C45-2015-12
6. D. Nadrljanski, Digitalni mediji – obrazovni softver, Pedagoški fakultet Sombor (2006)
7. O.I. Popova, Transformation of higher education in the conditions of the digital economy. Manage. Issues **5**(35), 158–160 (2018)
8. A. Scholkmann, "What I learn is what I like." How do students in ICT-supported problem-based learning rate the quality of the learning experience, and how does it relate to the acquisition of competences? Educ. Inf. Technol. **22**(6), 2857–2870 (2017). https://doi.org/10.1007/s10639-017-9629-7
9. A. Scholkmann, E. Lauridsen Lolle, K. Otrel-CassTobias, A. Tretow-Fish, Building a partnership for thinking through technology-facilitated iterative processes: an approach to iterative practice (IPA) in higher education; ECER 2019 session provided by 22. Res. Higher Educ. (2019)

10. R.M. Tamim, R.M. Bernard, E. Borokhovski, P.C. Abrami, R.F. Schmid, What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. Rev. Educ. Res. **81**(1), 4–28 (2011). https://doi.org/10.3102/0034654310393361
11. G.L. Tulchinsky, Digital transformation of education: challenges to higher school. Philos. Sci. **6**, 121–136 (2017)
12. E. Zhadko, O. Popova, N. Gagarina, University brand management in the conditions of education digitalization, in *16th International Conference Efficiency and Responsibility in Education* (2019), pp.1737–1746
13. https://www.wiscogroup.com/types-of-educational-software-and-other-classroom-aids/. https://techlancings.com/educational-software-types-and-advantages/

Chapter 3
Remote Teaching and Learning Math in English Through CLIL

Maria Guida and Letizia Cinganotto

Abstract The chapter will focus on teaching Mathematics through CLIL (Content and Language Integrated Learning) in remote and hybrid settings due to the pandemic. After highlighting the main pillars of CLIL, the chapter will try to investigate the opportunities and challenges of CLIL in Math in these new and unprecedented educational scenarios. Examples of repositories, webtools, digital boards used by teachers for remote CLIL teaching will be described as a way to foster students' engagement, interaction and interactivity. Excerpts from the interviews with a sample of Italian Math teachers engaged in CLIL activities during the pandemic will be reported as evidence of the potential of CLIL activities in Math also in remote and hybrid school contexts. Despite the challenges due to the pandemic, the teachers were able to deliver Math content in a meaningful way, through a problem-based or project-based learning approach which could facilitate and enhance the understanding of CLIL tasks. Communication and interaction among the students and with the teachers were fostered through the discussion, explanation and negotiation of the different CLIL activities, alternating both the L1 and the L2, adopting the practice of translanguaging, which can really work in a CLIL environment.

Keywords Mathematics · Math education · Remote teaching · Hybrid teaching · CLIL · K-12 students · Covid-19 pandemic · Digital teaching tools

This Chapter stems from the collaborative work of the authors. In particular, Maria Guida is the author of paragraphs 3, 5, 6. Letizia Cinganotto is the author of paragraphs 1, 2, 4, 7, 8. Abstract, Conclusions and References have been written collaboratively.

M. Guida (✉)
INDIRE, Florence, Italy
e-mail: marinu.guida@gmail.com

L. Cinganotto
University for Foreigners in Perugia, Perugia, Italy

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_3

3.1 Introduction and Methodology

The acronym CLIL (Content and Language Integrated Learning) [1] refers to an umbrella methodology entailing the learning of subject content in a foreign language. In Italy CLIL became compulsory in 2010 according to a reform law, introducing it in all upper secondary schools [2, 3]. The majority of schools, except for technical schools, can choose Mathematics, among the others, as the subject to be delivered through CLIL, also considering the teachers' competences in CLIL methodology and in the foreign language. In fact, the Italian CLIL teacher profile is based on language competences (C1 level of the Common European Framework of Reference for Languages) and on methodological competences, acquired by attending university courses.

During the pandemic the majority of schools and universities were forced to switch to online teaching and to reshape their teaching methodologies and techniques.

However, many teachers did not give up and struggled to keep on teaching CLIL also in the new educational scenarios, considering the potential of this student-centered methodology.

This chapter reports on a study conducted by the authors about opportunities and challenges of teaching Mathematics with the CLIL methodology during the Covid-19 pandemic, in remote and hybrid learning. In particular, authors' research questions consist in identifying those opportunities of teaching Math in CLIL that can be also identified in hybrid or remote teaching.

Here are the research questions which represent the starting point of the study:

> Which are the opportunities and challenges of the CLIL approach in teaching Math in hybrid or remote scenarios?
>
> Can young learners improve both their Mathematical thinking skills and second language skills through a CLIL approach even in remote/hybrid teaching?

As to methodology and tools, the present study adopted a qualitative design, based on the observation of some online lessons and several interviews to the teachers involved, to capture their perspective, experiences and perceptions about the period when they had to give hybrid classes of Math, in particular CLIL Math.

In particular, seven Italian teachers of CLIL in Math were interviewed by the authors: one of them is a primary school teacher and the other six are upper secondary school teachers. The primary school teacher (Teacher 7) teaches Math, Science and Physical Education in a comprehensive school in the province of Milan, while the other six teachers teach Math in CLIL in 3 different upper secondary schools (Teachers 1 and 2 in the north of Italy; Teachers 3 and 4 in the center and Teachers 5 and 6 in the south). The authors deemed useful to interview a higher number of upper secondary school teachers as CLIL is compulsory in Italy at that school level.

The interview was held online in a video-conference room during the pandemic in May 2021, starting from the above mentioned research questions. The authors wanted to create an informal and easy-going atmosphere, in order to let the teachers feel free to express their opinions and reactions to the remote and blended teaching of Math through CLIL. That is why the discussion was guided as an informal brainstorming and round table, with no particular rules in the turn taking. They would just raise their hand by using the specific function in the video-conference room and could take the floor. The discussion went very smoothly with no overlapping and it provided the authors with interesting insights which will be partly reported in this contribution by quoting some of the teachers' remarks.

The structure of the chapter is organized as follows: CLIL methodology is explained in general, showing its theoretical background, its typical tools and its effectiveness in order to reach the students' deep learning. After discussing pros and cons of the CLIL approach in Mathematical lessons, putting as a starting point a vision of Mathematical education nowadays, a picture of current remote and hybrid educational scenarios for CLIL and Mathematics is depicted. Comments and reflections from the interviews with the teachers are reported in different parts of the text, to support the discussion about opportunities and challenges of remote and hybrid teaching of Math in CLIL.

Finally, some examples of online lessons of Mathematics CLIL are described, providing suggestions and input for planning and implementing innovative and engaging CLIL activities in Math through the use of learning technologies.

3.2 Main Pillars of CLIL

CLIL has been mentioned by the European Commission and the Council of Europe as a driver for innovation, fostering language competences and subject knowledge at the same time. CLIL methodology is also a very powerful tool for enhancing plurilingualism, as suggested in the latest Council Recommendation for a comprehensive approach to the teaching and learning of languages [4]: in Italy the majority of schools chose English as the vehicular language, as it is the first foreign language, taught as compulsory from primary to upper secondary school. However, the use of other foreign languages is also encouraged and enhanced.

CLIL methodology points at using a variety of teaching techniques mainly taken from the field of language learning and teaching, aimed at providing comprehensible input in the foreign language [5] and helping them processing and elaborating that input, while activating cognitive skills and critical thinking skills, according to Bloom taxonomy, as in the adapted version reported below [6] (Fig. 3.1).

In fact, one of the best known CLIL pillars is the so-called 4Cs framework [7], which consists of:

– Content: subject delivery
– Culture: cultural and intercultural background
– Communication: interaction and communication among students and with the teachers about the subject content
– Cognition: the development of cognitive and critical thinking skills.

Fig. 3.1 Bloom taxonomy [6]

Task-based learning can be a very effective methodology for CLIL, as students are guided to carry out meaningful tasks using the foreign language in real-life contexts.

Mathematical tasks in a foreign language can be a good way for implementing CLIL in STEM (Science, Technology, Engineering, Math) and some examples will be mentioned in the next paragraphs.

An important dimension in CLIL methodology is scaffolding [8], through which the teacher can guide students step by step in the learning process.

Infographics, images, diagrams can represent good examples of scaffolding techniques, aimed at facilitating and supporting the students both in the language and in the subject content progression.

Another pillar of CLIL is feedback [9, 10], which is a very powerful tool for deeper learning, as it can give students the proper information to adjust the learning pathway and enhance progress.

Feedback can come from the teacher but also from peers (peer feedback): both the kinds of feedback can give important information to the students and help them direct their next learning choices.

Among the CLIL milestones, it is worth mentioning the practice of "translanguaging" [11], which means accessing different linguistic features or various modes of different languages, in order to maximize communicative potential. It means that in a CLIL environment it is allowed and encouraged to switch from L1 to L2 in order to empower communication, interaction and understanding, especially when the subject-specific language is particularly difficult as in the case of Math: it is important to foster subject-specific literacy among all the "pluriliteracies" that twenty-first century students need to develop in the Knowledge Society [12, 13].

3.3 A Dialogic Vision of Teaching Mathematics: The Added Value of CLIL

Teaching Mathematics through CLIL is promising but not entirely free from risks and dangers that must be analyzed, looking for strategies aimed at minimizing their impact or even prevent them. Some possible negative facts of CLIL incidence are mainly focused on time consumption, level of foreign language required from both students and teachers, lack of confidence with CLIL theoretical underpinnings, and insufficient teacher training courses [14].

On the other hand, according to Favilli et al. [15] teaching Mathematics in L2 requires a great ability in standard Mathematical terminology to interact in the classroom along with non-formal language skills to favor teachers' explanation and, subsequently, students' understanding.

Consequently, the disadvantages of CLIL might not be in the teaching–learning methodology, but rather in the complexity of the requirements and competences that teachers consider necessary to perform Mathematics in CLIL successfully.

Anyhow, these considerations should not be frightening because, besides the risks, there are many opportunities for CLIL to have a considerable positive effect on Mathematical classes and on student's learning. First of all, because of the attention paid, by the teacher first, to the language used and the disciplinary register that leads to increase the metalinguistic awareness (both in L1 and L2), the ability of facing word problems and consequently the intrinsic motivation, when students are supported by teachers in the process of acquiring such skills. Secondly, because CLIL rethinks the nature of tasks, pointing to an active and significant learning and finally, because of the aim at developing communication skills. This paragraph deals with discussing these statements below.

Let's start by clarifying what do we mean by the expression "language of Mathematics". It can be used with a variety of meanings [16] including the spoken language of the Mathematical classroom, the use of particular words for Mathematical ends (the register), the language of word problems or textbooks as a whole, including graphic, the language of written symbolic forms and even the "inner speech" of someone doing Mathematics alone. Language can be used to both conjure and control mental images in the service of Mathematics. Anyway, what are the aspects of Mathematical language that challenge students?

Notoriously, this language is highly precise, intolerant of ambiguity, concise, it mixes prose, symbols, formula, figures and diagrams, it uses large numbers of symbols, it is at times written one way and read in another ($\geq$becomes 'is greater than or equal to', / used in fractions is read as 'divided by'). In addition, there are several concepts that are easily confused such as area versus perimeter; dependent versus independent; direct proportion versus inverse proportion; expression versus equation; mean versus median versus mode; necessary versus sufficient; numerator versus denominator, square versus square root. There also words that take on an additional or a different meaning in Mathematical discourse than in ordinary language such as expression, column, factor, identity, mean, net, volume and so on [17].

Consequently, it is clear that the attention to the language is necessary even in Mathematical classes held in the mother tongue because of the peculiar characteristics of Mathematical language, exactly like in CLIL.

If the teacher assumes that students are able to deal with the language of Mathematics and does not carry out specific scaffolding actions in this sense, (just as in the CLIL lessons one works taking into account the foreign language) students will end up feeling the language of Mathematics as a foreign and unknown language more and more over the years, a growing up barrier between themselves and the learning of Mathematical concepts.

In this sense, teacher should accompany the pupils in developing systematic habits, approaches and processes for learning Math.

Coonan points out that what transforms a disciplinary lesson conveyed in L2/LS into a real CLIL lesson is the methodology adopted, the didactic choices, the strategies to support learning that the teacher uses [18].

Students are ideally supported getting in the habit of reading texts more slowly and carefully, paying attention to detail, reading problems several times, underlining clue/key words, looking up symbols immediately if they do not recall what they mean, always checking for the givens and what needs to be found out, focusing on the processes rather than the answer itself, having to prove verbally or in writing that they understood a concept or process instead of allowing them to just say they understood it, interpreting tables and diagrams, applying formulae.

These habits, one acquired in CLIL, can persist and can be applied even in L1 to school problems and life issues.

These work on language appear to be crucial because many students are unable to follow Math classes, even in their mother tongue, as they find them linguistically too complex, not only with regards to the textbook to be read and understood but also as to the classroom interaction. This situation brings, as a result, that students get demotivated, no longer interested in the subject, less committed and, eventually, they feel left behind and leave the school early [19].

As to Mathematics, this phenomenon was particularly evident and generally accepted since the results of the 2015 OECD PISA survey.

Several scholars state that the linguistic structure of a problem can influence the resolution of the problem by the students and affirm the strong relationship between language and resolution of verbal problems [20–22].

According to the research of Bonnet [23], students can indeed switch to the mother tongue when there is a conceptual problem, but that this does not normally lead to the solution of the problem. It seems clear, therefore, that rather than being an impediment, L2 processing actually has a great potential also and in particular for learning specific concepts of non-linguistic subjects, in particular Mathematics. In this sense, Math teachers can discover through CLIL how a variety of teaching techniques mainly taken from the field of language learning and teaching, aimed at providing comprehensible inputs in the foreign language [5] can be useful in Math classes.

Furthermore, Mathematical Language is one out of ten factors that Anthony and Walshaw [24] identify for effective pedagogy in Mathematics. These scholars emphasize, among other factors, the importance of promoting learning communities and constructive discourse classroom and choose carefully the tasks to intensify students' thinking, also dealing with the different panoramas that can be present in life. For example, in Italy, a decimal like 5,735 is represented with a comma, while in different cultures the digit 5 represents thousands.

Learners should understand the presence and the role of Mathematics in everyday situations [25] so Math contents should be seen as something positive for life, and this can be done with the proper choice of the tasks to be assigned, avoiding to insist too much on difficult procedures and formulas to be memorized [26, 27]. For instance, throughout the educational process, it is possible to see the teaching–learning of Mathematics transversely related to the objectives of sustainable development. According to Beswick et al. [28] teachers should recognize real contexts and applications in order to raise interest and attention to Mathematics. Therefore, the chance to participate actively in the development of a real project directly linked to Math is a powerful opportunity to engage students and enable them to carry out active learning. In addition, this entails the possibility of developing language skills in real settings. PBL (Project based learning) [29] is a methodology typically proposed for CLIL lessons and it is also invaluable for Mathematics lessons if the aim is to accomplish the above. Furthermore, CLIL students work more persistently on tasks, demonstrating a greater tolerance to frustration, and thus acquiring a greater degree of procedural competence in the non-linguistic subject [30].

With reference to the development of students' communication skills of Math content through CLIL and PBL, Dalton-Puffer [31] recognizes the crucial role of authentic communication between students and teacher with respect to the language and disciplinary teaching/learning process. She also highlights the "action with the language" that translates students' language skills into communicative events (for example, a presentation in class) and reflects their practical skills in final products (for example, an infographic, a research, a poster, etc.). Those products represent the tangible, observable and immediately appreciable outcomes of their learning, both linguistic and Mathematic.

3.4 Remote and Hybrid Educational Scenarios for CLIL

During the pandemic due to COVID-19 schools and universities were forced to teach online and educational scenarios have become more and more flexible, according to the specific situations and needs. That is why teachers had to rethink and reshape their teaching strategies, re-organizing their annual plan and the activities planned for ordinary pre-COVID settings. In fact, depending on the level of emergency and on the presence of any infected students or teachers in the school, different teaching solutions had to be put in place, such as hybrid, blended or fully online teaching episodes, often rotating the presence of the students in class, in order to guarantee physical distance and prevent infection.

Therefore, the use of platforms, webtools and learning technologies has become crucial for languages and CLIL, as well as for all the other subjects.

In particular, as far as language learning and CLIL are concerned, the use of learning technologies was already recommended and encouraged by the European Commission in the report titled "Improving the effectiveness of language learning: CLIL and Computer-Assisted Language Learning", dated 2014 [32]. The following options are mentioned in the report as examples of CALL (Computer Assisted Language Learning), that can foster the implementation of CLIL:

– authentic foreign language material, such as video clips, flash-animations, web-quests, pod-casts, web-casts, news broadcasts etc.;
– online environments where learners can communicate with foreign language speakers, through email, text-based computer-mediated communication (synchronous and asynchronous), social media, or voice/video conferencing;
– language-learning tools (online apps or software), for phonetics, pronunciation, vocabulary, grammar and clause analysis, which may include a text-to-speech function or speech recognition, and often include interactive and guided exercises;
– online proprietary virtual learning environments, which offer teacher-student and peer-to- peer communication;
– game-based learning.

Even in the above-mentioned "Council Recommendation on a comprehensive approach to language teaching and learning" (2019) [4], technologies are mentioned and recommended to improve the quality of language learning and teaching and to make CLIL (Content and Language Integrated Learning) more effective.

A wide range of webtools for language learning and CLIL were used by teachers during the pandemic and have become more and more popular in the current learning scenarios. As a general lesson learnt from the pandemic, teachers have found out the potential of learning technologies beyond the emergency linked to the pandemic [33].

In particular, repositories such as TED-Ed and Khan Academy can help teachers find materials to be assigned for flipped learning pathways or for revising content.

Khan Academy is particularly useful for Math, as teachers can find a wide range of resources in the shape of videos about different topics: they are attractive and colorful explanations by a teacher, often including quizzes, tests and other activities for self-study and self-assessment.

Other useful platforms can be Phet and Labster, recreating virtual labs, where students can be engaged in effective and stimulating CLIL tasks, and problem-solving activities, entailing the use of the language to solve problems, make hypothesis and investigate the topic through the eyes of a mathematician or a scientist.

Also the use of shared digital boards such as Padlet, Linoit, Whiteboard. chat, Jamboard has turned out to be very effective for engaging students in real time tasks to be performed in synchronous during live sessions with the teacher and the classmates, or in asynchronous for self-study or revision activities.

An example of a useful board for Math is Math Whiteboard, which provides students and teachers with specific tools and functions commonly used in Math, which are difficult to find in other digital boards. More and more teachers are using those digital and multimedia boards to engage students and actively involve them to respond and react to given inputs. Combining those activities on shared boards with oral interaction and explanation of given problems or other Math issues in the foreign language, can represent a very useful CLIL activity.

The remarks of the CLIL Math teachers interviewed during the pandemic show the added value of technologies in a CLIL setting, which most of them were already familiar with:

"I already used technologies for teaching Math in English before the pandemic, therefore it was quite easy for me. I found out a large number of digital boards and tools to facilitate my teaching remotely" (Teacher 1).

"Teaching Math online was not so difficult as I explained everything in synchronous on Zoom to my students, while writing on the Jamboard" (Teacher 2).

"I used Khan Academy, as there are so many videos on Math in English and it was easy to assign content and quizzes to my students" (Teacher 3).

The afore-mentioned comments from the teachers showed that their perceptions about remote Math teaching in CLIL was not so difficult, but technologies were the key to success.

"The use of webtools and platforms allowed me to engage my students in interesting conversations in English about the different problems to be explained and solved. We also spoke in Italian when it was too difficult to speak in English, but they fully understood the topic" (Teacher 2).

The afore-mentioned comment highlights the use of "translanguaging" in a CLIL environment, which can foster communication and interaction, facilitating deep understanding and deep learning.

3.5 Remote and Hybrid Mathematics

Math teachers never expected their job to be easy but during the outbreak they were thrown into a situation for which no one could have prepared and for which there is no end in sight, which requires an extraordinary effort. According to Ferretti, Del Zozzo e Santi [34], during the pandemic two different attitudes seem to emerge among Math teachers forced to remote teaching: one, which is characterized by the longing for restoration of the traditional didactic conditions, and another, which consists in embracing the new environment defined by digital technologies, which opens a new space of action.

However, in the first case, in Italy and abroad, remote learning of Mathematics was still dominated by a rigid or less interactive learning environment, which could be seen from how the teachers assigned Mathematics exercises, questions and instructions, as well as how they responded to student questioning [35].

In other words, teachers tended to adopt teaching strategies that reproduced standard classroom dynamics, mostly. [36]. "*We have moved from theater to television"*(Teacher 4), meaning that in both cases the students were passive users even if in the second case a distance transmission using technology was introduced.

On the other hand, the willing teachers of the second group have committed naivety out of inexperience sometimes but they have been able to learn from mistakes in order to improve and they also discovered threats and opportunities in remote learning of Mathematics, which have several implications for the return to the classroom.

"The first lesson learned was that presence and distance are infrastructural methods, not didactic strategies and the debate about which one is more effective is profoundly sterile", Teacher 5 stated during the interview. "*Classroom lessons are not*

without issues and technology in distance learning can certainly help us by opening up opportunities, but if we do not reflect well on the critical issues, we will not go anywhere" (Teacher 6). Teachers must develop awareness of the aspects of learning on which technologies have a profound impact and make choices consequently.

Obviously, "*to be able to realize a learning situation it is necessary first of all to have an interlocutor, meaning it is necessary to actively involve the students in the lesson and enable an interactive and therefore participatory and collaborative learning. But this is the difficult thing in distance learning and it is very different from the ordinary lessons"*. (Teacher 5).

However, with reference to Knowledge, which includes concept and procedures, traditional blackboard lectures, where the teacher usually demonstrates, lectures, and asks closed-ended questions, including teacher's gestures and facial expressions, are even nowadays still a highly popular means of teaching Mathematics. Normally, thanks to the physical presence of students in the classroom, the teacher can instantaneously fine-tune the evolution of the lecture according to his/her perception of the level of attention and the facial expressions of the students [37].

None of that can be achieved in distance learning, even though students need to have the possibility to interact with the teacher and each other, especially in early grades.

The condition of partial or reduced visibility, the delayed feedback, the slowness in understanding what students think are elements that play against and slow down the decision-making processes of the teacher and his ability to regulate the teaching flow in real time. Yet, as already mentioned in this chapter, among Math teachers a large use of online shared whiteboards has been observed in order to recreate the classroom atmosphere of scaffolding. "*The use of this tool allows students to solve algebraic exercises with the teacher's assistance, in the pen-mode that facilitates the writing of formulas, before working on them at home on their own*" (Teacher 4).

So, "*in order to preserve the quality of the traditional backboard lectures in remote teaching, lessons have to be designed providing several interactive moments, otherwise the students get lost, disengage and the teachers find themselves in an empty space speaking to no one"* (Teacher 3).

The lesson can take place synchronously, through a video conference system in a virtual classroom, or asynchronously through a recorded video lesson or by assigning ready-made materials to students that they will then study on their own. Classroom lessons are thus transformed into interactive digital lessons on the fundamental topics of the program with theory references, videos, activities in GeoGebra to explore geometry in a dynamic way, guided exercises and interactive exercises to be carried out on the notebook, animations useful to present a Mathematical property or a geometric figure, activities where a specific topic is reviewed by building interactive online maps. In addition to the lesson, students must also be involved in exercises, trying to ensure assistance to each one because no mold fits all. During the school closure, teaching methods that encourage active engagement, played an important role in mitigating the negative effect of remote learning. It will be possible to use interactive environments with video development of exercises and problems that support the student in the learning path, helping them to solve doubts and making them more aware of the solution strategies: game based responses, remote exercises based on student feedback [38], interactive blackboard mixed with videoconference.

Of course, it is hard for the teacher to provide explanations and targeted practices that meets students' needs but in this way, unlike in the pre-recorded video lesson, students can intervene at any time in the explanation to request clarification on unclear aspects of the topic and the teacher can be next to each student, personalizing the intervention and also able to correct errors and misunderstanding in real time.

Making the lesson interactive means making it participatory and collaborative, having the students in the center of the process, putting effort on maintaining the open dialogue in the class, the respectful discussion where sharing mathematical ideas and building common sense of concepts. Mathematics lessons based on the CLIL methodology are placed precisely on this wavelength.

3.6 Case Examples of Remote CLIL in Math

The CLIL approach has the dual objective of acquiring skills in Mathematics and in the non-native language through which it is conveyed. Achieving this dual objective requires the development of an integrated teaching and learning approach with special attention to the more general educational process [39].

CLIL is part of those methodologies requiring the student to be a leading actor in the construction of his/her own knowledge: learning the disciplinary content becomes the main objective and the acquisition of greater communication skills in L2 is a consequence.

It is a fact that teachers accustomed to the CLIL methodology have been facilitated in adapting their design to remote teaching, since technologies usually have an important role in this type of approach. Sometimes it was enough to replace the usual tools with similar tools that can be used online, often in a cooperative way, thus allowing to naturally maintain that social dimension of learning previously mentioned as important.

To clarify this point, we refer to a typical CLIL-style Math lesson plan.

Starting from an initial stimulus, the teacher launches a brainstorming with the dual purpose of engaging students and recalling their previous knowledge on the topic, inviting them to write their contributions in the form of a mind map. Then the teacher submits to the students the reading of a passage in English preceded by a glossary and followed by questions, without evaluation purposes, which serve to open the discussion so that students freely express their ideas and, at the same time, develop their expressive skills in L2. Some questions may be quantitative and include, for example, the use of a spreadsheet to tabulate data and discover regularity and patterns, or the use of Geogebra to study the possible transformations of a geometric figure and thus discover its properties in an exploratory and investigative way. However, Math is a discipline that makes use of the iconic non-verbal code (graphs, tables, maps, pies, figures, etc.) that not only plays as reinforce and integration with respect to a text / speech, but can also be used as a pedagogical tool for carrying out learning activities. Finally, the lesson ends with a request to explain in writing what has been learned and with a test on the contents of the didactic unit performed. As evident, this lesson can be easily transposed remotely by inviting students to use an online collaborative mind map during the brainstorming (e.g. Mindmaster), then use shared spreadsheet (e.g. Google Sheet), Geogebra in online version, Google Doc to write their own answers individually or collaboratively, if short, or maybe Storyjumper or Flippingbook for a longer report with a more accurate layout, Kahoot and Mentimeter for quizzes for quick feedback.

"The collaborative aspect of learning online can be enhanced through the common function of learning environments for splitting students in small groups for short discussion sessions, after which, the speaker of each group reports the negotiated answer to the whole class" (Teacher 5).

However, as already mentioned earlier in this chapter, there are several Open Educational Resources (OER) that teachers may adapt and use in their own contexts, that are educational materials in digital format, available online, adaptable to the needs of learners and of the context. A very famous repository of OERs for science and Math education is accessible on the portal of Scientix,[1] a ten-year European project that promotes and supports a Europe-wide collaboration among STEM (Science, Technology, Engineering and Math) teachers, education researchers, policymakers and other STEM education professionals. Another source of inspiration is the project STEAM-IT[2] aimed at the interdisciplinary dimension of teaching and learning and at the promotion of an integrated approach to knowledge.

Even if the lesson plan example provided earlier in this paragraph, concerns secondary education, several OERs can be found online even for teaching Mathematics to primary students. Of course, the materials should meet a number of criteria such as the relevance for primary school students, the ease of integration within the school curriculum and for the needs of so young pupils.

"*Materials must be visually attractive, engaging and motivating and have an appropriate cognitive load in order to be challenging for students, but not daunting"*) (Teacher 4).

One more example of repository for STEM subjects, including Math, is CLIL4STEAM,[3] an Erasmus project in which the two authors of this chapter are involved on behalf of Università Telematica degli Studi IUL[4]: a wide range of videoclips on different STEM topics have been produced as outputs of the project and are freely available online for teachers and students.

The videos can be effectively used adopting the well-known K-W-L chart, which is very common in a CLIL lesson: the chart is aimed at eliciting students to reflect according to the following questions:

---

[1] http://www.scientix.eu/home.

[2] http://steamit.eun.org/.

[3] https://clil4steam.pixel-online.org/.

[4] https://www.iuline.it/.

– *What I **K**now?*
  This step is aimed at eliciting previous knowledge and prerequisites.
– *What I **W**ant to know?*
  This step aims at fostering curiosity for the topic of the lesson.
– *What I **Learned**?*
  This step usually takes place at the end of the learning pathway and is aimed at activating reflection and meta-cognition in order to identify what has been learned and understood and what needs to be further investigated and explored in the following learning episodes.

Moving toward conclusions, based on what has been discussed so far, it can be affirmed that the attention to the language typical of a CLIL lesson continues to be effective also in the distance teaching of Mathematics as well as the development of communication skills. Finally, active learning, based on projects and/or problems used in a CLIL Math setting can also be implemented in distance or blended learning if the proper tools are used and if the teacher is able to redesign the tasks to be assigned to the students.

3.7 A Case Example of Remote CLIL in Math at Primary School Level

One of the most popular tools used by CLIL teachers for remote and blended teaching is Padlet, already mentioned in this chapter, which is a webapp allowing teachers and students to collect digital sticky notes, with texts, pictures, videos etc. Padlet has become more and more popular during live sessions with the students connected remotely: it is a shared board, through which everybody can express ideas, opinions, collect material, research etc. It is a very useful webtool for flipped learning, as videos or other digital content can be assigned before the live lesson to be held face-to-face or online remotely. Padlet can also be used as the teacher's dashboard, where material and content can be used and easily delivered during the lessons.

The image below is a screenshot from a Padlet realized by a primary school teacher,[5] within a MOOC, a Massive Open Online Course, named Techno-CLIL, moderated by one of the authors of this paper (Letizia Cinganotto), in cooperation with Daniela Cuccurullo [40]. As a learning diary of her course, the teacher collected resources, websites and other material discovered during the training initiative, that could be useful for her CLIL lessons in Math. In particular, she found out engaging and interactive websites, such as Interactive Sites for Education,[6] covering a wide range of Math topics for young children, with amusing and engaging activities and exercises (Fig. 3.2).

[5] The teacher is Michela Pinna. The link to the Padlet: https://padlet.com/changeling/twi3lt50xc0g.
[6] http://interactivesites.weebly.com/math.html.

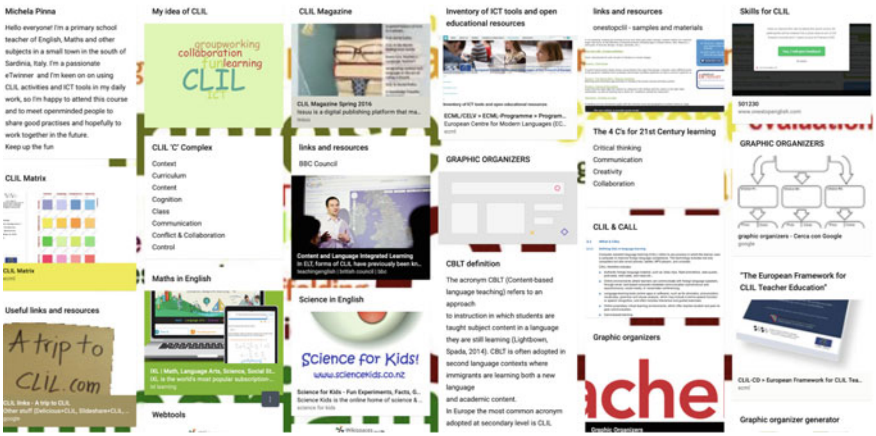


Fig. 3.2 Michela Pinna's padlet

One more example is provided by another learning diary from the same Techno-CLIL MOOC,[7] collecting useful resources for remote CLIL in Math, such as the diagram below, showing the potential of computational thinking in a foreign language according to CLIL, covering the 4 Cs framework, already mentioned in this chapter (Fig. 3.3).

Among the resources suggested by the teacher, that could be useful for remote CLIL in Math, iPractice Math[8] can be recommended for practice in Math, according to the different school grades. Another webtool posted on the Padlet is Algebra Class,[9] a very useful platform offering explanations and exercises for Algebra lessons. The material can be adapted by the teacher and also printed if necessary. Self-study can also be enhanced and facilitated through this website.

Teacher 7 had attended the Techno-CLIL MOOC before the pandemic and stated that it had been a great opportunity to learn more about the use of learning technologies for CLIL in Math and in the other subjects she teaches: "*I already knew a lot of webtools thanks to Techno-CLIL, so it was easy for me to start teaching online. I think it was easier for me compared to other colleagues who had to start from zero with the technologies*" (Teacher 7).

The above mentioned comment shows how crucial teacher training may be in the field of learning technologies for languages and for CLIL.

"My children had a lot of fun with the Math online games and activities in English I proposed during remote teaching thanks to the use of different platforms, open resources and webtools" (Teacher 7).

[7] The teacher is Maia Porombrica. The link to the Padlet: https://padlet.com/porombricamaia/xb3tbqg2ayxl.

[8] https://www.ipracticemath.com/learn/algebra/algebra-formulae.

[9] https://www.algebra-class.com.

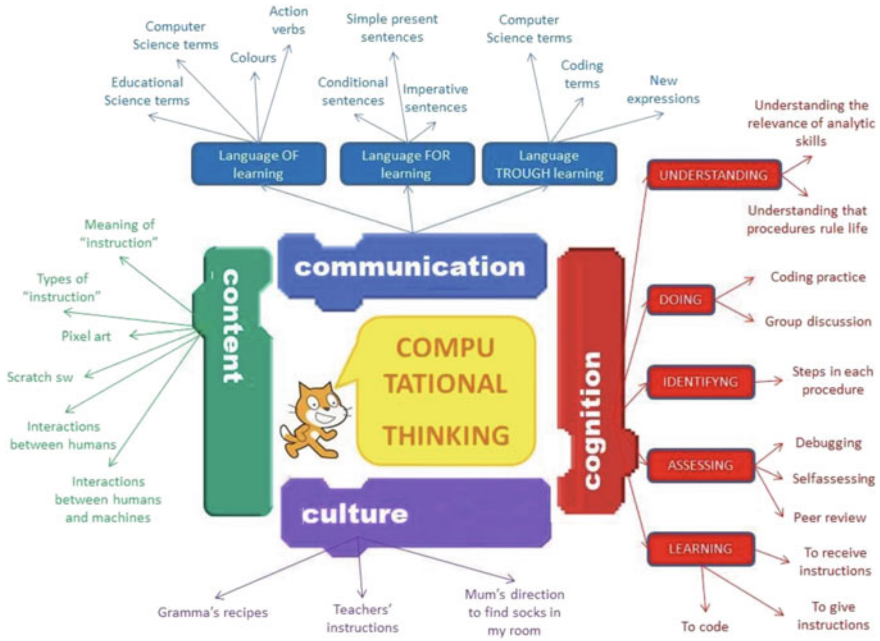


Fig. 3.3 Computational thinking in CLIL

Therefore, also primary school children could learn Math through CLIL by adopting an online game-based approach that is peculiar to early language learners and that can really engage them with an authentic use of the language for solving problems, quizzes, games and other interactive activities.

"We often spoke in Italian during the CLIL activities, as it is too difficult for them to be fully immersed in English especially for Math tasks" (Teacher 7).

Translanguaging is particularly helpful in primary school to facilitate the students' understanding and deep learning.

3.8 Discussion

The research questions which are the background of this study were the following:

– Which are the opportunities and challenges of the CLIL approach in teaching Math in hybrid or remote scenarios?
– Can young learners improve both their Mathematical thinking skills and second language skills through a CLIL approach even in remote/hybrid teaching?

The study aimed and integrating a desk research about the potential of CLIL in Math through learning technologies, with the description of some engaging and interactive online CLIL activities in Math and with comments and remarks from some teachers who were involved in an online video discussion and interview with the authors.

As general findings, the study confirmed the challenges and difficulties which are related to the teaching of Math in L1 and in L2 in the online mode, due to the subject-specific language of Math and to the pragmatic, prosodic and non-verbal communication which is so difficult to foster through a screen.

However, the teachers' comments have confirmed that through the choice of specific webtools, platforms and shared boards, it is possible to engage students in meaningful problem-based and project-based learning activities, empowering both the use of the L1 and the L2 through *translanguaging* where relevant and necessary.

Therefore, moving to the second research question, the study suggested that learners, even very young, can reach deep learning in Math and improve their Math knowledge and thinking skills through a better understanding of the task which can be easily described and solved. Encouraging verbal communication and explanation of tasks, problems and other Math issues in the L1 and L2 can help develop the students' communicative skills, fostering the active role of the learners in the educational process.

Teacher training in the field of learning technologies for CLIL should be encouraged and fostered as an important asset in the teacher's professional profile.

The reflections and considerations from this study are not exhaustive and only refer to the authors' perspective, considering the limitations due to the large number of possible CLIL topics in Math in remote and hybrid teaching and to the limited number of teachers being interviewed.

3.9 Conclusions

Moving from the main pillars of CLIL, the chapter highlighted the potential of CLIL in Math in remote and blended learning scenarios, linked to the COVID-19 emergency.

Mentioning the added value of Math in the Knowledge Society, for the development of the twenty-first century skills of our students, the chapter tried to highlight some methodologies and techniques related to the teaching of Math in a foreign language, namely English, in the remote, hybrid and blended educational scenarios linked to COVID-19 emergency. Examples of repositories, webtools, digital boards used by teachers for remote CLIL teaching have been mentioned as a way to foster students' engagement, interaction and interactivity interweaving Math content delivery and language competence development even in the unprecedented times we are all living during the pandemic. The interviews with a sample of Math teachers engaged in CLIL activities during the pandemic showed the potential of webtools, platforms and open resources to teach Math in CLIL remotely. Despite the challenges due to the pandemic, they were able to deliver Math content in a meaningful way, through a problem-based or project-based learning approach which could empower the structure and the value of a CLIL task. Communication and interaction were also fostered through the discussion, explanation and negotiation of the task both in the L1 and in the L2, facilitating deep learning and the development of communicative skills in a *translanguaging* mode.

References

1. D. Marsh, P. Mehisto, D. Wolff, R. Aliaga, T. Asikainen, M.J. Frigols-Martín, S. Hughes, G. Langé, (eds.), *CLIL Practice: Perspectives from the Field*. (CLIL Cascade Network/University of Jyväskylä Rovaniemi/Jyväskylä, 2009)
2. L. Cinganotto, CLIL in Italy. Lat. Am. J. Content Lang. Integr. Learn. **9**(2), 374–400 (2016)
3. L. Cinganotto, Apprendimento CLIL e interazione in classe. Aracne (2018)
4. Council of Europe, Council Recommendation on a comprehensive approach to the teaching and learning of languages (2019)
5. S.D. Krashen, The Input Hypothesis: An Update, in *Georgetown University Round Table on Languages and Linguistics 1991*. ed. by J.E. Alatis (Georgetown University Press, Washington, D.C., 1991), pp. 409–431
6. L.W. Anderson, D.R. Krathwohl (eds.), *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* (Longman, New York, 2001)
7. D. Coyle, CLIL planning tools for teachers (2005). https://www.unifg.it/sites/default/files/allegatiparagrafo/20-01-2014/coyle_clil_planningtool_kit.pdf
8. A. Walqui, Scaffolding instruction for english language learners: a conceptual framework. Int. J. Biling. Educ. Biling. **9**(2), 159–180 (2006)
9. J. Hattie, *Visible Learning for Teachers: Maximizing Impact on Learning* (Routledge, London, 2012)
10. J. Hattie, *Visible Learning: A Synthesis of Over 800 Meta-analyses Relating to Achievement* (Routledge, Oxon, 2009)
11. O. García, L. Wei, *Translanguaging: Language, Bilingualism and Education* (Palgrave Macmillan, New York, 2014)
12. D. Coyle, O. Meyer, *Beyond CLIL. Pluriliteracies Teaching for Deeper Learning* (Cambridge University Press, 2021)
13. L. Cinganotto, Pluriliteracies and LOCIT for CLIL, in *Conference Proceedings, 12th International Conference Innovation in Language Learning* (2019)
14. J. Šulistová, The content and language integrated learning approach in use. Acta Technol. Dubnicae **3**(2), 2013 (2015). De Gruiter open. https://doi.org/10.1515/atd-2015
15. F. Favilli, L. Maffei, R.J. Peroni, Teaching and learning mathematics in a non-native language: introduction of the CLIL methodology in Italy. US-China Educ. Rev. A (2013). ISSN 2161-623X
16. D. Pimm, M. Keynes, Mathematics classroom language: form, function and force, in *Didactics of Mathematics as a Scientific Discipline* (Kluwer, 1994)
17. P. Mehisto, Y.L.T. Ting, CLIL Essentials for Secondary School Teachers (Cambridge University Press, 2017)
18. C.M. Coonan, La metodologia task-based e CLIL, in *Il futuro si chiama CLIL: una ricerca interregionale sull'insegnamento veicolare*, ed. by F. Ricci Garotti (IPRASE del Trentino, Trento, 2006)
19. V. Orozco, M. Tatiana, Mathematics through clil: a comprehensive literature review and a didactic proposal to introduce clil in an ecuadorian monolingual school. Master's Dissertation Universidad de Jaén Universidad de Córdoba (2020)

20. T.P. Carpenter, J.M. Moser, The acquisition of addition and subtraction concepts in grades one through three. J. Res. Math. Educ. **15**, 179–202 (1984). https://doi.org/10.5951/jresematheduc.15.3.0179
21. L. Verschaffel, B. Greer, E. De Corte, *Making Sense of Word Problems* (Swets & Zeitlinger, Lisse, 2000)
22. V. Bermejo, P. Ester, I. Morales, A constructivist intervention program for the improvement of mathematical performance based on empiric developmental results (PEIM). Front. Psychol. **11**, 582805 (2021). https://doi.org/10.3389/fpsyg.2020.582805
23. A. Bonnet, Chemie im bilingualen Unterricht–Kompetenzerwerb durch Interaktion. Opladen: Leske und Budrich (2004)
24. G. Anthony, M. Walshaw, Characteristics of effective teaching of mathematics: a view from the west. J. Math. Educ. **2**(2), 147–164 (2009). December 2009
25. K. François, J.P. Van Bendegem (eds.), *Philosophical Dimensions in Mathematics Education* (Springer, New York, 2007)
26. M. Guida, Professional development of mathematics teachers in the age of I4.0-Can mathematics education contribute to build a better world?, in *Developing Mathematical Literacy in the Context of the Fourth Industrial Revolution IGI-Global*, ed. by E.O. Cardoso Espinosa (2021)
27. M. Guida, Rendere visibili il pensiero degli studenti ed il loro apprendimento in matematica [Making student's learning visible], in *La didattica della matematica, strumento concreto in aula*, ed. by B. D'Amore, S. Sbaragli. Atti del XXXII Convegno Nazionale Incontri con la matematica Castel San Pietro (Bo) (2018), pp. 16–18 XI 2018. ISBN: 88-371-2100-6.
28. K. Beswick, R. Callingham, T. Muir, Teaching mathematics in a project-based learning context: initial teacher knowledge and perceived needs, in *Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia)*, ed. by J. Dindyal, L.P. Cheng, S.F. Ng (MERGA, Singapore, 2012).
29. A. Lotti, Problem-Based Learning. Apprendere per problemi a scuola: guida al PBL per l'insegnante (Franco Angeli, 2018)
30. H. Vollmer, Content and language integrated learnig CLIL: a special case of language across curriculum (LAC), in *Bongartz Fremdsprachendidaktik inhalts- und lernerorientiert*, vol. 18. (Peter Lang AG, Frankfurt, 2010), págs. 27–47
31. C. Dalton-Puffer, *Discourse in content and language integrated learning (CLIL) classrooms* (John Benjamins, Amsterdam, 2007). ISBN 978-9-02721-981-7
32. European Commission, Improving the effectiveness of language learning: CLIL and Computer Assisted Language Learning (2014)
33. L. Cinganotto, *Lessons Learnt from Remote CLIL and Online Interaction during COVID-19 Emergency-Conference Proceedings–13th International Conference Innovation in Language Learning–Virtual Edition PIXEL 2020* (2020)
34. F. Ferretti, A. Del Zozzo, G. Santi, La didattica della matematica a distanza ai tempi del Covid-19 e la sua interazione con l'identità docente. [Remote teaching of mathematics at the time of Covid-19 and its interaction with the teacher identity]. Annali online della Didattica e della Formazione Docente, vol 12, N° 20 (2020). https://doi.org/10.15160/2038-1034/2290
35. INDIRE-Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa [National Institute for Educational Documentation, Innovation and Educational Research] (2020) Pratiche didattiche durante il lockdown. Report 2 [Teaching Practices During Lockdown. Report 2]. Table 11, p. 19
36. C. Giovannella, M. Passarelli, D. Persico, Measuring the effect of the Covid-19 pandemic on the Italian learning ecosystems at the steady state: a School Teachers' Perspective (2020)
37. S. Busto, M. Dumbser E. Gaburro, A simple but efficient concept of blended teaching of mathematics for engineering students during the COVID-19 pandemic (2021). https://arxiv.org/pdf/2010.14247.pdf

38. M. Ranieri, J.E. Raffaghelli, I. Bruni, Game-based student response system: revisiting its potentials and criticalities in large-size classes. Active Learn. Higher Educ. (2018). https://doi.org/10.1177/1469787418812667
39. D. Marsh, Language awareness and CLIL, in: *Encyclopedia of Language and Education*, ed. by N.H. Hornberger. (Springer, Boston, MA, 2008). https://doi.org/10.1007/978-0-387-30424-3_152
40. L. Cinganotto, D. Cuccurullo, Techno-CLIL, Fare CLIL in digitale, I Quaderni della Ricerca n. 42, Loescher (2019)

Chapter 4
The Potential of Artificial Intelligence for Assistive Technology in Education

Katerina Zdravkova

Abstract The right to education is a fundamental human right and an indispensable prerequisite for the development of human beings. To become well-rounded and independent from others, people with various disabilities should have an equal access to quality education. Assistive technologies support persons with different disabilities to keep and improve their functioning, which reinforces inclusive education. Artificial intelligence is their driving force, empowering a plethora of AI supported educational tools intended for people with special needs and elderly people, encompassing the tools for visual, hearing, communication, intellectual, cognitive and motor impairment. This paper also introduces the futuristic assistive technologies, in line with the prospective ethical challenges of AI supported educational tools.

Keywords Assistive technologies · Social inclusion · Visual impairment · Hearing impairment · Intellectual impairment · Cognitive impairment · Communication impairment · Motor impairment · Futuristic assistive technologies

4.1 Introduction

Artificial intelligence (AI) is becoming the most powerful and beneficial technology, positively impacting various daily activities [1]. It has significantly improved medical diagnostics, media and e-commerce, the service sector, transportation, education, and environment [2]. Natural language processing has enhanced and upgraded text and speech processing, morphological and syntactic analysis, and in recent years it contributed to lexical, relational and discourse semantics [3]. Although the quality of computational linguistics applications is still inferior to human achievements, the quality gap has considerably narrowed, making these applications very useful for

K. Zdravkova (✉)
Faculty of Computer Science and Engineering, University Ss. Cyril and Methodius, Skopje, North Macedonia
e-mail: katerina.zdravkova@finki.ukim.mk

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_4

practical use, particularly the machine translation and question answering. By establishing software robotics, which is usually synonymized with robotic process automation (RPA), AI supports the automation of digital and physical tasks, enables cognitive insights by detecting patterns within massive databases, and encourages cognitive engagement [4]. Accordingly, RPA is augmenting human capacities, amplifying effectiveness and improving quality of life.

By creating AI-based vision, cognitive, hearing and sign to text aids, AI has considerably powered accessible and assistive technologies [5], enabling people with various disabilities to reduce their psycho-physical barriers and inequality [6], and to encourage and support their social inclusion [7]. Education has significantly benefited from assistive technologies, reshaping the learning and teaching perspectives of millions and enabling the unhindered access to the wealth of knowledge [8]. It is part of the AI for social good (AI4SG) movement, which is a global trend aiming to improve the well-being of the world by implementing AI solutions [9]. It is undeniable that AI can have a great impact on education because it can easily detect students who might fall below grade level, determine the exact interventions necessary to support graduation on time and last, but not the least, AI can facilitate access to information to children with disabilities [10].

AI promotes personalization, ensuring inclusive education for all and better learning outcomes [11]. UNESCO working papers on education policies predict that the future with AI will be beneficial for the sustainable development of education, particularly if the six challenges, including the comprehensive public policy; teachers' preparation; ethical considerations as well as the increased research are seriously taken into account [11]. Particularly important is to ensure inclusive education and equity, making AI for education a core value [12]. According to the International Telecommunication Union (ITU), a specialized agency responsible for information and communication technologies (ICT) by the United Nations, ICT accessibility should become the main priority for persons with disabilities [12]. Since 2014, when the above-mentioned assertion was published, ITU has concluded that namely the AI is the science that "has the potential to support and enhance the accessibility of ICTs" [13]. Illustrating that the current intersection between accessible ICT, assistive technology and AI is small, ITU concludes that "AI use in the field of ICT accessibility is still in its infancy" [13].

Pandemic conditions and the necessity to replace in-class learning and teaching with digital accessibility made the accessible and assistive technologies more necessary than ever [14]. Many initiatives were immediately put into action, such as Digital Education Action Plan [15], iTutor in USA (https://itutor.com/), which is one of the many successful intelligent tutoring systems [16], and Get Skilled Access in Australia [17]. So far, there is no official report evaluating their accomplishments. Thus, it is crucial to know how to reach the available assistive tools and how to achieve a greater accessibility for everyone who needs it.

This paper presents a plethora of AI supported educational tools proposed for people with special needs. The main motivation to start such a comprehensive review was the author's long-term experience with assistive technologies [18], which among other educational systems includes the avatar visualization of Macedonian sign language intended for people with communication intelligibility [19]. The appreciation of the exceptional effects of AI-powered inclusive educational tools was recently intensified by the fact that they transformed the life of the girl with cerebral palsy [18]. Little V, now in her mid-twenties, managed to overcome most of her educational barriers caused by cerebral palsy and she is a very successful student of graphical design who competently uses an adapted keyboard and mouse to make fascinating drawings.

The systematic review presented in this paper intends to make a summary of the current research confirming that AI can have a great potential for assistive technology of education. It predominantly covers papers and reports published after 2015.

All the AI-supported tools presented in the paper were first selected implementing qualitative and quantitative ranking of papers selected from WoS master journal list and core collection. There were several qualitative criteria defined by the author: type and diversity of embedded AI agents, operating systems portability, multilingualism, and price. Presence of several AI-enhanced accessibility options, possibility to activate them from different devices, availability in the native language of the students, and the price, increase the availability of technological tools for users with disabilities. The second part of search methodology was quantitative ranking. It organizes the clusters of similar tools according to their number of users and the approval rate given by the users, whenever this information was provided. For each disability, five tools were taken into consideration for further analysis. Due to their massive usage and their impact on inclusive education, the amount of tools for visual impairment was doubled. The review starts with the text-to-speech, magnifying and tactile software for learners with visual impairment; speech-to-text and word prediction systems for learners with speech or communication disabilities; text-to-sign language converters, assistive listening devices and mobile applications for learners with hearing impairments; word recognition, math, spelling and social skills applications for people with intellectual disabilities; and cognitive orthotics and assistive technology for augmenting learning, cognition and development. It further presents the AI assisted mobility impairment. The last part of the paper embraces the futuristic assistive technologies and neural implants, which synchronize AI with human brain. The paper concludes with the contribution of AI for education, tackling the prospective ethical challenges of AI supported educational tools.

4.2 Learners with Visual Impairment

According to the World Health Organization, blindness and visual impairment affect at least 2.2 billion, or approximately 28% of world population [20], out of which almost 50 million are blind [21]. Reduced or absent eyesight disturbs all aspects of life, causing disabled communication, social isolation, depression, cognitive decline and even an increased risk of premature death of elderly people, who lose their independence.

In the last several decades, many assistive technologies for the visually impaired and blind people have been developed, enabling people to “overcome various physical, social, infrastructural and accessibility barriers” and facilitating them to “live active, productive and independent lives” [22]. Computer accessibility settings, modified keyboards, electronic books, talking calculators, image descriptors, visual localization systems, screen magnifiers, screen readers, voice assistants, tactile dots and text to Braille translators are nowadays used to support education of visually impaired or blind students. The following paragraphs introduce the most popular educational tools and their connection with the AI.

The most frequently used desktop operating systems: Windows, macOS and Linux, and mobile operating systems: Android and iOS have built-in accessibility features intended for blind and low-vision users, such as screen readers of text-to-speech (TTS) synthesizers, high-contrast themes and enlarged cursors. All Web browsers offer accessibility features for zooming the displayed screen content.

Modified keyboards for visually impaired persons range from keyboards with larger letters or large print stickers to tactile Braille keyboards [23]. Electronic books are special text collections of books, magazines, and newspapers formatted to be accessible to persons with visual impairments and blindness [24]. None of these technologies is AI supported, but their educational impact is significant, particularly because they are available to all the students for free. For example, Talking Books (rnib.org.uk/talking-books-service) gives free access to 32,000 books for adults and children, while Project Guttenberg (gutenberg.org/) has a collection of 60,000 books. Many countries have similar initiatives, creating collections of audio books, for example: in Serbian (knjigaprica.com/), Russian (akniga.org/) and Macedonian language (samoglas.mk/). To create these collections, many voice actors were engaged to read the books. Good quality TTS readers can efficiently replace them. TTS engines already power talking calculators, which have a built-in speech reader responsible to read the pressed keys and the result of the performed arithmetic operation [25]. Many of them are supplemented with voice-controlled interfaces, enabling a calculation of spoken operations and equations [26].

Image descriptors are written captions, which provide the essential information about photos, graphics, gifs, and video. Automatic image captioning combines computer vision and deep learning techniques to create the captions and converts them into a speech by implementing natural language processing (NLP) procedures [27].

Visual localization systems replace the conventional assistive tools, enabling easy navigation and supporting the awareness “of ambient environments and prevents them from coming across potential hazards” [28]. To perform this task, these systems, for example GoogLeNet, employ the deep convolutional neural networks [29].

Screen magnifiers enlarge the screen display, supporting the low-vision users. Most of the modern desktop magnifiers, such as: DaVinci Pro HD OCR, Onyx OCR 24, Merlin Elite Pro–Full HD Desktop and TOPAZ OCR Desktop Video Magnifier are enhanced with high definition cameras, optical character readers (OCR) and TTS readers [30].

Text magnifier and reader ZoomText (zoomtext.com/) is powered with the world's leading screen reader, JAWS for Windows, making the Fusion (freedomscientific.com/products/software/fusion/), a "screen magnification and visual enhancements for screen viewing ease". From the beginning of March until June 30 2020, free licenses were offered to facilitate the blind students study at home.

Voice assistants, such as: Amazon Alexa, Google Assistant, Apple Siri, Microsoft Cortana and Samsung Bixbi incorporate voice recognition, speech synthesis, and many NLP techniques, making them one of the most successful AI-complete applications. They can also have a great potential in education [31]. Unfortunately, due to the various privacy concerns and vulnerability of the channels by which personal data can be accessed [32], they might be counterproductive for the students with disabilities, particularly those who are not IT savvy.

For the deaf-blind students, who are estimated to be around 10,000 only in the United States [33], tactile assistive technologies seem to be the best accessibility solutions for everyday activities and education. They range from tactile dots, via haptic interfaces to text-to-Braille translators.

Tactile dots or bumps enable easier orientation at home or in the office achieved by marking computer keyboards, phone keypads, remote controls and home appliances with peel-and-stick bumpers (braillebookstore.com/Bump-Dots.1).

Haptic interfaces are tactile devices, which enable getting a sense of touch "by applying forces, vibrations, or motions to the user" [34]. Haptics has already been used to support the teaching of physics, chemistry and biology, providing alternative educational settings where students can manipulate and experience physical properties of objects, or molecular and microscopic structures thus allowing a richer understanding of concepts [35]. So far, there have been very few attempts to use haptic perception as an educational assistive technology [36], but haptics has the ability of full inclusion of blind students making it very promising for the future education of all students.

For the students who are familiar with the Braille alphabet, a variety of electronic devices, which embrace Braille note takers, writers and displays have been created [30]. Some of them enable bidirectional translation, from text to Braille and from Braille to text, enhancing writing and reading skills of blind students, without the need of a Braille teacher [37]. These technologies perform the OCR implementing various machine learning (ML) practices [38].

Table 4.1 on the following page presents 10 very popular AI supported educational tools for vision impaired students. They all contain a text-to-speech synthesizer, usually leveraging neural network techniques to deliver a human-like voice. NVDA and JAWS, which are the most frequently used screen readers have additional languages apart from the default English. NVDA is powered with Acapela TTS voices, supporting 28 languages and implementing 90 quality voices (acapela-group.com/solutions/acapela-tts-voice-for-nvda/). Screen magnifiers are not AI driven tools, but document readers, which are a complementary part of ZoomText Fusion and Select-to-Speak implement OCR of written or printed documents, mainly powered by neural networks (NN) [39]. The newest versions of JAWS, ZoomText, and Fusion interact with the users via their Voice Assistant, which supports

Table 4.1 AI supported educational tools for vision impaired students

Assistive tool	URL to access the tool	Features	AI agents	Availability	Price
JAWS (Job access with speech)	support.freedomscientific.com/	Screen reader	TTS NLP	Windows English Dutch German Spanish French	Home US only: $90 per year
		Image description			
		Voice Assistant			
NonVisual desktop access (NVDA)	nvaccess.org	Screen reader	TTS	Windows web based 50 languages	Free
		Braille display			
ZoomText	zoomtext.com	Screen magnifier	TTS NLP	Windows english	Home US only: $80 per year
		Screen reader			
ZoomText fusion	zoomtext.com	Screen reader	OCR TTS NN NLP		Home US only: $160 per year
		Document reader			
		Text magnifier			
		Braille support			
DaVinci Pro HD OCR	nelowvision.com/product/davinci-pro	Video magnifier	OCR TTS	Windows english	$3995
		Speech reader			
Onyx OCR 24	store.freedomscientific. com/products/onyx-ocr	Video magnifier	OCR TTS	Windows english	$3795

(continued)

Table 4.1 (continued)

Assistive tool	URL to access the tool	Features	AI agents	Availability	Price
VoiceOver	apple.com/accessibility /vision/	Screen reader	TTS NLP	macOS iOS English Spanish	Free
		Auditory descriptor			
VoiceOver+Braille	apple.com/accessibility/ vision/	Screen reader	TTS	macOS iOS iPadOS English Spanish	Free
		Auditory descriptor			
		Braille input			
Select-to-speak	support.google.com/accessibility/android/answer/7349565?hl = en	Screen reader	TTS	Android	Free
		Document reader			
Web anywhere	webinsight.cs. washington.edu/wa/	Screen reader	TTS	All operating systems	Free

English, German, Dutch, Spanish and French (blog.freedomscientific.com/whats-new-in-jaws-zoomtext-and-fusion-2021/).

Half of the presented assistive technologies are free, making them very popular. For example, NVDA is currently used by more than 70,000 vision impaired students worldwide. It announces controls and text while interacting with gestures on touch screens. Most of the commercial products are offered for an affordable price for home or student use. Unfortunately, corporate versions are too expensive, disabling their massive use. Still, the major challenge of all the solutions is the limited amount of languages and the availability for one operating system.

4.3 Learners with Hearing Impairments

According to the World Health Organization, more than 450 million people have hearing loss, 34 million of them are children [40]. Apart from congenital and acquired causes, including genetic problems, infectious diseases, ear infections, excessive noise, and ageing, more than 1 billion young people "are at risk of hearing loss due to exposure to noise in recreational settings" [40]. Hearing loss and deafness have: a functional impact affecting the ability to communicate and become academically successful; social and emotional impact, due to exclusion from communication; and economic impact, because the unemployment rates for people with hearing loss are high.

According to the US National Institute of Deafness and other Communication Disorders [41], to help people with hearing disabilities, three types of assistive technologies can be implemented: alerting devices, assistive listening devices, and augmentative and alternative communication devices.

Alerting devices emit a loud sound or blinking light to inform the person with hearing loss about some event. They typically include clocks, wake up alarms, visual alert monitors, remote receivers, and vibrating pagers [42]. AI contribution in these devices, if it exists in any way, is negligible and therefore, they will not be further explored.

Amplification of sounds is made with the assistive listening devices (ALD), mainly hearing aids or cochlear implants. They include: hearing or induction loops systems, which amplify the sound within a public area and is received by the hearing aids and cochlear implants; FM or infrared systems, which transmit amplified sounds in classrooms; and personal amplifiers, which increase sound levels and reduce background noise [43]. ML technologies are implemented to optimize speech and signal processing, and to measure or support the evoked potential, prediction of postoperative performance and surgical anatomy [44].

Augmentative and alternative communication (AAC) devices incorporate various communication methods, which supplement or replace speech or writing [45]. They range from picture boards and touch screens presenting symbols or items the person frequently uses; devices projected to communicate words; and speech generating devices [46]. In recent years, brain-computer interfaces for AAC communication have been invented [47]. They will be explained in more detail in Sect. 1.8.

AAC devices can be unaided and aided [48]. Unaided AAC are software solutions, which use facial expression, vocalizations, gestures, and sign language and systems to replace the spoken language [49]. The generation of visual alternatives, typically implementing 3D avatar technology, relies on word tokenization, which embeds several ML and NLP tools, including semantics [50]. For sign language recognition, supervised support vector machine learning models are used [51].

Aided AAC are devices used to transmit or receive messages, incorporating processes for augmenting, complementing or replacing speech [52]. They are divided into no-tech, low-tech and high-tech [52]. The first two categories have been used for decades, and they embrace facial expressions, voluntary motor movements and communication boards or books. High-tech AAC are AI supported, typically implementing machine learning and deep learning. Special education teachers emphatically endorse high-tech AAC tools, suggesting that AAC can "improve the experiences of teacher and student users" [53].

Table 4.2, presented on the following page, offer an overview of five of the most frequently used AAC applications and devices, which can be used at school enabling a better communication of hearing impaired students.

TapSOS (tapsos.com/) is a non-verbal application associated with British Telecom since 1993, enabling "UK citizens who are deaf, hard of hearing, have speech problems, or are in difficult situations" to access the emergency services by simply tapping over the icon of a required service, indicating the location and providing

Table 4.2 AI supported educational tools for hearing impaired students

Assistive tool	URL to access the tool	Features	AI agents	Price
Roger voice	rogervoice.com/en/	Calling and receiving phone calls	STT TTS	$5.99 per month
Ava	ava.me/	Lip-reading	Visual speech recognition	$14.95 per month
		Live transcription		
Signly	signly.co/	British sign language translation	Pattern matching TTS	Free
VoxSci	voxsci.com/	British sign language translation	STT	£5 per month
Logan ProxTalkerMid-Tech AAC device	logantech.com/products/proxtalker	Sound tagger	Pattern matching NLP	$3149
		Picture system		
		RFID technology		

more detailed information about the accident by tapping the additional icons. It is neither AI supported, nor intended for schools, but is one of the most valuable lifesaving applications, and deserves to be mentioned.

Rogervoice is an application that produces live transcriptions during phone calls. The transcriptions from text to speech (TTS) are available for more than 100 different languages. The application was currently used to facilitate more than 1,500,000 phone calls worldwide. Very similar application intended for mobile phones is Live Transcribe (android.com/accessibility/live-transcribe/). It includes 70 languages and dialects, which are transcribed using Google's speech recognition technology as they are spoken.

Ava (acronym for Audio-Visual Accessibility) is a mobile application capable of lip movement recognition, which presents live transcriptions. To perform the lip reading, Ava implements several AI techniques belonging to visual speech recognition, including speech recognition, speaker recognition and mining of multimedia content. Ava has a special program for schools, including online classes. According to Ava team, more than 150,000 people and many institutions use it.

Signly is a browser extension for Google Chrome and Microsoft Edge, which displays a sign language translation of Lloyds Bank and Network Rail website. It currently has no educational purposes, but the same approach might be incorporated into many educational sites to display sign language descriptions of the lectures.

Available on both, AppStore and Google Play, VoxSci transcribes voice messages into text messages, which are delivered to hard of hearing and deaf as SMS to mobile phones, or as e-mail to e-mail addresses. For a monthly price of 5 British pounds, they provide translation of 30 voicemail texts, making it slightly inconvenient for educational purposes.

The Logan ProxTalker has 80 prerecorded sound tags, which are placed over 5 location buttons. After being pushed, they generate a voice output. This AAC device has additional large tags for the students with visual impairment, and it is wheelchair mountable.

This section presented a range of tools and devices for hearing impaired students. They are accessible to many young students, mainly by offering a written transcription of spoken language. Surprisingly, very few applications are intended to use the 3D avatar sign language representation.

Interpretation of sign language gestures of US English has been patented in 2011 [54]. By that time, very few applications enabling sign language interpretation have been created [55]. They will significantly improve communication of deaf students with their teachers who are not skilled in sign languages. These tools are predominantly machine learning [56] and NLP based [57], showing the potential of artificial intelligence to support education of hearing impaired students. So far, there is a shortage of competent sign language interpreters, and in spite of the exceptional intellectual skills of some deaf students, many of them are not able to continue their education mainly due to communication barriers. An additional problem is the fact that only 17% of deaf or hard of hearing people use any hearing aid [40]. By creating new and affordable AI based technologies, the situation will undeniably improve.

4.4 Learners with Speech or Communication Disabilities

Speech disorders, sometimes called speech impediments embrace "difficulties with forming specific words or sounds, as well as difficulties with making words of sentences flow smoothly, like stuttering or stammering" [58]. They can be combined with language disorders, like aphasia, which is a difficulty of speaking parts of language and auditory processing disorder, i.e. a difficulty to understand the meaning of the sounds [58]. Additionally, many students have communication problems of different origins [59]. Speech-to-text and word prediction systems are the first solutions intended for learners with speech or communication disabilities. Recent survey of text-to-speech software suggests the commercial text-to-speech applications: Dragon Anywhere, Dragon Professional, Otter, Verbit, Speechmatics, Braina Pro, Amazon Transcribe, Microsoft Azure Speech to Text, and Watson Speech to Text, and the free solutions: Google Gboard, Just Press Record, Speechnotes, Transcribe and Windows 10 Speech recognition [60]. Their capabilities are fascinating, in some cases reaching an accuracy of 99.9% when the audio is clear. According to provided information, Speechmatics and IBM Watson Speech to Text use machine learning to correct those errors that were flagged up by their users, to prevent their repetition.

Word prediction systems detect the sequence of typed characters and suggest the prospective words in a prediction list. They are built into word processors [61]. Very popular are two mobile word prediction applications: Co:Writer Universal (cowriter.com/) and Dyslexia Keyboard (ghotit.com/).

For many researchers, the best solution to help children overcome their communication problems are the augmentative and alternative communication (AAC) tools [59]. The Logan ProxTalker has already been introduced in Sect. 1.3. AssistiveWare (assistiveware.com) suggest three mutually compatible AAC products: Proloquo4Text. Proloquo2Go and simPODD. They support non-verbal expression of children with various communication problems and speak the created words, phrases and sentences using human-like voices.

Proloquo4Text is a TTS supporting easy expression, implementing word and sentence prediction. It is multilingual and includes the following 9 languages: English, Danish, Dutch, French, German, Italian, Norwegian, Spanish, and Swedish. For a price of €129.99, it can be used on iPhone, iPod and Apple Watch users.

Proloquo2Go is a symbol-based application, which has an incorporated word vocabulary of more than 10,000 words developing full grammatical sentences. It presents a set of the so called core words, the words that are the most frequently used to make up 80% of what people say. Proloquo2Go is easy customizable, offering the creation of own buttons from existing 25,000 symbols, which can be extended with own photos. Similarly to Proloquo4Text, it is available for the same Apple's devices for English, Spanish, French, and Dutch for €279.99. Together with Proloquo4Text and Pictello and Keedogo (Plus), an application for reading, writing and typing using a simplified keyboard layout, they make the AAC Essentials Bundle for a unique price of €329.99.

PODD is an acronym for Pragmatic Organisation Dynamic Display, a "huge book of laminated pages and complex symbols". PODD is suitable for users who cannot speak. They can combine the symbols to explain the message they are not able to pronounce. simPODD is usually combined with Prologui2Go, extending the basic symbols with the large list of own symbols. For an annual price of €149.99, it is available from App Store.

Speech and communication disabilities affect comprehension, and production of oral and written language. They are frequent, affecting from 7.7% of young children in US [62] to 10% in UK [63]. Speech and language therapies are the most common methods to prevent, assess and treat these communication problems. Language therapists, known as logopedists are the specialists who employ these methods to assist the disabled children in their communication. It is projected that their employment will grow 25% in the following 10 years [64]. Speech-to-text and word prediction systems are a beneficial alternative of logopedists for those students whose deficiency is connected with hearing disorders, voice and speech problems. For the students with some additional problems, for example, autism, developmental and learning disabilities, AAC can facilitate communication. Unfortunately, all the available AAC systems on the market at the moment are rather expensive and created for a limited amount of languages, making them helpful for the privileged students, whose schools and parents can afford using them as a complementary communication tool.

4.5 Learners with Intellectual Disabilities

Intellectual disability is a neurodevelopmental disorder, demonstrated by limitations in cognitive functioning and adaptive behavior [65]. It affects communication, social and self-care skills. According to some sources, approximately 200 million people have an intellectual disability, which is significantly more frequent in the low-income countries [66]. Unfortunately, intellectual disability is not curable, for that reason, the treatment should be directed towards normalization of behavior and gaining emotional well-being of the people with limited intellectual abilities [67].

To "protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity", UNESCO has adopted the Convention on the Rights of Persons with Disabilities [68]. Among the 50 articles of the convention, the two crucial for this paper are accessibility and education. In the recent years, many assistive technologies have been created but very few are intended for the intellectually disabled students [69]. Several computer and electronic devices for children with learning disabilities, such as: alternative keyboards, audio books, electronic math sheets, graphic organizers, speech readers, spell checkers and word-prediction applications can be beneficial for children with mild intellectual disability. However, much more has to be done to reduce their eternal struggling with the attention, learning and completing of educational tasks.

Table 4.3 AI supported educational tools for intellectually disabled students

Assistive tool	URL to access the tool	Features	AI agents	Price
Co:Writer universal	cowriter.com	Word prediction Topic dictionaries	STT TTS	$4.99 per month
Ginger	gingersoftware.com/solutions/ld_professionals	Spelling check Grammar check	NLP	Free
Inspiration 10	inspiration-at.com/inspiration-10	Mind-mapping Concept mapping	TTS	£58 or €67 without VAT
Lingraphica AAC	aphasia.com/	Communication AAC tool	TTS	Covered by Medicare Medicaid
Beamz interactive music system	thebeamz.com/	Interactive music making	Eye tracking	From $370 to $530

Major goal of assistive technologies for intellectually impaired is to improve their information access. To achieve this goal, AI based solutions have been developed, each enhancing or supporting a different aspect of student's academic and home life. They are presented in Table 4.3.

Co:Writed Universal was already mentioned in Sect. 1.4 as one of the best systems for word prediction. It also enables spelling correction, reading of the text while it is typed, opportunity to dictate the text, as well as dictionaries which suggest the corresponding vocabulary related to the topic a student is working on.

Ginger supports students with learning disabilities to easily write error-free texts offering clues how to carry on with the sentence, based on the context of the already written words. Within its premium edition, TTS feature reads the words together with a brief explanation of its meaning and a list of alternatives. Audio assistance is available in UK and US English.

Inspiration 10 is one of the most popular mind-mapping applications. Improved with UK and US spelling, this application enables students to create mind and concept maps and to organize graphic organizers, outlines and presentations. Moreover, it enables adding notes to symbols, text-to-speech and spell checking. Mind-mapping software will be explained in more details in Sect. 1.6.

Lingragrafica is an AAC application intended for people who survived a stroke or brain injury. It is a speech generating device, based on a system of icons that feature pictures, text and verbal output. They can also be a valuable tool for children with developmental or intellectual disabilities, which have trouble to communicate.

Beamz Interactive Music System is a versatile device accessible to students of all learning and physical abilities. It is intended for home use, for therapy and rehabilitation and for schools. Beamz is powered by Tobii EyeGaze (tobiidynavox.com/), an eye tracking technology that allows interaction, navigation and control of the devices by eye movement. Beamz is not an educational tool, but it has a very nice emotional impact for the intellectually disabled.

For centuries, people with intellectual disabilities were totally excluded from any education. Inclusive education has contributed to their active involvement and engagement enhancing their well-being. New assistive technologies are steadily improving their community living, improving their abilities to communicate and express the needs in a completely new way. Artificial intelligence is the core of most assistive technologies intended for these vulnerable and generous people who deserve a better and more dignified life.

4.6 Learners with Cognitive Disabilities

In the past, cognitive disabilities were equated with intellectual disabilities [70, 71]. Recent studies recommend to consider aphasia, autism spectrum, attention deficit, dyslexia, dyscalculia, intellectual and memory loss as a separate disability type, particularly because they do not necessarily affect general intellectual skills [72].

Cognitive disorders encompass problems with attention, processing speed, short-time and long-term memory, logic and reasoning, language processing, as well as math processing [73]. According to this detailed review "attention, processing speed, and short-term memory are part of automatic processing", while "long-term memory, logic and reasoning, language processing and math processing are part of higher thinking". As a result, cognition impaired have a diminished independence, which affects their daily activities, entertainment and social activities, and engaging in work.

Assistive devices intended for students with cognitive impairments are known as cognitive assistants [74]. These are interactive AI systems intended to improve the daily activities and education of the users "by augmenting their cognitive abilities or complementing a cognitive impairment" [74], thus they are a part of the cognitive orthotics [75]. Cognitive orthotics assistants are ubiquitous and pervasive platforms and services, aimed to support learning, memory, keeping records, making documents and organizing the thoughts [76].

All the above mentioned cognitive features are part of the mind-mapping or concept-mapping applications, software tools that enable the creation of visual diagrams, which can further be exported into documents, spreadsheets or presentations [77]. Many universities worldwide, particularly in the UK, have uploaded mind-mapping software together with magnification and screen-reading applications on all computers on campus.

Mind-mapping, concept-mapping and argument-mapping software packages are valuable mapping tools, which "enable the visual display of information, concepts and relations between ideas" [77]. They stimulate creative thinking of students and

Table 4.4 Mind-mapping applications for cognitive impaired students

Mid-mapping tool	URL to access the tool	Features	AI agents	Price
XMind 2020 Mobile	xmind.net	Brainstorming	Spell checking ML	$39.99 per 6 month
		Planning		
		Problem solving		
XMind 8 Pro	xmind.net	Brainstorming	Spell checking ML	$59 for teachers / students
		Planning		
		Problem solving		
MindView AT	matchware.com/assistive-technology-software	Visual planning	STT TTS	$15–$20 per month
		Screen reader		
Mindomo	mindomo.com	Project planning	Spell checking screen reading STT	€3 for students €5 for teachers per month
		Learning skills		
		Thinking skills		
Popplet	popplet.com	Drag and drop visualization	Not specified	$19.99 per year for students
		Collaborative brainstorming		

increase the achievements in learning science [78]. The in-depth survey of their impact on students with mild to moderate cognitive impairment has confirmed that the majority of reviewed students had a subjective impression that their functional performance has improved after implementing mind-mapping software [79]. Table 4.4 presents the most frequently mind-mapping applications used in education.

XMind is a cross platform tool used by tens of million users. Apart from enabling graphical representation of some problem, it is also useful for collecting notes, which can be organized in a graphical way and exported in a structured document. XMind has already in-built conceptual maps, enhancing visual perception of some well-known problems. XMind versions can be adjusted to support many languages, including Chinese, English, German, Indian, Japanese, Portugese, Russian, Slovenian and Spanish. They can be added into an own dictionary to facilitate the spell checking. XMind has several versions, including the mobile XMind 2020, and the professional XMind 8 Pro. The only AI feature they support is spell checking. XMind is dual licensed, under the EPL, with the prices indicated in Table 4.4 and under the LGPL.

MindView AT is an assistive technology for academic purposes. In parallel with the intuitive visualization, it includes text-to-speech, Dragon speech-to-text add-on, word prediction and high-contrast mode. Moreover, it enables easy integration with JAWS and ZoomText, making it available for multiple disabilities. Similarly to XMind, it has around 100 education examples in several disciplines, like history, geography, languages and physics, which are very intuitive and facilitate remembering by visual stimuli. At the moment, it is available for Windows and MacOS in English, French and German. Monthly price depends on the period of subscription, which is annual, for two or for three years.

Mindomo is a browser based mind mapping assistive technology intended for students who suffer from Dyslexia, ASD, ADHD or who are easily distracted. Considering the fact that “90% of information transmitted to the brain is visual” [80], Mindomo presents information and details with colorful and interesting structured graphs. Visual presentation is extended with audio explanation, contributing to a better comprehension of presented information. Basic functionalities are available in a free limited option, which is appropriate for training the students to use the application prior to start using it at school.Popplet is recommended for younger students, including the K-12. It is used in more than 100 different languages, mainly due to their predominantly visual and very intuitive approach. Popplet supports individual and group subscriptions, which is convenient for younger students, for whom teachers set up student accounts and then oversee the use. No AI features are reported about this application, making it inconvenient for students with more severe vision impairment.

A more powerful instrument for students and teachers with cognitive disabilities are the assistive technologies for augmenting learning, cognition and development. A very exhaustive review of assistive technology for cognition (ATC) was made by Gillespe, Best and O’Neill [81], proposing a division of ATC devices into “those that affected self-awareness and those that involved the prioritization of action”. They include word prediction software, voice recorders, speech recognition, cueing/memory aids and educational software. Cueing/memory aids are the most frequently used ATC gadgets, which help people to recall various information, ranging from tasks and appointments to steps in how to accomplish activities. The most valuable ATC for educational purposes are Read and Write Gold (texthelp.com/en-gb/products/read-write/) and Kurzweil 3000 (kurzweiledu.com/k3000-firefly/overview.html). Read and Write Gold is used by more than 25 million users who improve their reading and writing, including students who have dyslexia. It has an advanced spellchecker and word prediction module and reads the online text to “give tired eyes a break”. Moreover, it increases concentration by masking the screen. Kurzweil 3000 is a universal assistive technology with several features for vision impaired, like text-to-speech, OCR and text magnification. It is adjusted for students with dyslexia, including a talking calculator.

Cognitive disabilities affect communication and learning, inhibiting life and school activities. Many assistive technologies can contribute to their reduction, particularly those which are associated with vision or hearing impairment and lack of concentration.

4.7 Learners with Mobility Disabilities

Mobility disability or impairment is any disability that affects movement. It includes upper or lower limb loss or disability, lack of manual dexterity and disability in coordination with other parts of the body. The World Health Organization estimates that 75 million people, or around 1% of world population need a wheelchair [82]. Wheelchair accessibility is a privilege for many students, particularly in the developing countries. Knowing that education is a fundamental human right, many students are discriminated on the basis of motion disability. Apart from wheelchairs, students can access schools using the mobility aids like walkers, scooters, crutches, canes, prosthetic and orthotic devices [83].

Many adaptive tools, including modified keyboards, specialized handles and grips, adaptive sticks, mouth sticks, automatic page turners, and sip-and-puff systems can support them in performing various tasks at school [84].

There are very few specialized assistive technologies for students with mobility impairment. One fantastic application, which is available for Android devices is Mouth4All Switch (mouse4all.com/en). It can assist students with "cerebral palsy, spinal cord injury, ALS, multiple sclerosis, Parkinson, neuromuscular disease" to manipulate the touchscreen without a need to touch it. Instead, an AAC approach is enabled, based on switch access scanning, which activates the selected option either by highlighting the items on the screen, or by announcing the items via voice output. Currently, it is available in Spanish and in Italian for $7.99 to $99 per item.

The most popular switch access scanning assistive technology is the Assistive Context-Aware Toolkit (01.org/acat/). It was used by Stephen Hawking since mid-1980s. It is free, open source application currently available in English, French, Spanish and Portuguese. Powered by Microsoft's Speech Synthesizer API and the default TTS voice on the target machine, it can be easily extended to other languages. ACAT has a vision switch using "the webcam to track the user's face and to detect facial gestures". To accelerate the creation of the words, it has a word prediction option.

The mobility aids and adaptive tools are not covered in this paper. Some of them are not AI supported, others are not intended for education. The development of many assistive and adaptive tools for motion impaired people is still in its infancy. Some of them belong to futuristic assistive technologies, which will be clarified in the next section.

4.8 Futuristic Assistive Technologies and Neural Implants

Small Danish startup Envision (letsenvision.com/) modified Google glasses turning them into AI-powered smart glasses, which extract information about the world surrounding the blind person and interpret them using a natural language. This is a nice opportunity to experience the visual world hands-free. Envision glasses are powered with a text recognition module, enabling students to listen the content of their study materials. These glasses are non-invasive, but still unexplored and a rather expensive solution, with a pre-order reduced price of $1699.

Students and teachers with vision impairment caused by degenerative retinal diseases or age-related macular degeneration can undergo a surgical treatment to get a cortical and retinal implant, i.e. a bionic eye [16]. This is a very innovative assistive technology at its initial stage and very few companies and research groups have advanced enough to start producing them massively [16]. Moreover, they are extremely expensive, for example, Argus II and Orion, the only FDA approved bionic eye costs $150,000. Orion is one of the first implants inserted to human brain.

Many hearing impaired students use cochlear implants [85]. These small electronic devices stimulate the cochlear nerve, permitting people to gain better hearing and speech perception. Those students who received their cochlear implants during early childhood managed to gain an ability for better pronunciation, which resulted in a more expressive and receptive vocabulary [85].

Auditory brainstem implants (ABI) have been researched for almost 50 years and the results are very promising for all ages, including children who managed to achieve an environmental sound awareness and word detection few months after ABI was activated [86]. A more futuristic assistive technology than the bionic eyes is the optogenetic sensory restoration of hearing [87]. Optogenetics uses the light to control genetically modified cells and selectively stimulates or inhibits neural pathways. Future optical cochlear implants, powered by optogenetics can improve speech recognition [81]. Additionally, the same approach can be used to restore vision [88].

The futuristic assistive technologies “used to treat disease, rehabilitate the body after injury, improve memory, communicate with prosthetic limbs, and more” are the neural implants [89]. Neural implants are devices, which are placed inside the body to interact with human neurons. They cause a deep brain stimulation in an effort to “reduce the symptoms of various brain-based disorders” [89]. This approach has already proved beneficial. It improved communication skills and cognitive control, and suppressed some movement disorders [90]. Retinal, optogenetic and neural implants can revolutionize the assistive technologies we now use. They synchronize the human brain with AI. So far, these implants have not been intensively used and tested, so their positive impact and contraindications are still unknown. Many research centers extensively explore them and have already delivered the first prototypes. After several years, the futuristic assistive technologies will no longer be a science fiction.

4.9 Conclusions

Artificial intelligence has intensively evolved. It has invented many techniques, which became pervasive and reached a mainstream use. AI has dramatically transformed the world, supporting or replacing many routine activities and assisting people to perform better. AI powered assistive technologies bridged the communication gap, facilitating even the people with multiple disabilities to access and exchange information in real time. Accessibility wizards of most operating systems, text and screen magnification, text-to-speech add-ons, translation of the text to Braille alphabet and mind-mapping applications have significantly contributed to this success.

The future of education systems, particularly after the pandemic will embrace adaptive learning technologies, replacing the in-person activities with more inventive online activities, which support human communication and the inclusion of students with some impairment.

Although the technology has considerably advanced, the access to sophisticated assistive educational tools is still a privilege of wealthier, predominantly English speaking students. The problem should be solved internationally and nationally.

The international community should unite AI researchers, educationalists and software developers. Pedagogues will suggest to researchers how to invent new and more available solutions that fulfil all the pedagogical and methodological methods, aspects and implications, caring about the content and context [91]. Then, researchers and software developers will transform them into new and more powerful tools. Many free and open FOOS initiatives presented in this paper prove that this ambitious goal can be reached.

National authorities should increase the reach of assistive tools, making them available to all. The order of activities is the opposite from the order of qualitative factors for selecting the tools presented in the introduction of this paper. At first, ministries of education should purchase the software licenses for the tools, providing them to all the impaired students in the country. The second obligation is to localize them, bypassing the language difficulty. Portability will be enabled by the international software developing community, with careful supervision by experienced pedagogues.

The most popular learning management systems (LMS): Blackboard, Canvas, Desire2Learn and Moodle already contain several accessibility plugins based on speech recognition, speech synthesis and voice assistants, reducing the need of additional assistive technologies. In parallel, many universities provide accessible hardware and assistive technologies on campus. Whenever accessible LMS plugins are not sufficient, students have an access to same accessibility software solutions for a very reasonable price.

It is expected that in the near future, new LMS plugins will support the behavioral signal processing [92], enabling technology to understand the emotions of the students and inform the teacher about the emotional state in real time. They will check whether students stay focused during their lessons, or if they are distracted or frustrated. If their interest to attend the lectures is low, they can be forwarded to some virtual reality (VR) [93], and/or augmented reality (AR) alternative, like Google Expeditions and Tour Creator (edu.google.com/products/vr-ar/expeditions/). Google Expeditions is a software platform that offers over 900 VR and 100 AR excursions created in partnership with the most famous museums worldwide.

It is undeniable that AI has a great potential to support and even transform the lives of students with disabilities. This paper tried to prove this claim by presenting many AI driven assistive technologies and their power to overcome the disability barriers. Some researchers have a completely opposite opinion. For example, Smith & Smith think that AI and disability is still "too much promise, yet too little substance" [94]. One of the major arguments supporting this provocative assertion are the ethical concerns of AI systems, which instead of working for the sake of the disabled people, increase their discrimination. They also have an impression that AI at the same time assists and frustrates the disabled people. How right are they? Unfortunately, a lot.

Some assistive technologies, for example: DaVinci Pro HD OCR and OnyxOCR 24 from Table 4.1 and Logan ProxTalker from Table 4.2 are not affordable to students who need them. Hardware, software and operating systems incompatibilities, language obstacles, and particularly the high price of many tools have already been mentioned throughout this paper. Inability of students with motor impairment to get into lecture rooms, incapability to listen the lectures or see the presentations due to hearing and vision impairment, insufficient time to complete the time limited examinations caused by cognition or motion problems are not an exception, on a contrary, they are still a problem in many countries. All these obstacles are related to social disparity [95].

Many students are not capable for independent learning, either because they are incompetent for fully independent life due to some disability, or because they simply strive for human contact and empathy. Online teaching and learning and intelligent assistive systems should complement human-delivered care. During the pandemic, human contacts were kept to a minimum, severely affecting students with cognition or intellectual impairment.

Students with disabilities usually have limited information access. Very few of them are IT savvy [96]. Experienced teachers cope with these problems. Unfortunately, intelligent assistive technologies collect many sensitive data, harming both, students' personal privacy and their medical confidentiality [87]. Behavioral monitoring additionally worsens the problem.

Futuristic assistive technologies might interfere human dignity [97]. Ethical problems embrace: the selection of candidates for neural implants, responsibility of unpredicted reactions, liability for caused dangers, predator's monitoring, potential interference of brain activity and security breaches [97]. It is still too early to find a solution to all these ethical challenges, but they should be taken into consideration as soon as possible.

Carl Sagan wrote: "Every generation worries that educational standards are decaying" [98]. In 2020, traditional education was instantly transformed to online education. Students with disabilities were the most affected by this urgent shift. AI assistive technologies may become the moral agents that contribute most to AI4SG.

References

1. I. De Falco, G. De Pietro, G. Sannino, Evaluation of artificial intelligence techniques for the classification of different activities of daily living and falls. Neural Comput. Appl. **32**(3), 747–758 (2020)
2. S. Ren, T.M. Choi, K.M. Lee, L. Lin, Intelligent service capacity allocation for cross-border-E-commerce related third-party-forwarding logistics operations: a deep learning approach. Transp. Res. Part E Logist. Transp. Rev. **134**, 101834 (2020)
3. E.M. Bender, A. Lascarides, Linguistic fundamentals for natural language processing II: 100 essentials from semantics and pragmatics. Synth. Lect. Hum. Lang. Technol. **12**(3), 1–268 (2019)
4. T.H. Davenport, R. Ronanki, Artificial intelligence for the real world. Harv. Bus. Rev. **96**(1), 108–116 (2018)
5. E.A. Draffan, P. Heumader, Artificial intelligence, accessible and assistive technologies, in *International Conference on Computers Helping People with Special Needs* (2020), pp. 53–58
6. J.M. Górriz, J. Ramírez et al., Artificial intelligence within the interplay between natural and artificial computation. Advances in data science, trends and applications. Neurocomputing **410**, 237–270 (2020)
7. E. Serrano, M.C. Suárez-Figueroa, J. González-Pachón, A. Gómez-Pérez, Toward proactive social inclusion powered by machine learning. Knowl. Inf. Syst. **58**(3), 651–667 (2019)
8. E. Eaton, S. Koenig et al., Blue sky ideas in artificial intelligence education from the EAAI 2017 new and future AI educator program. AI Matters **3**(4), 23–31 (2018)
9. L. Floridi, J. Cowls, T. King, M. Taddeo, How to design AI for social good: seven essential factors. Sci. Eng. Ethics 1771–1796 (2020)
10. G.D. Hager, A. Drobnis, F. Fang et al., Artificial intelligence for social good (2019). https://arxiv.org/ftp/arxiv/papers/1901/1901.05406.pdf
11. F. Pedro, M. Subosa, A. Rivas, P. Valverde, Artificial intelligence in education: challenges and opportunities for sustainable development (2019)
12. M. Msimang, D. Rice, C. Thorén, Digital inclusion, model ICT accessibility, Policy Report (2014). https://www.itu.int/dms_pub/itu-d/opb/phcb/D-PHCB-SIS_A.01-2014-PDF-E.pdf
13. E.A. Draffan, M. Wald, Artificial intelligence and information communication technology accessibility, Accessible Europe (2019). https://www.itu.int/en/ITU-D/Digital-Inclusion/Documents/AI%20and%20ICT%20Accessibility_webEA3_Final.pdf
14. J. Lazar, Accessibility research in the pandemic: making a difference in the quality of life for people with disabilities, in *The 22nd International ACM SIGACCESS Conference on Computers and Accessibility* (2020), pp. 1–1
15. European Union, Digital Education Action Plan, (2020). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0624&from=EN
16. G. Paviotti, P. Rossi, D. Zarka, Intelligent tutoring systems: an overview. Pensa Multimedia (2012), pp. 1–176
17. G. Lever, J. Hicks, Creating real inclusion: a call to arms to the tourism industry in support of people with disability, in *CAUTHE 2020: 20: 20 Vision: New Perspectives on the Diversity of Hospitality, Tourism and Events*, vol. 41 (2020)
18. K. Zdravkova, Educational software for children with cerebral palsy (a Case Study) (2003). http://ciit.finki.ukim.mk/data/papers/4CiiT/4CiiT-20.pdf
19. B. Joksimoski, I. Chorbev, K. Zdravkova, D. Mihajlov, Toward 3D avatar visualization of macedonian sign language, in *International Conference on ICT Innovations* (Springer, Cham, 2015), pp. 195–203
20. WHO, Blindness and vision impairment (2020). https://www.who.int/health-topics/blindness-and-vision-loss#tab=tab_1
21. R.R. Bourne, J. Adelson, S. Flaxman et al., Global prevalence of blindness and distance and near vision impairment in 2020: progress towards the Vision 2020 targets and what the future holds. Invest. Ophthalmol. Vis. Sci. **61**(7), 2317–2317 (2020)

22. A. Bhowmick, S.M. Hazarika, An insight into assistive technology for the visually impaired and blind people: state-of-the-art and future trends. J. Multimodal User Interfaces **11**(2), 149–172 (2017)
23. C. Southern, J. Clawson, B. Frey, G. Abowd, M. Romero, An evaluation of BrailleTouch: mobile touchscreen text entry for the visually impaired, in *Proceedings of the 14th International Conference on Human-Computer Interaction with Mobile Devices and Services* (2012), pp. 317–326
24. R.K. Bhardwaj, S. Kumar, A comprehensive digital environment for visually impaired students: user's perspectives. Library Hi Tech (2017)
25. E.C. Bell, A.M. Silverman, Access to math and science content for youth who are blind or visually impaired. J. Blind. Innov. Res. **9**(1) (2019)
26. A. Pradhan, K. Mehta, L. Findlater, "Accessibility came by accident" Use of voice-controlled intelligent personal assistants by people with disabilities, in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (2018), pp. 1–13
27. H. MacLeod, C.L. Bennett, M.R. Morris, E. Cutrell, Understanding blind people's experiences with computer-generated captions of social media images, in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (2017), pp. 5988–5999
28. S. Lin, R. Cheng, K. Wang, K. Yang, Visual localizer: outdoor localization based on convnet descriptor and global optimization for visually impaired pedestrians. Sensors **18**(8), 2476 (2018)
29. C. Szegedy, W. Liu et al., Going deeper with convolutions, in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (2015), pp. 1–9
30. New England Low Vision and Blindness, Top desktop electronic video magnifiers – 2019 (2019). https://nelowvision.com/2019/04/01/top-desktop-electronic-video-magnifiers-2019/
31. G. Terzopoulos, M. Satratzemi, Voice assistants and artificial intelligence in education, in *Proceedings of the 9th Balkan Conference on Informatics* (2019), pp. 1–6
32. E. Furey, J. Blue, Can I Trust Her? Intelligent personal assistants and GDPR, in *2019 International Symposium on Networks, Computers and Communication* (2019), pp. 1–6
33. NLS (2019) Deaf-Blindness. https://www.loc.gov/nls/resources/deaf-blindness/
34. T.D. Sreelakshmi Subash, Haptic technology: a comprehensive review on its applications and future prospects. Mater. Today Proc. **4**(2), 4182–4187 (2017)
35. R Espinosa-Castaneda, H.I. Medellin-Castillo, Virtual haptic perception as an educational assistive technology: a case study in inclusive education. IEEE Trans. Haptics (2020)
36. N. Hynes, D. Jebaraj, J. Kumar, S. Immanuvel, R. Sankaranarayanan, Portable electronic braille devices–an overview, in *AIP Conference Proceedings*, vol. 2142, no. 1, pp. 140018 (2019)
37. S. Sultana, A. Rahman, F. Chowdhury, H. Zaman, A novel Braille pad with dual text-to-Braille and Braille-to-text capabilities with an integrated LCD display, in *2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies* (2017), pp. 195–200
38. K. Smelyakov, A. Chupryna, D. Yeremenko, A. Sakhon, V. Polezhai, Braille character recognition based on neural networks, in *2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP)* (2018), pp. 509–513
39. T.C. Wei, U.U. Sheikh, A.A.H. Ab Rahman, Improved optical character recognition with deep neural network, in *2018 IEEE 14th International Colloquium on Signal Processing & Its Applications (CSPA)* (2018), pp. 245–249
40. WHO, Deafness and hearing loss (2020). https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss
41. NIDCD, Assistive devices for people with hearing, voice, speech, or language disorders (2019). https://www.nidcd.nih.gov/health/assistive-devices-people-hearing-voice-speech-or-language-disorders
42. M.S. Farooq, Learning through assistive devices: a case of students with hearing impairment. Bull. Educ. Res. **37**(1), 1–17 (2015)
43. A.M. Rekkedal, Assistive hearing technologies among students with hearing impairment: factors that promote satisfaction. J. Deaf Stud. Deaf Educ. **17**(4), 499–517 (2012)

44. M.G. Crowson, V. Lin, J.M. Chen, T.C. Chan, Machine learning and cochlear implantation-a structured review of opportunities and challenges. Otol. Neurotol. **41**(1), e36–e45 (2020)
45. T. Zarifian, A. Mahnam, A. Vosoughi, Augmentative and alternative communication systems for post-stroke patients with severe communication and motor impairment. Adv. Biosci. Clin. Med. **66**, (2017)
46. H. Tegler, M. Pless, M.B. Johansson, K. Sonnander, Speech and language pathologists' perceptions and practises of communication partner training to support children's communication with high-tech speech generating devices. Disabil. Rehabil. Assist. Technol. 581–589 (2018)
47. J.S. Brumberg, K.M. Pitt, A. Mantie-Kozlowski, J.D. Burnison, Brain–computer interfaces for augmentative and alternative communication: a tutorial. Am. J. Speech Lang. Pathol. **27**(1), 1–12 (2018)
48. M. Glacken, D. Healy, U. Gilrane, S.H.M. Gowan, S. Dolan, D. Walsh-Gallagher, C. Jennings, Key word signing: Parents' experiences of an unaided form of augmentative and alternative communication (Lámh). J. Intellect. Disabil. **23**(3), 327–343 (2019)
49. Y. Bouzid, M. Jemni, The effect of avatar technology on sign writing vocabularies acquisition for deaf learners, in *2016 IEEE 16th International Conference on Advanced Learning Technologies* (2016), pp. 441–445
50. B.D. Patel, H.B. Patel, M.A. Khanvilkar, N.R. Patel, T. Akilan, ES2ISL: an advancement in speech to sign language translation using 3D avatar animator, in *2020 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE)* (2020), pp 1–5
51. N. Kumar, Sign language recognition for hearing impaired people based on hands symbols classification, in *2017 International Conference on Computing, Communication and Automation* (2017), pp 244–249
52. Y. Elsahar, S. Hu, K. Bouazza-Marouf, D. Kerr, A. Mansor, Augmentative and alternative communication (AAC) advances: a review of configurations for individuals with a speech disability. Sensors **19**(8), 1911 (2019)
53. R. Aldabas, Barriers and facilitators of using augmentative and alternative communication with students with multiple disabilities in inclusive education: special education teachers' perspectives. Int. J. Incl. Educ. 1–17, (2019)
54. N. Afzulpurkar, T.H. Phuc, U.S. Patent No. 7,949,157 (U.S. Patent and Trademark Office, Washington, DC, 2011)
55. B.G. Lee, S.M. Lee, Smart wearable hand device for sign language interpretation system with sensors fusion. IEEE Sens. J. **18**(3), 1224–1232 (2017)
56. K. Dabre, S. Dholay, Machine learning model for sign language interpretation using webcam images, in *2014 International Conference on Circuits, Systems, Communication and Information Technology Applications (CSCITA)* (2014), pp. 317–321
57. S.S. Wazalwar, U. Shrawankar, Interpretation of sign language into English using NLP techniques. J. Inf. Optim. Sci. **38**(6), 895–910 (2017)
58. CDC, Language and Speech Disorders in Children (2020). https://www.cdc.gov/ncbddd/childdevelopment/language-disorders.html
59. R.J. Simeonsson, E. Björck-Åkessön, D. Lollar, Communication, disability, and the ICF-CY. Augment. Altern. Commun. **28**(1), 3–10 (2012)
60. N. Fearn, B. Turner, Best speech-to-text software in 2020: free, paid and online voice recognition apps and services (2020). https://www.techradar.com/news/best-speech-to-text-app
61. H.N. Lee, V. Ashok, I.V. Ramakrishnan, Repurposing visual input modalities for blind users: a case study of word processors, in *2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)* (2020), pp. 2714–2721
62. NIH, Quick statistics about voice, speech, language and swallowing (2016). https://www.nidcd.nih.gov/health/statistics/quick-statistics-voice-speech-language
63. J Bercow, Ten Years On: an independent review of provision for children and young people with speech, language and communication needs in England (2018)
64. BLS, Speech-language pathologists, occupational outlook handbook (2019). https://www.bls.gov/ooh/healthcare/speech-language-pathologists.htm

65. R.L. Schalock, Intellectual disability, in *The Encyclopedia of Clinical Psychology* (2014), pp. 1–7
66. Special Olympics, Intellectual disability, What is Intellectual Disability? (2020). https://www.specialolympics.org/about/intellectual-disabilities/what-is-intellectual-disability
67. G. Katz, E. Lazcano-Ponce (2008) Intellectual disability: definition, etiological factors, classification, diagnosis, treatment and prognosis **50**(S2), 132–141
68. S.M. Márton, G. Polk, D.R.C. Fiala, Convention on the rights of persons with disabilities (2013). https://www.refworld.org/pdfid/5280d17a4.pdf
69. R. Erdem, Students with special educational needs and assistive technologies: a literature review. Turkish Online J. Educ. Technol. **16**(1), 128–146 (2017)
70. K.L. Crow, Four types of disabilities: their impact on online learning. TechTrends **52**(1), 51–55 (2008)
71. C.T. Ramey, S.L. Ramey, Prevention of intellectual disabilities: early interventions to improve cognitive development. Prev. Med. **27**(2), 224–232 (1998)
72. P. Eling, Developmental cognitive deficits: a historical overview of early cases, in *A History of Neuropsychology*, vol. 44 (2019), pp. 141–163
73. G. Sims, J. Delisi, An introductory guide to understanding cognitive disabilities (2019). https://www.deque.com/blog/an-introductory-guide-to-understanding-cognitive-disabilities/
74. S.M. Preum, M. Sirajum, M. Ma, M.S. Yasar, D.J. Stone, R. Williams, H. Alemzadeh, J.A. Stankovic, A review of cognitive assistants for healthcare: trends, prospects, and future directions, ACM Comput. Surv. **1**(1), Article 1 (2020)
75. H. Pigot, J. Bauchet, S. Giroux, Assistive devices for people with cognitive impairments. The engineering handbook of smart technology for aging, disability, and independence (2008), pp. 217–236
76. A. Costa, V. Julian, P. Novais (eds.), *Personal Assistants: Emerging Computational Technologies*, vol. 132. (Springer, 2017)
77. M. Davies, Concept mapping, mind mapping and argument mapping: what are the differences and do they matter? High. Educ. **62**(3), 279–301 (2011)
78. I.W. Widiana, I.N. Jampel, Improving students' creative thinking and achievement through the implementation of multiple intelligence approach with mind mapping. Int. J. Eval. Res. Educ. **5**(3), 246–254 (2016)
79. J.A. Fleeman, C. Stavisky et al., Integrating cognitive rehabilitation: a preliminary program description and theoretical review of an interdisciplinary cognitive rehabilitation program. NeuroRehabilitation **37**(3), 471–486 (2015)
80. Walter E, Gioglio J (2014) The power of visual storytelling. McGraw-Hill Education
81. A. Gillespie, C. Best, B. O'Neill, Cognitive function and assistive technology for cognition: a review. J. Int. Neuropsychol. Soc. **18**(1), 1–19 (2012)
82. WHO, Assistive technology (2018). https://www.who.int/news-room/fact-sheets/detail/assistive-technology
83. G. Spinelli, M. Micocci, W. Martin, Y.H. Wang, From medical devices to everyday products: exploring cross-cultural perceptions of assistive technology. Des. Health **3**(2), 324–340 (2019)
84. M. Oliver, Communication devices and electronic aids to activities of daily living. Atlas of orthoses and assistive devices (2019), pp. 403–417
85. C.M. Connor, S. Hieber, H.A. Arts, T.A. Zwolan, Speech, vocabulary, and the education of children using cochlear implants: oral or total communication? J. Speech Lang. Hear. Res. **43**(5), 1185–1204 (2000)
86. K. Wong, E.D. Kozin, V.V. Kanumuri et al., Auditory brainstem implants: recent progress and future perspectives. Front. Neurosci. **13**, 10 (2019)
87. T. Moser, A. Dieter, Towards optogenetic approaches for hearing restoration. Biochem. Biophys. Res. Commun. (2020)
88. S. Kleinlogel, C. Vogl, M. Jeschke, J. Neef, T. Moser, Emerging approaches for restoration of hearing and vision. Physiol. Rev. (2020)
89. E Waltz, How do neural impants work?, in *(2020) IEEE Spectrum* (2020). https://spectrum.ieee.org/the-human-os/biomedical/devices/what-is-neural-implant-neuromodulation-brain-implants-electroceuticals-neuralink-definition-examples

90. A.S. Widge, S. Zorowitz, I. Basu et al., Deep brain stimulation of the internal capsule enhances human cognitive control and prefrontal cortex function. Nat. Commun. **10**(1), 1–11 (2019)
91. G.I. Mukhamedov, U.N. Khodjamkulov, A.M. Shofkorov, Pedagogical education cluster: content and form. Theor. Appl. Sci. **1**, 250–257 (2020)
92. S. Narayanan, P. Georgiou, Behavioral signal processing: deriving human behavioral informatics from speech and language. Proc. IEEE **101**(5), 1203–1233 (2013)
93. V.S. Pantelidis, Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. Themes Sci. Technol. Educ. **2**, 59–70 (2009)
94. P. Smith, L. Smith, Artificial intelligence and disability: too much promise, yet too little substance?, in *AI and Ethics* (2020), pp. 1–6
95. T. Wangmo, M. Lipps, R.W. Kressig, M. Ienca, Ethical concerns with the use of intelligent assistive technology: findings from a qualitative study with professional stakeholders. BMC Med. Ethics **20**(1), 1–11 (2019)
96. L.R. Shade, R. Singh, Honestly, We're not spying on kids": School surveillance of young people's social media. Soc. Media+Society **2**(4), 2056305116680005 (2016)
97. K. Zdravkova, Reconsidering human dignity in the new era. New Ideas Psychol. **54**, 112–117 (2019)
98. C. Sagan, The demon-haunted world: Science as a candle in the dark. (Ballantine Books, 2011)

Chapter 5
Adaptive and Intelligent Web-Based Learning and Control Technologies

Valery M. Kaziev and Lyudmila V. Glukhova

Abstract The current problem of evolution of adaptive and intelligent technologies of modern education, their influence on digital infrastructure of educational environment is considered. The purpose of the study is an evolutionary system analysis of the digital opportunities for the effective development of the information and educational space of universities from the Russian model of competence-oriented education. Formal (mathematical) model of adaptive learning decision making is proposed. Research methods are analysis-synthesis, composition-decomposition, aggregation, logical, formalization, modeling, etc. Key methods, approaches and technologies of adapting and intellectualizing web-learning are considered, as well as didactic aspects. The main goals of adaptive vocational education are highlighted. The issues of self-organization, web-education, their adaptation to digital transformations in society, the environment of the educational system were investigated. The list of basic intelligent web learning technologies is proposed. The main directions of web-learning systems for implementation of individual, adaptive, interactive and cognitive approaches to training are highlighted. The results of the work are applicable to improving the legal basis of the Russian system of remote and digital technologies at all levels of education. A general mathematical model of the student's adaptive profile is proposed, taking into account the learning scenario, learning success, the adaptation mechanism and the starting state. The results of the work will help solve these problems more effectively and more fully.

Keywords Adaptability · Intellectuality · Information technologies · Training · Educational environment · Evolution

V. M. Kaziev
Kabardino-Balkarian State University, Nal'chik, Russian Federation
e-mail: kkvkvm@yandex.ru

L. V. Glukhova (✉)
Togliatti State University, Togliatti, Russian Federation
e-mail: prof.glv@yandex.ru

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_5

5.1 Introduction

Learning priorities and procedures are changing dynamically in education in the context of building a digital society, high rates of digital transformations, and individual characteristics of training, training conditions and technologies and the socio-economic evolution of society. The demand for a professional of the highest level of training is growing. It's necessary to improve the professional education focused on competences—knowledge, abilities, skills of search of optimal or rational solutions at stochastic changes and dynamic feedback from an environment.

First, education needs to be developed by diversifying educational programs, supporting flexible management and adaptive learning technologies. Adaptive learning technologies we understand in this work (if not specifically specified) in the system sense, as a methodological system including a training process control system, mechanisms for regulating this process (according to the degree of training) and supporting the system technologies. Sometimes, in working order, we specify adaptation as a management process, as a rule, according to the parameters of the training criteria.

Secondly, we need a transition to a paradigm focused on competencies and the training of competent professionals with the necessary information and communication, cognitive, creative, social and special competencies. Thirdly, the transition to the professional development of the individual and mobilities to master new technologies, "digital" professions is relevant. Fourth, Web learning, distributed, cloud computing and intelligence learning should be applied broadly and deeply (in the sense of deep intellectual penetration, machine learning).

An adaptive approach will mean methods and technologies for adaptation, taking into account a range of individual opportunities and needs of students. But this is hindered by the imperfection of adaptive systems, reducing problems only to their technical, computer aspects, emphasizing the "rigid" adaptation mechanism. Often there is no trainee model profile that takes into account individual possibilities for implementing the evolutionary adaptation mechanism and the learning hypothesis is poorly defined.

In an adaptive system, the learning process and training content are "adjusted" to the goals, competencies, and even mood of the student, building an individual learning trajectory. There is no universal platform, for example, that takes into account the psychological profile of the trainee or allows predicting all the basic parameters of learning success. Caution is also needed in choosing the mechanism for adapting the learning process and its formalization (logical output), forecasting, standardization, security, etc.

Popular adaptive or conditionally adaptive platforms are Moodle, 2U, Wiley, LoudCloud, Canvas, BlackBoard, RealizeIT, ACW (AdaptCourseWare), Knewton, SmartSparrow, Geekie, etc.

The COVID-19 pandemic opened the doors of universities and schools to new technologies and innovations in education. It mobilized research in adaptive learning technologies. Instead of classical connections (contact, synchronous and real), new ways of feedback and personalization of training (adaptive, asynchronous and virtual) are used. Instead of highly personalized adaptability, "soft", flexible and customizable adaptive learning technologies are used.

This work is devoted to the system analysis-synthesis of the category of adaptability in training and adaptive intelligent educational systems. Particular attention is paid to the smart-paradigm that supports the requirements of specific, measurable, achievable, reliant & time bound and as well as the knowledge models of the semantic network's type. Such a knowledge model is a graph that effectively formalizes the concepts and relationships of educational material, updating the mechanisms of adaptation and individualization in training.

In Russian laws on education, the main goal of electronic education is the use of all kinds of distance and digital technologies at all levels of education (Article 16 of the Law).

Modern adaptive and mobile training is developed on the methods of knowledge engineering, modern educational infrastructure, process intellectualization and taking into account the current achievements of the trainee in the training process [1].

Previously, learning adaptability was understood, albeit at a sufficient level, but in a narrow sense, as computerization, for example, in testing—only as adaptive testing. But its current, wide understanding is based both on formal systems (ontology, algebra, cognitology, fractals, etc. [2]) and on modern technologies (artificial intelligence, tracking, machine learning, etc.), teaching methods and tools based on adaptation to the level of competencies and the pace of learning of each student. Adaptive learning is closely connected with intellectual systems, in particular, [3] with the issues of accelerating learning, competency learning "through life", game learning, the development of social skills and intercultural competence, etc.

There are various adaptive training systems, in particular, Smart Sparrow—a service (platform and support for developing management plans and strategies based on the feedback of the trainees themselves), Knewton (a corporate solution for partnering with well-known educational companies), and ScootPad (with multi-level automation).

In the work [4] are accepted the basic benefits of adaptive learning:

(1) personalized training;
(2) generating data and analytics for early training adjustment;
(3) training efficiency;
(4) provision of available content and various methods and tools (video, animation, multiple choice, etc.);
(5) targeted adaptation by indices and training criteria;
(6) improvement of results of training and attestation tests;
(7) involvement and activation, cooperation of trainees and trainees;
(8) use of interactive motivating exercises (situational scenarios);
(9) saving the time and resources of the educational system;
(10) reinforcement of interactions of type "teacher—student (group of students)".

The Higher Education Horizon Report [5] analyzed adaptive learning with personalized Harvard Graduate School of Education (HGSE, How People Learn Project) content.

The problem of adaptive learning and the development of appropriate ICT tools [6] and the entire infrastructure environment of the university is inextricably linked [7]. The positions of system analysis and properties of emergence, adaptive testing are considered in [8]. The article [9] is devoted to the use of web technologies for information support of the educational process.

The subject of adaptive training is absorbed by smart-pedagogy [10] (as a subject of cybernetics swallowed up by the subject of informatics). Digital transformations in society require adaptive mechanisms and criteria for adaptive regulation of the educational process for universities [11]. This is also required by the digital economy [12]. Therefore, problems of sustainable development of education [13] are studied and projects of information and educational environment of large and small universities are developed [14].

The evolution of e-Education involves the development of the capabilities of the environment (infrastructure) [15], which does not outpace the technologically strongly scientific, methodological and didactic components of the evolution vector and professional competencies. In the context of Russian education, this is a complex, vector (multicomponent) process [16]. Relevant practical tools for this process are multi-agent systems [17].

The pandemic made adjustments: according to the Ministry of Education and Science of the Russian Federation, by April all universities of the ministry had completely switched to distance learning platforms, although studies (HSE, 2019) showed that university teachers with a degree only “3+ ” estimated their ownership of distance learning technologies. Many are content with university opportunities and solutions (LMS platforms, e-mail, instant messengers, etc.). Few those who open “all the charms” of a mass online course (MOOC with versions of connective MOOC, task-based MOOC, xMOOC [18]). Many are content with a “combustible mixture” of educational technologies: distance learning, mobile training, etc., achieving, results that are quite acceptable and comparable to the traditionally used training.

Growing demand for LMS (Learning Management System) updates the problem of choosing the best system. You can use the results of the comparative analysis given in [19]. A freely distributed system with open code Moodle [20] is popular. Ready-made solutions, claiming universality, do not always implement it, so some universities order (develop) the system for their own requirements.

For example, a CATS (Care About the Students) system [21] with Microsoft SQL Server and Web server, client terminals in the MVC ASP.NET infrastructure, and the SCORM (Shared Content Object Reference Model) standard [22].

It’s important to formalize educational processes and procedures of adaptation, describing them in general terms, creating an individual formal model (individual profile) of management for each trainee. Models and tools can be the same, for both base and special levels, but with different parameter values. As parameters, for example, the ability to perceive information and the tendency to forget, etc., can be used.

5.2 Competency-Based Vocational Education

There are evolutionary directions of vocational education within the framework of the educational paradigm. A paradigm that is democratic, harmonious, efficient (efficient and sustainable), open and integrated from the point of view of the interests of society.

The main objectives of the reform of vocational education are:

(1) implementation of new GEF, taking into account the requirements of international standards (for example, ISO 9001:2015, etc.);
(2) creative approach to interdisciplinary professional tasks;
(3) humanistic training and self-training;
(4) democracy, fairness of the educational environment in relation to each student;
(5) continuous, sufficient and implemented in the spirit of partnership quality of education (competencies, methods, technologies, value, etc.);
(6) continuing education, carried out on the principles of partnership, etc.

The basic principles of GEF development are being implemented:

(1) versatility;
(2) openness;
(3) integrity;
(4) fundamentality;
(5) equal opportunity;
(6) motivation;
(7) professionalism;
(8) variability;
(9) cooperation;
(10) multilevel hierarchy of educational goals and programs;
(11) self-organization;
(12) reliability (stability);
(13) continuity.

Much depends on the accepted model of economic evolution. It can be different: “service economics”, “creative economy”, economics based on a “competence society”.

The Russian model of competence societies based on the principles:

(1) digital design, use of automated (intelligent) design systems;
(2) smart structures, self-training and self-organization;
(3) modular distributed organization and integration of technological chains (for example, blockchain technologies);
(4) modern management (outsourcing, crowdsourcing, Government Relations, etc.) [23];
(5) adaptive business processes and structures (intelligent business, 3D simulation environments, etc.).

But the key “element” of digital transformations in society is a professional, a specialist with competencies in a specific subject area, as well as integrated vocational education and adaptive training based on principles (schemes):

(1) competencies—actualization—production of knowledge—competencies;
(2) the purpose of training is self-learning, the purpose of self-learning is self-knowledge and self-development;
(3) the function of the teacher is to manage (tutor) the process of updating and accumulation of competencies;
(4) the evolution of professional virtual communities with synergistic goals activated self-education, self-training, etc.;
(5) standardization and unification—the basis for improving the quality of education and competitiveness in the educational and labor markets;
(6) management of the educational process—of the 3H-class (Humanization, Humanization and Harmonization) with the activation of effective and multilateral feedback;
(7) the quality of education and educational services is determined by the cost of actualization, capitalization of competencies.

Specialists are in demand that is able to set tasks and plan resources, ways to solve them, capable of heuristics, cognitology, team work of like-minded people.

It’s difficult for businesses and enterprises to predict the need for specialists with certain competencies [24]. But companies expect that a university graduate admitted to the company will begin to “pay off” in a few months. Therefore, a partnership between the educational institution and the business community is also important.

Competence is assessed by the readiness of the specialist to perform professional activities in various situations, and the quality of education is a measure of compliance with the qualitative characteristics of the educational product with the needs of the target audience. In relation to the producer of educational services, one can distinguish both the competencies of graduates formed in the process of training, and the state of the educational environment, the conditions of the educational process itself.

Competence adapts to the dynamic changes and preferences of the educational system (see Fig. 5.1), specified in the practice process so as to give the trainee the opportunity to update, implement:

(1) problematic situations;
(2) system analysis of the problem;
(3) methodology for solving problems;
(4) resources, structures, planning and management criteria for solving the problem;
(5) the creative union of like-minded people, technologies for solving the problem.

For example, competencies to solve innovative tasks (abilities for innovative thinking) include:

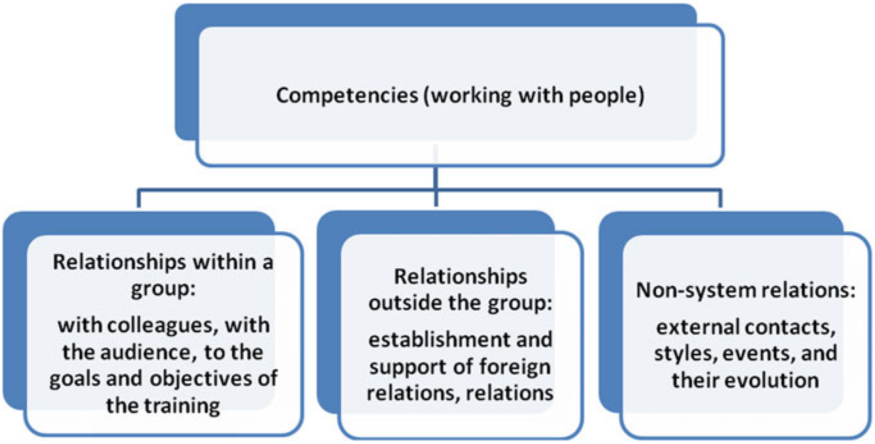


Fig. 5.1 KPIs (competency indicators model structure)

(1) openness to new;
(2) the ability to look for alternative solutions;
(3) the ability to look at the problem from the outside;
(4) the ability to respond quickly to a changing situation;
(5) leadership in innovative processes, etc.

If the adaptation training procedure and model are adequately selected, then they should optimize the training time without reducing the learning criterion (compared to non-adaptive learning). The use of an adaptive mechanism involves standardized calibration, which contributes to climbing the ladder of difficulty within the topic, module.

Relevant methodologies are used in the educational systems of a number of EU countries. The principle of "learning by doing" in competently oriented learning is one of the most important principles. The main types of competency models are used (i.e. a complete set of competencies and indicators of targeted professional behavior)—professional, managerial and corporate.

The evolution of adaptive learning is often hampered by much of traditional learning. For example, man–machine approach and "rigid" adaptation mechanism, not intellectuality. It leads to unconsistency of learning and adaptation models, insufficient formalization of learning logic, ineffective (linear) algorithms of educational activities, etc.

From a scientific point of view, the category "adaptive training" involves the personalization of training based on electronic courses, systems and platforms focused on individual goals and approaches to the psychological capabilities and competencies of the trainee. Adaptive learning models are implemented using modern methods: expert assessments, multi-agent, modular, fuzzy logic and sets, neural networks, ontologies, etc.

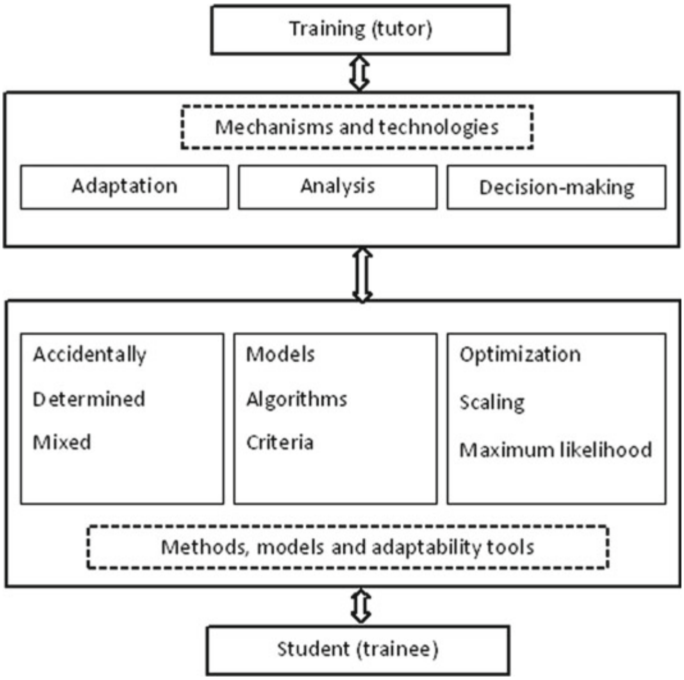


Fig. 5.2 Adaptive learning information logic

From an applied, technological point of view, cloud computing, blockchain, cognitive schemes, multi-agent systems, intelligent systems, situational modeling, etc. are of interest.

Figure 5.2 shows simplified adaptive learning information logic.

Adaptive learning has sufficient developing potential, its algorithms are based on statistical estimates of parameters, indicators, analytics, formal systems and knowledge models, and intelligent decision-making.

The methodological scheme is shown in Fig. 5.3.

Adaptive training increases manageability, interactivity, adequate reflection of achieved competencies, unification, scalability, friendliness (integration of the trainee into an adaptive environment), administration, etc.

The adaptive system can be formalized using the tuple S = <A, B, C, D, E, F>, where A is the system subsystems (information, interface, functional, linguistic, etc.), B is a set of training scenarios, C is the models of trainees, D is the evaluation base (training success), E is the adaptation mechanism, F is the initial (starting) state.

We considered $P_1(A), P_2(A), \ldots, P_n(A)$ the adaptive learning profiles (5.1):

$$P(A) = \bigcup_{i=1}^{n} P_i(A). \tag{5.1}$$

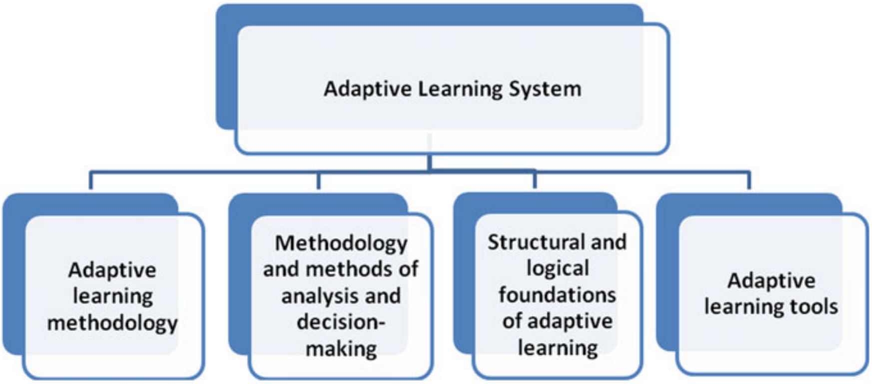


Fig. 5.3 Methodological scheme of adaptive training

where $P_i(A)$ defines a "phase" portrait of the situation (5.2):

$$P_j(A,\alpha) = \bigcup_{i=1}^{n} \delta^{\alpha ji}, \quad \delta^{\alpha ji} = \begin{cases} i, & \alpha_{ji} = 1, \\ 0, & \alpha_{ji} = 0. \end{cases} \tag{5.2}$$

Enter the adaptive situation profile (5.3):

$$P(A,\alpha) = \sum_{j=1}^{N} P_j(A,\alpha) = \sum_{j=1}^{N} \bigcup_{i=1}^{n} \delta^{\alpha ji}. \tag{5.3}$$

By eliminating duplication of profiles in $P(A)$, the information volume $P(A, \alpha)$ can be found by the formula (5.4):

$$V(A,\alpha) = \sum_{j=1}^{N} \sum_{i=1}^{n} V_i^{\alpha ji} + \sum_{i=1}^{n} V_j(A), \tag{5.4}$$

where the second term corresponds to the information volume $P(A, \alpha)$.

The adaptive system is also formalized by the tuple S = <A, B, C, D, E, F>, where A is the information, interface, functional, linguistic and other subsystems, B is many training scenarios, C is the models (profiles), D is the evaluation base of learning success, E is the adaptation mechanism, F is the initial state.

The effectiveness of the adaptive procedure depends on the effectiveness of profile allocation, that is, on the development of libraries, profile databases, their expert evaluation.

For example, for adaptive service testing (models) are relevant:

(1) TaaS (Testing as a Service), providing a test base, design methodology, implementation and analysis of test results in the applied field and education;

(2) TPaaS (Testing Platform as a Service), providing a virtual platform for testing, for example, through the "clouds";
(3) TSaaS (Testing Soft as a Service), providing a test shell, for example, through a Web browser.

Example. The cloud intellectual platform of the class IPaaS (Intelligent Platform as a Service) is intended for the remote distributed development and support of application (tool) cloud services. For example, a computer training simulator or an expert system for medical students.

Web-based training requires a wide range of adaptive and intelligent educational technologies, interface procedures, management, analysis and administration depending on the success of the training.

The computer adaptive training system includes subsystems:

(1) administration (security, registration, authentication, etc.);
(2) filling with educational material, tasks, their editing;
(3) training (delivery of educational content, its visualization, assistance);
(4) monitoring the achievements of the trainee;
(5) an adaptive mechanism (analysis of the level of competencies, training, classification, scaling, refinement of the training strategy).

In web-based training, both decision making and process, learning technology are adaptive. For example, models such as Knowledge Based System and Intelligent Tutoring Systems are used, taking into account the educational achievements and difficulties of the student. Minimizes the risks of "conflict" for continuing training and current competencies, choosing a solution for moving to a new productive level [25].

Intelligence learning systems is supported by the accounting and use:

(1) fuzziness (sets, logic, procedures);
(2) expert, heuristic procedures;
(3) multi-criteria (selection of levels) and parameterization;
(4) situational activation of various training scenarios;
(5) adequacy to hypotheses, models (trainee, process).

"Learning agents" allow you to build distributed and multi-agent models, for example, P2P. Activity of trainees and information resources, quality of interactions due to elimination of intermediaries and intermediate links is increased. The market of adaptive and intelligent educational technologies and products of private (for self-education) and professional consumption (for consulting, training, retraining, increasing competencies) is being formed.

Adaptive learning systems are innovative solutions based on artificial intelligence, self-organization and self-learning technologies, analytics, for example, the Learning Analytics.

Evolving list of adaptive and intelligent web learning technologies includes the following technologies (systems):

(1) telecommunication infrastructure, access to educational resources at this point, in this place, with these requirements;
(2) GRID and cloud technologies (computing), dynamically configurable virtual educational resources (platforms, services) according to the principles of pay only for what you use, use only what you need now and here, quickly, in real mode, use data for an increasing audience;
(3) Big Data, increasing the volume of updated data (both structured and unstructured), their diversity;
(4) Data Mining, analysis of hidden, not "surface" connections, regularities of data, their ranking;
(5) situational (scenario) modeling;
(6) neural network analysis and genetic algorithms;
(7) expert-training systems and technologies of their automated construction using knowledge engineering and ontologies;
(8) pattern recognition and taxonomy;
(9) 3D analysis, visualization, virtualization;
(10) cognitive analysis (cognitive circuitries and networks);
(11) analysis of Markov series, etc.

Example. The IaaS class VCL cloud storage, cloud service (Infrastructure as a Service) provides everything you need to design, implement, and operate an application environment on demand. This provides benefits for training: speed, scalability, the ability to choose a cloud service and solution, storage, teamwork in a web browser. Including, "behind the firewall" of the university. VCL can provide students and teachers with infrastructure (private cloud), extend the service to a branch of the university (public cloud). This is a solution for interactive service support of users, educational and research laboratories, university branches, adaptive monitoring and training (filling the student's private cloud with materials, service and applications for training). You can do without the support of many computer classes, adapting educational services during training, with effective feedback [26].

Cloud computing integrates many mechanisms (key ones are shown in Fig. 5.4).

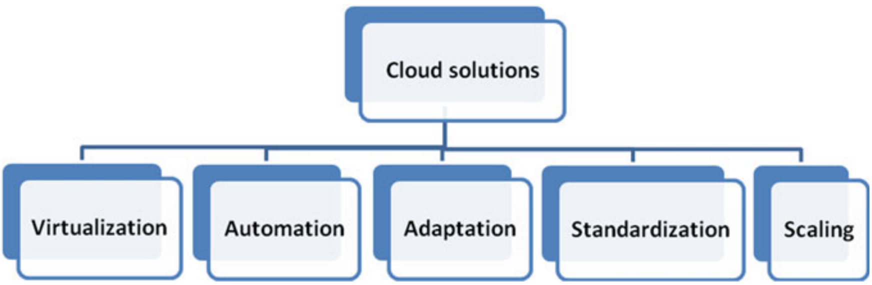


Fig. 5.4 Basic cloud mechanisms

Example. The multi-agent approach allows you to manage the trainee (agent) at each stage of training. The agent has its own local goals, resources and rules of behavior, interaction with the environment (the space of agents). In the process of specific training, he can himself choose educational goals and behaviors. For example, the IACPaaS cloud platform (Intelligent Application, Control and Platform as a Service) supports the development, management and remote use of application and tool multi-agent cloud services and their components in various areas [27].

All adaptive and intelligent web learning technologies have the main goals—the formation and development of:

(1) new competencies and their inclusion in digital relations;
(2) standards of behavior ("according to the model") in society and collective;
(3) educational web communities and social networking groups, for example, educational activity;
(4) creative approach to choosing non-standard solutions, etc.

The effectiveness of adaptive learning is determined by efficiency and relevance:

(1) building models (trainee, training);
(2) data, analytics;
(3) methods, especially the mechanism of adaptability;
(4) control parameters of the training process;
(5) platform efficiency, training infrastructure.

Intelligent web-based training systems (educational environments) are carried out in the areas of construction and use:

(1) adaptive intellectual (based on models of knowledge, competencies) models of the trainee, training and learning processes;
(2) intelligent analyzers of feedback and solutions, which provide analysis of behavior and response of the trainee, its completeness and ways of adaptive correction of the wrong solution;
(3) interactive intellectual support of solved tasks taking into account successfully solved earlier tasks;
(4) intelligent internal architecture and infrastructure adaptively embedded in the external environment (partner and educational networks, open systems).

The core of intelligent learning systems is the knowledge base that supports the evolutionary model of the subject area. The intellectualization of the educational system ensures its adaptability, but problems ("curses") of dimension and complexity (a large and complex system [28]) arise in the space of educational opportunities.

Intelligent web learning environments focus on situational learning processes and scenarios, allowing you to choose the best simulation option. It's selected according to the indicators of learning and learning activities (according to the hypothesis and model of learning), on the principles indicated above, especially the principles of systematality, flexibility, sustainability, efficiency and evolution.

Adaptability requires pooling resources (time, space, tools, information, etc.). An adaptive system has a self-organizational ability with its attribute—manageability, self-regulation. Self-developing adaptive systems have invariant, systemic measures of complexity.

Only with the development of smart pedagogy and adaptive learning technologies, it became possible to provide the teacher and student with a choice by tracking the level of training, interactively changing the structure, parameters and algorithms of training based on its results.

5.3 Conclusions

With traditional training, it's impossible to provide all the basic information and communication capabilities and needs of the trainee. It's important to implement individual, adaptive, interactive and cognitive approaches to learning and take into account internal invariants of the educational process or cognitive invariants—logical, structural or functional.

The quality of education is determined not only by compliance with federal standards, but also by the requirements of the educational market and labor market. Specific educational goals and results should be evaluated in terms of competence, key abilities—communication, technological, entrepreneurial, etc.

A poorly structured and complex learning and control process with a competent approach is difficult to organize without adaptive procedures and technologies that allow you to realize the individual creative abilities of the trainee. Intelligent provision of training and dynamic monitoring, control, analysis and prediction of its quality is required.

In the future, self-study is the highest goal of adaptive learning. Therefore, it's necessary to develop adaptive infological models and mechanisms that contribute to the self-development of trainees and trainees, their expectations.

But there is no targeted use of high-tech tools for intelligent support of web training and educational process management. Personalized training strategies do not sufficiently take into account the abilities of the trainee, stability and the duration of his active state.

Training content should be structured, for example, by a semantic network or hierarchically, taking into account the didactic features of the training course, the strategy of learning, cognitive abilities and the level of basic knowledge and the rate of forgetting and memorizing the trainee. The system analysis-synthesis of adaptive and intelligent web learning problems will make it possible to perform this more efficiently and more fully.

The results are applicable to improving the Russian legal basis system of digital technologies, in particular, when classifying them and eliminating conflicts in determining mechanisms for control, feedback and adaptive control of the learning process.

The issues investigated in the work relate to the self-organization of the education system, the results will allow you to fully explore the evolutionary potential of the system, a list of basic adaptive technologies and intelligent web-learning technologies, improve the legal framework of the system, taking into account the adaptive profile of the student and the learning scenario.

References

1. E.K. Ryann, *A Field Guide to Learning Management Systems, ASTD Learning Circu*its (*Electronic Resource*) (2009). https://docplayer.net/8677072-A-field-guide-to-learning-management-systems-lms.html (date of appeal: 03. 06. 2020)
2. N. Serdyukova, V. Serdyukov, *Algebraic Formalization of Smart Systems. Theory and Practice*. (Springer Nature, Switzerland, 2018)
3. P.J. Durlach, A.M. Lesgold (eds.), *Adaptive Technologies for Training and Education*. (Cambridge University Press, 2012). ISBN: 9780521769037. https://doi.org/10.1017/CBO9781139049580
4. Tim Bristol. Top 10 benefits of adaptive educational tools (2020). https://evolve.elsevier.com/education/expertise/adaptive-learning/top-10-benefits-of-adaptive-educational-tools/ (date of appeal: 10. 07. 2020)
5. K. DePaul, *Adaptive Learning Technologies: Preparing Students through Personalized Content*. (Shutterstock, December 6, 2018)
6. A.A. Andreev, Some problems of pedagogy in modern information-educational environments. Innov. Educ. **6**, 98–112 (2004). ([in Russian])
7. M.I. Bashmakov, S.N. Pozdnyakov, N.A. Reznik, Information learning environment. -Svet, 400 p. (1997). (in Russian)
8. V.M. Kaziev, B.V. Kazieva, Testing in modern higher education. -M.: INTUIT, -137 p. (2015). ISBN 978-5-9556-0168-7. (in Russian)
9. I.V. Serafimovich, O.M. Konkova, A.V. Raikhlina, Formation of the electronic information and educational environment of the university: interaction, development of professional thinking, management. Open Educ. **23**(1), 15–26 (2019). https://doi.org/10.21686/1818-4243-2019-1-000-000. (in Russian)
10. V.L. Uskov, J.P. Bakken, A. Penumatsa, C. Heinemann, R. Rachakonda, Smart pedagogy for smart universities. in *Smart Innovation, Systems and Technologies* (2018), pp. 3–16. https://doi.org/10.1007/978-3-319-59451-4
11. V.P. Tikhomirov, N.V. Dnieprovskaya, Smart education as the main paradigm for the development of the information society. Mod. Inf. Technol. IT Educ. **1**(11), 9–13 (2015). ((in Russian))
12. A.V. Raikhlina, Development of smart education as an element of building a knowledge economy in the region. Econ. Manag. Probl. Solut. **5**, 199–204 (2017). ((in Russian))
13. V.A. Starodubtsev, E.O. Frantcuzskaya, Sustainable development of education: the connection of technology and pedagogy. Open Educ. **21**(1), 34–43 (2017). (in Russian)
14. B.S. Sadulaeva, R.S. Sadulaeva, Designing the information and educational environment of the university. New Sci. Dev. Strat. Vectors **3**, 21–27 (2015). ((in Russian))
15. L.A. Danchenok, P.Y. Nevostruev, SMART-training: basic principles of educational process organization. Open Educ. **1**, 70–74 (2014). (in Russian)
16. Concept of creation and development of information and educational environment of open education system of the Russian Federation. http://do.sgu.ru/conc.html (date of appeal 17. 01. 2019). (in Russian)
17. L.V. Glukhova, N.A. Serdyukova, Multi-agent information system of risk management of innovation budgeting. Inf. Syst. Technol. Manage. Secur. **2**, 165–170 (2013). ((in Russian))
18. T.Y. Bystrova, V.I. Larionova, E.V. Sinitsyn, A.V. Tolmachev, MOOC educational analytics as a tool for predicting the success of students. Educ. Issues **4**, 139–166 (2018). (in Russian)

19. Y.B. Popova, Classification of automated training management systems. Syst. Anal. Appl. Inform. **2**, 51–58 (2016). ((in Russian))
20. Control system of the courses Moodle [Electronic resource]. Official site of Moodle moodle.org. https://moodle.org/about/ (date of appeal: 20. 07. 2020)
21. Y.B. Popova, Learning management system CATS. Sci. Tech. **18**(4), 339–349 (2019). https://doi.org/10.21122/2227-1031-2019-18-4-339-349. (in Russian)
22. SCORM standard and its application. https://cccp.ifmo.ru/scorm/index.html (date of appeal: 20. 07. 2020)
23. L.S. Ruzhanskaya, E.A. Yakimova, D.A. Zubakina, Strategic management: a textbook. -Ekaterinburg: Ed. Urals. Univ. 112 (2019). ISBN 978-5-7996-2851-2. (in Russian)
24. A.A. Sherstobitova, M.O. Iskoskov, V.M. Kaziev, M.A. Selivanova, E.N. Korneeva, University financial sustainability assessment models. in *Smart Innovation, Systems and Technologies*, vol. 188 (Springer, 2020), pp. 467–477. https://doi.org/10.1007/978-981-15-5584-8
25. P. Jorion, *Value at Risk: The New Benchmark for Managing Financial Risk*, 3rd edn. (McGrow-Hill, New York, 2007), pp. 1–603
26. G.Y. Yalamov, T.S. Shikhnabieva, Adaptive educational information systems: approaches to intellectualization. Man Educ. **4**(57), 85–90 (2018). (in Russian)
27. V.V. Gribova, A.S. Kleshchev, F.M. Moskalenko, V.A. Timchenko, L.A. Fedorishchev, E.A. Shalfeeva, Cloud platform IACPaaS for the development of shells of intelligent services: state and development prospects. Softw. Prod. Syst. **31**(3), 527–536 (2018). https://doi.org/10.15827/0236-235X.031.3.527-536. (in Russian)
28. V.M. Kaziev, Introduction to the analysis, synthesis and modeling of systems: a textbook. -M.: Binom. Knowledge Lab. Intuit (2007). ISBN 5-94774-511-9. https://www.intuit.ru/studies/courses/83/83/info (date of appeal: 20. 06. 2020). (in Russian)

Chapter 6
Exemplar Use-Cases for Training Teachers on Learning Analytics

Arvind W. Kiwelekar, Manjushree D. Laddha, and Laxman D. Netak

Abstract Learning Analytics (LA) provides a rich set of methods, techniques, and tools to analyze learners' data. However, educators without a background in data analysis and statistical methods experience difficulty comprehending the potentials and pitfalls of learning analytics based pedagogical practices and Engineering Sciences experience this difficulty. This chapter documents a set of exemplars used to demonstrate learning analytics applications in daily classroom activities. These exemplars have been designed and used mainly to train newly recruited teachers on data analysis methods during faculty induction programs. Exemplars demonstrate the application of statistical methods such as hypothesis testing, analysis of variance (ANOVA), correlation analysis, and regression analysis. Each use case's broad objective is to describe the application's context so that teachers can apply it in a similar situation. The chapter provides ready-to-use examples for conducting teachers training programs on Learning Analytics.

Keywords Learning analytics · Hypothesis testing · Analysis of Variance (ANOVA) · Correlation analysis · Regression analysis

6.1 Introduction

Education domain is currently experiencing two kinds of changes on a large scale. The first change is driven by advancement in digital technologies, which emphasize the deployment of online courses for effective course delivery [1]. Evidence-based

A. W. Kiwelekar (✉) · M. D. Laddha · L. D. Netak
Department of Computer Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad 402103, India
e-mail: awk@dbatu.ac.in

M. D. Laddha
e-mail: mdladdha@dbatu.ac.in

L. D. Netak
e-mail: ldnetak@dbatu.ac.in

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_6

reforms drive the second change [2], which suggests adopting data-centric teaching methods. Both changes complement each other because educators can use the data generated from learning platforms for producing evidence.

Mainly such evidence is used to claim the attainment of learning outcomes. Data needs to be analyzed through appropriate methods from Statistics or Machine Learning to extract helpful information demonstrating learning outcomes. However, many teachers lack the required knowledge of these methods from Statistics and Machine Learning. Hence they struggle to adopt such practices and consequently failing to justify the learning outcomes. To overcome this problem, we identify a few exemplar use-cases to demonstrate applications of various statistical techniques.

These use-cases highlight appropriate situations for the use of each statistical method. Four different statistical methods called (i) Hypothesis Testing, (ii) ANOVA, (iii) Correlation Analysis and (iv) Regression Analysis are described in this chapter. These exemplars have been used to introduce Learning Analytics and Statistical methods in various teachers training programs. They have found it helpful and practical to explain the nuances behind applying statistical methods to analyze learning data in different scenarios.

6.2 A Use Case for Hypothesis Testing

Hypothesis testing is one of the most useful statistical methods commonly employed to justify a claim using collected data. Here, a claim or a belief hold by a person (e.g. a teacher, a Head of the Department) or an institute (e.g. a particular University) is formulated as a hypothesis. For example, a piece of news in the Times of Higher Education dated 23rd December 2020 claims that *Students cheating exploding in Covid era.*

The validity of such claims can be tested through the statistical method of hypothesis testing. It consists of formulating two kinds of statements called *Null Hypothesis* and *Alternative Hypothesis.* A null hypothesis assumes that there is no relationship between two variables. An example of the null hypothesis can be *there is no connection between Covid outbreak and students cheating*. The null and alternative hypothesis is formulated using population parameters such as *average* and *proportion.*

6.2.1 Method

The following steps are typically performed during hypothesis testing:

1. Describe the hypothesis in words. It is described in terms of population parameters such as averages and proportions.
2. Define null H0 and alternative H1 hypothesis.

3. Identify the test statistic to be used for testing the validity of the null hypothesis. Usually, the *Z-statistics* is used when we know the standard variance of the population and population has normal distribution. The *t-statistics* is used when we do not know the value of standard variance of the population.
4. Decide the criteria for rejection of a null hypothesis. This is called the significance value or α value. It is typically 0.05 for a population with a normal distribution.
5. Calculate the p-value i.e. probability value which is the conditional probability of observing the test statistic.
6. Take the decision to reject or retain the null hypothesis based on p-value and the significance value α.

The following section illustrates the application of these steps with an example.

6.2.2 Are Students Interested in Higher Education?: An Example of Hypothesis Testing

Let us consider a situation where a Head of the Department of Computer Engineering at Dr. B. A. Technological University (DBATU) claims that *students at the institute are loosing interest in higher education.*

To support the claim, the head uses data collected from an exit survey which is conducted annually. Students from the final year are the respondents to it. The survey includes a question to judge students' career choices at the beginning of the program. The exit survey consists of a question: *When you took the admission to B. Tech in Computer Engineering program, what was your goal in life?* Only 11.6% of the students respond with an option of higher education, as shown in Fig. 6.1.

Further the head compares institute proportion with the national average of students qualifying the GATE examination. In India, students aspiring postgraduate

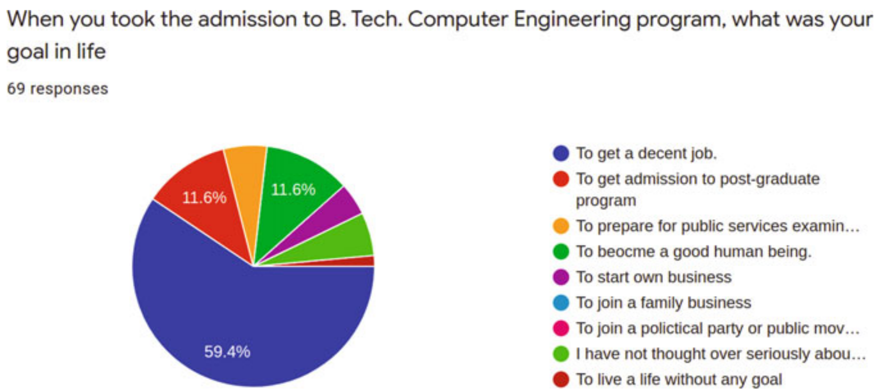


Fig. 6.1 Results of exit survey conducted at DBATU

education need to appear and qualify the Graduate Aptitude Test for Engineering (GATE), a national-level mandatory test. The national average of students qualifying GATE is 17%.

We can validate the head's claim that, *Students at the institute are loosing interest in higher education, through the hypothesis testing.*

1. **Define null H_0 and alternative H_1 hypothesis**: The null and alternative hypothesis are as follows.

   H_0: The proportion of students interested in higher education is below the national average of 17% of students qualifying in GATE.

   H_1: The proportion of students interested in higher education is not below national average 17% of qualifying students in GATE.
2. **Identify the test statistic**: We will use the z-test for proportion as we know the population parameter and distribution. Student's performance in examination typically follows the normal distribution or bell curve. The z-statistic is defined as below

$$Z = \frac{\hat{p} - p}{\sqrt{\frac{p(1-p)}{n}}}$$

   With the values of $\widehat{p} = 11.6\%$, p = 17%, and n = 70 i.e. class size the value of z-statistic is −1.20.
3. The critical values for hypothesis testing for population proportion based on the sample are: −1.96 and 1.96. The value of z-statistics is greater than −1.96 ($-1.20 > -1.96$) and less than 1.96 ($-1.20 < 1.96$). It tells that z-statistic is not part of rejection region. Hence, we will retain the null hypothesis.
4. We can calculate the p-value using Microsoft Excel function NORM.S.DIST(−1.2). The calculated p-value is 0.11. It is greater than the α-value i.e. 0.05. So also, we will retain the null hypothesis.

Threats to Validity The observation is valid for the particular university as the sample size reflects the trend in the particular institute.

Also experts say that an observation to be valid the value of the expression $n\,\widehat{p}(1 - \widehat{p}) >= 10$. In our case, the value of the expression $n\,\widehat{p}(1 - \widehat{p})$ is 7.11 which is less then 10. It is because of small n in comparison with students appearing in the GATE. Typically students in the range of 100–200 thousands appear for the GATE.

6.2.3 Use-Cases of Hypothesis Testing from Literature

The hypothesis testing to test the validity of beliefs or opinions has been found useful for many researchers, as listed in Table 6.1. For example, in Ref. [3] authors test the validity of the claim: *In education systems with greater school clustering by past achievement, students have higher academic achievement than otherwise.* Similarly

Table 6.1 A few use-cases of hypothesis testing from literature

Sr. no	Statistic method	Purpose	Source
1	Regression	To improve students' learning achievements by grouping students into section	[3]
2	Correlation statistics Spearman's and Kendall's	To report the quality of ranking and rating of peer assessment using simulation approach	[4]
3	Effect or influence of learning environment on mind wondering and retention in online learning	Regression and Chi-Square test	[5]

in Ref. [4], authors validate the claim: *ranking-based peer assessment produces higher rank-order correlation between the assessment score and true artifact quality as compared to the rating-based peer assessment*. These approaches use the standard method for hypothesis testing, as described in this section.

6.3 Use-Case for ANOVA

The term ANOVA stands for *Analysis of Variance*. It is a statistical method to study the impact of a particular phenomenon on a dependent variable. This systematic method investigates whether there are statistically significant differences between the means of more than two independent groups. In this section, we illustrate the application of ANOVA to answer the question: *Does the choice of reference material affect students' performance?* In this case, the students who refer to different books or reference material form separate groups. The mean of their performance is compared to check the impact of selecting study material on their performances.

6.3.1 An Example: Does the Choice of Reference Material Affect student's Performance?

We have applied the ANOVA technique to check the impact of students' choice of reference material on their performances. In this context, we selected a course on C-Programming offered at DBATU to the students from the first year of B. Tech. in Computer Engineering. Because course on C-Programming is a first introductory course on programming intended to develop programming skills.

The course curricula prescribe two different books on C-Programming authored by E. Balagurusamy (EB) and Herbert Schildt (HS). Some students prefer to study

Table 6.2 Descriptive statistics for whole class and 4 groups formed by reference material used to study

Measures	Whole class	Name of reference books			
		EB	HS	DM	Mix
Count	69	23	13	22	11
Mean	61	59	59	58	72
Std. Deviation	14	12	13	16	13
Min	40	40	40	40	40
Max	95	80	80	95	86
Reference books	EB: E. Balgurusamy				
	HS: Herbert Schildit				
	DM: Digital material				
	Mix: Multiple resources				

either from a third book not prescribed in the syllabus or from the digital material available (DM) on the Internet. Some of the students prefer to study from more than one of the resource (Mix). Hence, there are four different groups in the class as per the choice of reference material used for the study; these are referred to as EB, HS, DM, and Mix, respectively. So the ANOVA test can be used in this context to answer the question *does the choice of reference material affect students' performance?*

The summary descriptive statistics of the whole class and four groups as formed according to their choice of material is given in Table 6.2. It includes the values min, max, mean, and standard deviation. The null and alternative hypothesis for the ANOVA test is formulated as:

$$\mathrm{H}_0 : \mu_{\mathrm{EB}} = \mu_{\mathrm{HS}} = \mu_{\mathrm{DM}} = \mu_{\mathrm{MIX}}$$

where μ is the mean value of corresponding group. The null hypothesis states that there is no difference between the mean μ values of four different groups formed according to their reference books' choice. All mean values are the same.

The alternative hypothesis states that the mean values of all four groups are different.

$$\mathrm{H}_A : \mu_{\mathrm{EB}} \neq \mu_{\mathrm{HS}} \neq \mu_{\mathrm{DM}} \neq \mu_{\mathrm{MIX}}$$

In the ANOVA case, the F-test is the test-statistic used to check whether the results are statistically significant or obtained by chance. The F-test is defined as:

$$F - Test = \frac{\frac{\sum_{i=1}^{k} n_i(\mu_i - \mu)^2}{k-1}}{\frac{\sum_{i=1}^{k}\sum_{j=1}^{n_j}(Y_{ij} - \mu_i)^2}{n-k}}$$

where,

K = Number of groups,

n_i = Number of observations in a group i

n = Total number of observations

Y_{ij} = Observation j in group i

μ_i = Mean of group i

μ = Overall mean.

We performed the ANOVA test using Python's *StatsModel* API. The ANOVA table obtained after the test is shown in Table 6.3. The value of F-statistic is 2.81. The critical value of F-statistic (Fc) can be calculated from Microsoft Excel function *FINV (α, degreeOfF reeedom, Sample size)*. The degree of freedom is 3 in our case, as four groups are present. With sample size of 69 and α equal to 0.05, we get F_c as 2.71. The F-statistic value is slightly greater than the critical value F_c. Hence, we reject the null hypothesis and the alternative hypothesis is retained (Fig. 6.2).

Further, the value of $eta_s q(\eta^2)$ is 0.11 signify that the choice of reference material students' performances is a moderate one.

Table 6.3 ANOVA table: the output of statmodels in python

	sum_sq	*df*	*mean_sq*	*F*	*PR(>F)*	*eta_sq*	*omega_sq*	F_c
C(Ref)	1713.35	3.0	571.11	2.81	0.04	0.11	0.07	2.71
Residual	13,196.34	65.0	203.02	NaN	NaN	NaN	NaN	

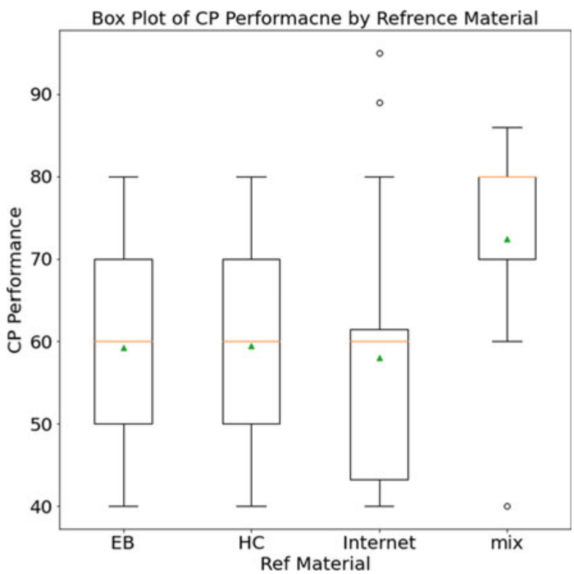


Fig. 6.2 Box plots for 4 groups performed according to reference material

6.3.2 Use-Cases of ANOVA from Literature

As observed from Table 6.4, the technique of ANOVA has been applied by many researchers to investigate the impact of different phenomenon on learning activities. In Ref. [6], authors have used ANOVA to study the impact of various kinds of background music on reading comprehension. The impact of student's choice about sequencing the completion of assignment on their performance has been analyzed using ANOVA. Further, an improvement in student's performance has been observed when such choice is offered.

6.4 A Use-Case for Correlation Relation

The correlation analysis is a powerful statistical method and it is quite useful from the learning analytics point of view. The purpose of correlation analysis is to check the association between two random variables. The correlation analysis plays an essential role during machine learning model development mainly to build predictive models. Correlation analysis is useful to investigate the strength of the relationship between the predicted variable and predictors. It is also helpful to check collinearity between two independent variables to eliminate redundant independent variables and thus reduce the number of features required to build predictive models.

The strength of the relationship between two random variables X and Y is measured by Pearson correlation coefficient when both X and Y are numeric and continuous variables. The Pearson correlation coefficient r is given by

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sigma_x \sigma_y}$$

where, (i) X, Y are mean values of X and Y, and

(ii) X_i, Y_i individual values of X and Y.

Table 6.4 A few use-cases ANOVA from literature

Sr. no	Techniques	Purpose	Source
1	ANOVA	To interpret patterns of students skill growth from learning curves for group of students and correlates with performance of groups of students	[7]
2	ANOVA	The impact of different types of background music on reading comprehension	[6]
3	ANOVA	To investigate the effect of choice on student assignment completion and learning gains. To investigate better performance between choice group and prescribe group	[8]

	CP	DSA
count	69	69
mean	61	61.56
std	14.80	15.67
min	40	40
max	95	95

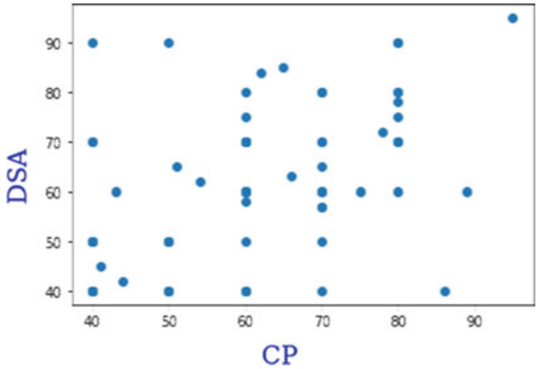


Fig. 6.3 Summary statistics and scatter plot for correlation analysis

The value of r is always between −1 to 1. A high absolute value of r, i.e. $|r|$ indicates a strong relationship between X and Y. When the value of r is positive, the relationship between X and Y is positive. Similarly, X and Y negatively related when r is negative (Fig. 6.3).

The correlation coefficient is also used to formulate the hypothesis. With r as a correlation coefficient of a sample and ρ as the population correlation coefficient the null and alternative hypothesis is formulated as:

$$H_0 : \rho = 0 \text{ There is no correlation between two random variables.}$$

$$H_1 : \rho \neq 0 \text{ There is correlation between two random variables.}$$

The t-statistic is typically used to check the statistical significance of correlation analysis. It is given by

$$t - value = r\sqrt{\frac{n-2}{1-r^2}}$$

6.4.1 *An Example: Does a Student's Performance in a Course Depend on a Pre-requisite Course?*

As an example of correlation analysis we would like to answer the question: *Does a student's performance in a course depend on a pre-requisite course?* A teacher normally assumes that a student's performance in a course depend on knowledge and skill acquired in a pre-requisite course. This assumption can be validated through the application of correlation analysis.

We consider two courses offered at DBATU at the first and second year of B. Tech. in Computer Engineering program. Courses are *C-Programming (CP)* and *Data Structure and Algorithm (DSA)* offered at first and second year respectively. C-programming is a pre-requisite course for Data Structure and Algorithm. Further, we use the marks obtained by students in both the courses to analyze the association between pre-requisite course and the main course. Table 6.3 shows the descriptive or summary statistics of both courses. The null and alternative hypothesis can be formulated in this case as given below:

H_0 : $\mathrm{r_{cp,dsa}} \leq 0.50$: There is no correlation between CP and DSA performance of students.

H_1 : $\mathrm{r_{cp,dsa}} > 0.50$: There is a correlation between CP and DSA performance of students.

We have calculated the Pearson Correlation coefficient for the data described in Table 6.3, and the value for $r_{cp,\ dsa}$ is 0.47. Pearson Correlation Coefficient can be calculated either in Excel sheet or in Python. Corresponding t-statistic value is 3.87. Critical value of t-statistic is 1.99 which can be calculated using Excel function *TINV (0.05, 67)*. Value t-statistic is greater than the critical value of t-statistic; so the null hypothesis H0 is rejected. Also, the p-value is 0.0002 (calculated using Excel function *T.DIST.2 T(3.87, 67)*), which is less than the α value of 0.05, indicating that the results are statistically significant. Hence, we can claim that students' performance in DSA depends on his/her performing in a pre-requisite course on C-Programming.

6.4.2 Use-Cases of Correlation Analysis from Literature

Researchers have used the correlation analysis to investigate the association between various parameters affecting learning. Few examples of such use cases are listed in Table 6.5. In Ref. [9], the authors have checked the dependency between students' confidence level and their performance in a course. An association between recurrently generated words by learners and their reading comprehension performance has been explored in [10]. In Ref. [11], researchers use correlation analysis to study the association between academic performance with learning strategies and course feedback in flipped classroom settings.

6.5 Use-Case for Linear Regression Analysis

Regression analysis is a powerful yet simple technique used to build predictive models. Predictive models attempt to predict the value of a dependent variable or an output variable from a set of independent or input variables as accurately as possible. While doing so, the model development methods make certain assumptions. Method

Table 6.5 A few use-cases of correlation analysis from literature

Sr. no	Techniques	Purpose	Source
1	Correlation	It revealed that recurrence indices were significantly related to the students comprehension score at both surface and deep levels	[10]
2	Pearson correlation	While writing the journals, grade and word count are significantly related. No significant correlation was found between journal grade and any sentimental levels (positive, negative and overall sentiment)	[12]
3	Pearson correlation	To correlate overconfidence and under confidence with students' overall course performance	[9]
4	Kruskal Wallis test	To examine association between learning strategies and academic performance	[11]
5	Spearman's correlation	To understand student use of digital data, online services to their own practices of privacy self management and their relation and concern about use of their data in the context of learning analytics	[13]

of Linear Regression Analysis assumes a linear relationship between an output variable and input variables. Hence, this kind of relationship is represented as a linear equation between input and output variables as given below

$$\mathscr{Y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n$$

where, (i) $x_1, x_2, \ldots, x_n$ are input variables, (ii) $\beta_0, \beta_1, \ldots, \beta_n$ are coefficients of input variables, (iii) β_0 a Y-intercept, and (iv) Y is an output variable.

In the case of *Simple Linear Regression (SLR)*, we predict an output variable's value from a single input variable. The *Multiple Linear Regression (MLR)* predicts an output variable's value from more than one input variables.

Two different kinds of model development methods exist to build linear regression models. The first one is called *Ordinary Least Square* method and the second is known as *Gradient Descent Method*. The purpose of both methods is to estimate the values of linear coefficients i.e. $\beta_0, \beta_1, \beta_2, \ldots,$ and β_n.

The *Ordinary Least Square* method uses a statistical approach to build the regression model that minimizes the error between predicted and actual value. The *Gradient Descent Method* is an iterative method that guesses linear coefficients in each iteration values to find the best optimal combination of linear coefficients.

6.5.1 Predicting the Students Performance from Pre-requisite Courses

As an example to illustrate the application of linear regression analysis, we use the task of predicting the student's performance in a course from the prerequisite courses. We use the same set of courses in the previous section, i.e. C-Programming and Data Structure and Algorithm. The course C-Programming (CP) is a pre-requisite course for Data Structure and Algorithm (DSA). In this case, our objective is to estimate the marks in *Data Structure and Algorithm* from the marks of C-Programming. Hence, this is the case of applying simple linear regression. The predictive model can be described using the following equation.

$$DSA\_Marks = \beta_0 + \beta_1 XCP\_Marks$$

DSA_Marks and *CP_Marks* are the marks obtained in the course on Data Structure and Algorithm and C-Programming respectively.

We have used the Ordinary Least Square method provided in *Stats_Model* API of Python programming language to find the values of β_0 and β_1. The calculated values of β_0 and β_1 are 31.00 and 0.50 respectively as shown in Fig. 6.4. Thus the equation for the predictive model becomes

$$DSA\_Marks = 31.00 + 0.50XCP\_Marks$$

The model has a residual prediction error of 13 means that predicted marks would be in the range of ± 13. This high expected range may be due to weaker linear strength observed between DSA marks and C-Programming, i.e., Pearson Correlation

```
                            OLS Regression Results
==============================================================================
Dep. Variable:     Data Structure and Algorithm   R-squared:                       0.224
Model:                                      OLS   Adj. R-squared:                  0.212
Method:                           Least Squares   F-statistic:                     19.34
Date:                          Thu, 07 Jan 2021   Prob (F-statistic):           4.01e-05
Time:                                  09:59:49   Log-Likelihood:                -278.55
No. Observations:                            69   AIC:                             561.1
Df Residuals:                                67   BIC:                             565.6
Df Model:                                     1
Covariance Type:                      nonrobust
==============================================================================
                  coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const          31.0038      7.149      4.337      0.000      16.735      45.273
C-Programming   0.5010      0.114      4.398      0.000       0.274       0.728
==============================================================================
Omnibus:                        1.668   Durbin-Watson:                   2.166
Prob(Omnibus):                  0.434   Jarque-Bera (JB):                1.100
Skew:                           0.290   Prob(JB):                        0.577
Kurtosis:                       3.215   Cond. No.                         268.
==============================================================================

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
```

Fig. 6.4 A summary report of simple linear regression model

Table 6.6 A few use-cases of regression analysis

Sr. no	Technique	Purpose	Source
1	Regression	To find out strong relationship between pre and post requisite skill	[14]
2	Linear regression	To predict learning group productivity under the given restrictions or privacy constraints	[15]
3	Regression and root mean square error	From the instructor dashboard prediction of low scored students and identify students who need help from peer tutors or instructor	[16]

coefficient of 0.473 only (as seen in previous section). A Course instructor can use this predicted range of marks to identify students at risk at the beginning of the course.

6.5.2 Use-Cases of Regression Analysis from Literature

Researchers have used regression analysis for multiple purposes as listed in Table 6.6. One of the everyday use cases is to predict the performance on post-requisite skill set from the pre-requisite skill set. For example, in [14] authors use the data collected from the adaptive testing platform and multiple linear regression techniques to predict the performance on post-requisite skills.

The authors in [15] use simple linear regression to identify the factors contributing to the formation well-functioning group when learners share no personal data. The Ref. [16] use the logistic regression technique to identify the student's loss of interest in a MOOC at an early stage from the various engagement factors collected such as time spent watching videos and submission of assignment.

6.6 Conclusion

A large amount of data is being generated when educational institutes start using digital technologies such as the Learning Management System. Knowledge and skills to analyze this data are required to use this data meaningfully. Teachers can use various statistical methods to extract meaningful information from this data. The chapter illustrates applications of a set of such statistical methods in day-to-day learning activities.

Four statistical methods viz, hypothesis testing, ANOVA, correlation analysis and regression analysis are described with one example of each method. The use of these methods depends on the context of application. For example, hypothesis testing is useful to conclude by comparing the means of a sample with a population or known accepted value. At the same time, ANOVA is used to measure the impact of a common phenomenon on multiple groups. The correlation analysis is used to check the association among various variables, while regression analysis is useful for predicting a dependent variable's values.

We describe a typical example highlighting the context in which a particular method is appropriate. Further, a few examples from the existing literature have been briefly described. The illustrated examples in the chapter and use-cases from the current literature lay the foundation upon which teachers can devise novel use-cases or experiments to investigate various learning theories' and their implications.

Appendix: A Primer on Statistical Terms and Definitions

The following are most commonly used terms from Statistics. Here we reproduce their definitions from [17]

1. **Population** It is the set of all possible data for a given context.
2. **Sample** It is the subset taken from population.
3. **Types of Data** A Data can be broadly classified into four categories. These are: (i) Continuous, (ii) Discrete, (iii) Ordinal, and (iv) Nominal. Discrete and continuous data is numeric type data. A continuous random variable such as temperature may take any value from the number space. A discrete random variable such as color can take a fixed set of values. For example, red, blue green etc. An implicit order of hierarchy is understood in case of ordinal type of variable such performance level may be excellent, very good, good and fair. No such implicit order is assumed in case of nominal type of random variable
4. **Mean** is the arithmetical average value of data and is one of the most frequently measures of central tendency. It is defined as:

$$\mu = \sum_{i=1}^{n} \frac{x_i}{n}$$

5. **Mode** is the most frequently occurring value in the data set. Mode is the only measure of central tendency which is valid for qualitative (nominal) data since the mean and median for nominal data are meaningless. In the bar chart (and histogram), mode is the tallest column.
6. **Median** It is the value that divides the data in to two equal parts, that is the proportion of observations below median and above median will be 50%. Median is much more stable than the mean value that is adding a new observation may not change the median significantly. However the drawback of median is that it is not calculated using the entire data like in the case of mean.
7. **Variance** It is the average of the squared differences from the Mean.

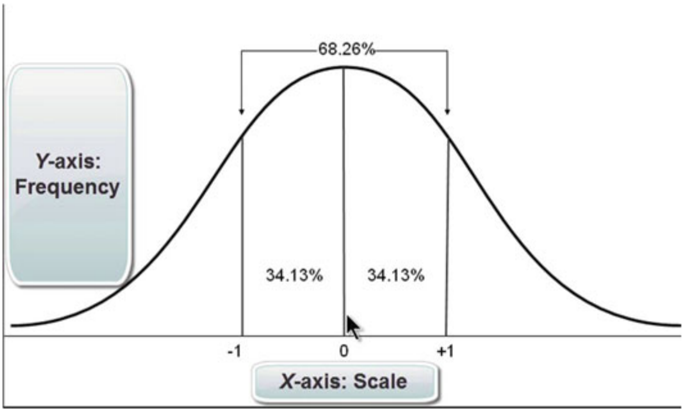


Fig. 6.5 Normal distribution

$$\text{var} = \sum_{i=1}^{n} \frac{(x_i - \mu)^2}{n}$$

8. **Standard Deviation** It is a measurement of how far data is spread out from the mean, or average. The Standard Deviation is a measure of how spreads out numbers are. It is typically defined as

$$\sigma = \sqrt{\text{var}}$$

9. **Normal Distribution** It is a continuous probability distribution that is symmetrical on both sides of the mean, so the right side of the center is a mirror image of the left side. The area under the normal distribution curve represents probability and the total area under the curve sums to one. It is symmetrical bell-shaped graph as shown in Fig. 6.5.

10. **Co-Variance** It signifies the direction of the linear relationship between the two variables. By direction we mean if the variables are directly proportional or inversely proportional to each other. Increasing the value of one variable might have a positive or a negative impact on the value of the other variable.

$$Cov_{x,y} = \frac{\sum (x_i - \mu_x)(y_i - \mu_y)}{n - 1}$$

11. **Correlation** It is a measure of the strength and direction of relationship that exists between two random variables. It is a measure of association between two variables.
12. **Pearson Correlation Coefficient** measure the strength of the linear association relationship using numerical measure

$$PCC = \frac{Cov_{x,y}}{\sigma_x \sigma_y}$$

13. **Mean Square Error** It measures the average of the squares of the errors i.e., the average squared difference between the estimated values ($\hat{y}$) and actual value (y).

$$MSE = \sum_{i=1}^{n} \frac{\left(y_i - \hat{y}\right)^2}{n}$$

14. **t-test** is used when the population follows a normal distribution and population standard deviation is unknown. It shows how significant the differences between groups are.
15. **z-test** is a statistical test to determine whether two population means are different when the variances are known and the sample size is large. It can be used to test hypotheses in which the z-test follows a normal distribution.
16. **Chi-Squared test** It is used for testing relationships between categorical variables.

References

1. M. Kiseleva, N. Kiseleva, E. Kiselev, Changes in education under the influence of digital technologies: main problems and risk of division. KnE Soc. Sci. 22–28 (2020)
2. R.E. Slavin, How evidence-based reform will transform research and practice in education. Educ. Psychol. **55**(1), 21–31 (2020)
3. M.M. Chiu, B.W.-Y. Chow, S.W. Joh, How to assign students into sections to raise learning, in *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (ACM, 2017), pp. 95–104
4. D. Babik, S. Stevens, A.E. Waters, Comparison of ranking and rating scales in online peer assessment: simulation approach, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 205–209
5. T.L. Varao-Sousa, C. Mills, A. Kingstone, Where you are, not what you see: the impact of learning environment on mind wandering and material retention, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 421–425
6. X. Hu, F. Li, R. Kong, Can background music facilitate learning? Preliminary results on reading comprehension, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 101–105
7. L. Chen, A. Dubrawski, Learning from learning curves: discovering interpretable learning trajectories, in *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (ACM, 2017), pp. 544–545
8. S.A. Adjei, A.F. Botelho, N.T. Heffernan, Sequencing content in an adaptive testing system: the role of choice, in *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (ACM, 2017), pp. 178–182
9. A. Aghababyan, N. Lewkow, R. Baker, Exploring the asymmetry of metacognition, in *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (ACM, 2017), pp. 115–119

10. L.K. Allen, C.A. Perret, A.D. Likens, D.S. McNamara, What'd you say again?: recurrence quantification analysis as a method for analyzing the dynamics of discourse in a reading strategy tutor, in *LAK* (2017), pp. 373–382
11. W. Matcha, D. Găsević, N.A.A. Uzir, J. Jovanović, A. Pardo, Analytics of learning strategies: associations with academic performance and feedback, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 461–470
12. Y. Chen, B. Yu, X. Zhang, Y. Yu, Topic modeling for evaluating students' reflective writing: a case study of pre-service teachers' journals, in *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (ACM, 2016), pp. 1–5
13. S. Slade, P. Prinsloo, M. Khalil, Learning analytics at the intersections of student trust, disclosure and benefit, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 235–244
14. S.A. Adjei, A.F. Botelho, N.T. Heffernan, Predicting student performance on post-requisite skills using prerequisite skill data: an alternative method for refining prerequisite skill structures, in *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (ACM, 2016), pages 469–473
15. T. Hecking, D. Doberstein, H.U. Hoppe, Predicting the wellfunctioning of learning groups under privacy restrictions, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge* (2019), pp. 245–249
16. M.L. Bote-Lorenzo, E. Ǵomez-Śanchez, Predicting the decrease of engagement indicators in a mooc, in *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (2017), pp. 143–147
17. U.D. Kumar, *Business Analytics: The Science of Data-Driven Decision Making*. Wiley (2017)

Chapter 7
Impact of Lesson Planning on Students' Achievement Using Learner Profile System

Munazza A. Mirza, Khawar Khurshid, Zawar Shah, Faryal Shah, Andrew Levula, and Aleksandra Klašnja-Milićević

Abstract This study proposed and evaluated a Learner Profile System (LPS), which is a web-based solution to generate multiple types of learner profiles. The contents of the profiles include the basic information about the learners, such as, demographics, preference profile, interest profile, learning styles (LS), and motivational goal orientation (MGO). The pilot study of the instrument, a specifically designed Student Survey (SS) for the LPS, was conducted on the middle school students (N = 60) to measure the construct validity and reliability. The internal consistency reliability of the MGO across two motivational aspects was 0.6530, and the exploratory factor analysis revealed four components. Afterwards, an experimental study was done on the middle school students (N = 307), in order to examine the impact of LPS on learners' achievement. To supplement the above data, semi-structured interviews were conducted to explore teachers' perception and their perspective regarding the feasibility and use of the LPS. The analysis of the results showed that the group which

M. A. Mirza · K. Khurshid (✉)
School of Electrical Engineering and Computer Science, National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
e-mail: khawar.khurshid@seecs.edu.pk

M. A. Mirza
e-mail: mmirza.msite17seecs@seecs.edu.pk

Z. Shah · A. Levula
Sydney International School of Technology and Commerce, Sydney, Australia
e-mail: zawar.s@sistc.nsw.edu.au

A. Levula
e-mail: andrew.l@sistc.nsw.edu.au

F. Shah · A. Klašnja-Milićević
Australian Institute of Higher Education, Sydney, Australia
e-mail: f.shah@aih.nsw.edu.au

A. Klašnja-Milićević
e-mail: akm@dmi.uns.ac.rs

A. Klašnja-Milićević
Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_7

learned using the LPS demonstrated significant improvement in their assessment scores in comparison to the controlled group. This study supported the hypothesis of a positive impact on learners' achievement through the use of personalized learning profiles.

Keywords Remote learning styles · Learner profile · Index of learning style · Student-centered · Learning profile system · Pre-test · Post-test

7.1 Introduction

The traditional lecture-based teaching approach for learning is still being practiced in most of the schools around the world [1]. This conventional way of teaching leads to rote learning, where the students are expected to follow the monotonous routine of listening to the lectures, and reciting the lesson if called upon by the teacher. Teachers consider it very difficult to develop individualized learner-based lesson activities. They prefer coming to the class with pre-planned lessons having no understanding of their students' background knowledge, interests and learning needs. As a result, the teachers are unable to engage their students during the lecture, which leads to low motivation. In order to have a successful learning experience, learner's subjective involvement must be taken into consideration.

Educational interventions that emphasize on learner's personal interests, engagement, attitudes are the key to gain larger goals, such as, enhanced motivation and better outcome in learning [2]. This however, demands to change the one-size-fits-all approach to teaching. A heterogeneous classroom needs to be taught by addressing learning characteristics [3]. Student-centered approach requires knowing individual needs of each learner and then addressing them in classroom. This pedagogical approach leads to enhanced engagement, motivation and increase in each student's knowledge. If the learner is engaged, she/he will be more devoted, focused and persistent, and this will make learning a worthwhile experience.

To cultivate engagement and motivation in learning process of educational experience, learner-centered approach is required [4]. In learner-centered approach, the focus is on learners' needs, their autonomy and independence. Students are provided with opportunity to explore their capacities, interests and skills [5]. Student-centered approach demands teachers to know their learner's needs, which requires development of comprehensive learner profiles. Powell and Kusuma-Powell, suggested that teachers can use learner's information to unlock their learning potential [4]. Literature supports the effectiveness of the student-centered approach, [4–10, 5] usefulness of learner profile [11–14] and the digital tools [15–17] that help the teachers to attain learner profiles for designing instructions. However, there is no literature on standardized, concise and comprehensive tools that help in developing the learner profiles.

Learner profile is a collection of broad data that provide specific information about the students. It provides the ways that help teachers design instructions with respect to their learner characteristics. The basic information of the students is gathered usually when they are enrolled in school. Later, several diagnostic approaches can be used to develop in-depth understanding of the learners' needs. To identifying learners' characteristics, development of learner profile is an appropriate way for providing quality education. These learner profiles provide the essential information for student-centered instructional designing. There are various elements of learner information to develop learner profile. Teachers usually use learners' performance data and information related learning disabilities sometime to understand their students. For providing individualized learning experience, teachers must know more than student's name, age, family background, friends, and this demands systematic way i.e., development of learning profile [4]. The better a teacher understands learners' differences, the more she/he can accommodate their learning needs [18].

In Pakistan, teachers use lecture-based approach to teach, where students passively receive information; this causes lack of motivation and engagement. It is challenging to change traditional culture of chalk and talk in classroom. Teacher thinks that it is impossible to cater individual differences in their pedagogical approach. Teachers use the same teaching methods as they were taught. They think that they have high workload and limited time, which does not allow them to put extra effort to improve the quality of teaching [1]. Parents are paying high tuition fees willingly so that their children can learn skills and capabilities that will help them lifelong. Learners cannot reach their potential unless they are fully engaged and motivated to do the required hard work. 95% of students are enthusiastic learner in kindergarten, but 37% of student loses their love of learning as they reach secondary level [2]. It is not enough to present instructional material in orderly manner, use experiential approach and provide feedback for effective teaching. Quality educational experience requires student-centered approach. Students are only motivated to adopt deep learning tactic when teachers are more involved with students to know their learning needs [19]. To provide quality education, motivating students by providing engaging learning environment, there is need of investment on teacher's qualification and more specifically the resources that assist teachers to improve their instructional design. Effective contextualized and relevant, learner-centered pedagogy is a key ingredient for the quality education. It is ultimately linked with the learner's motivation, engagement, skill building and performance [20].

Teachers in Pakistan need resources to assist in reducing their workload and manage their time. This can help them develop instructional strategies for student-centered approach and quality ensured educational experience. Thus, the purpose of the study is to develop a web based LPS that provides teachers with comprehensive and concise learner profiles so that they understand the learner's characteristics. This can assist the teachers in understanding their learner's individual requirements for learning, which further aids them in learner-based instructional designing. A quantitative technique, the quasi-experimental pre- and post-test method, was used to evaluate the impact of the instructional approach based on learner profile for mathematics and Urdu Language performance. Teacher's perception regarding the use of LPS for the instructional designing is also acquired, which aids this study to understand the impact of LPS for instructional designing and improve the LPS in future.

7.1.1 Research Questions and the Associated Hypotheses

RQ1: Is there a positive impact of learner profile-based instruction on student's achievement?

RQ2: What is the teacher's perception on the use of LPS for instructional designing and implementation?

RQ1 is sought to derive following null hypotheses:

Hypothesis 1 (H01): There is no difference found in the achievement of 8th grade mathematics students who were taught through instructional design using learner profile system in comparison to the controlled group.

Hypothesis 2 (H02): There is no difference found in the achievement of seventh grade language (Urdu) students who were taught through Instructional design using learner profile system in comparison to the controlled group (H02).

RQ2 explores the qualitative aspects of use of LPS for instructional designing to have in-depth understanding of intervention.

7.2 Literature Review

Students are only motivated to adopt deep learning tactics when teachers are more involved with students to know their learning needs [5, 19]. However, in Pakistan teachers are performance oriented, relying on textbooks only without creative and advanced pedagogies to enhance individual learner's capability [1]. The supportive climate and cognitive activation through teaching strategies benefits heterogeneous classroom a great deal and plays a vital role on student's performance [21]. To meet the need of heterogeneous classroom, teachers need to consult learners in the instructional design process and attain information regarding learner preferences [22, 23], learner's motivational aspects [24] and interests [5, 7, 12].

Hulme et al. [25] stress on language learning abilities for the communication and learning in classroom and suggested that when activities are planned to teach language skills, significant improvement in the oral language and reading comprehensions are observed. Literature implies that when activity sheets are used to identify the learner's interest it leads to enhance motivation and engagement [12]. Chamberlin and Powers[7] developed learner profile based on learning preferences and interests and found it rewarding in terms of enhanced mathematical understanding.

Knowing about the student benefits to form a constructive teacher-student connection increases the trust between the teacher and students [24]. Park et al. [11], suggested a learner profile system through multidimensional characteristics analysis (i.e., memory, concentration, visual perception, learning condition and teacher assessment of learner) using real-time monitoring system. The learner profiling had a positive impact on improving learning, motivation, satisfaction and cognitive abilities [11], but the suggested process was very long and unrealistic to use in classroom. When student's individuality needs to be addressed in the teaching and learning process, there is a need to take an account of learner's accessibility [6]. Wang et al. characterized students to four profiles (i.e., surface understanding, passive, mixed, and high engagement) and implied that students with high engagement profiles were associated with the best mean value of academic achievement [13].

The learning profiles aid in identifying the learning characteristics and LS [9]. LS can be described as the learner's tendencies to, interact, perceive, process and respond to information in educational environment. LS supporters advocate that in order to provide optimal educational environment for learning, diagnosis of individual LS is necessary. LS are a key factor when learner's diversity needs to be addressed [26]. Student and teaching LS need to be match as they affect the learning outcome of students [27]. Its relationship has been associated with many factors, such as, achievement, motivation, gender, occupation, academic programs, geographic location, instructional designing, special education [26, 28]. Identifying LS and adjust instructional design accordingly helps improve LS [29–32]. The secondary school students' achievement for technological literacy is significantly associated with addressing LS [32]. Among the experienced higher studies educators, 33% would continue to use LS inventories for better outcome and 58% educators think that LS benefits individualized learning [33].

After extensive literature review it has been found that Felder-Silverman Index of Learning styles (ILS) tool is most suitable for identifying the learning characteristics. ILS is a free self-administered 44 items tool. It is a concise and comprehensive tool to identify learning style in light of four dimensions of educational experience (i.e., processing, perception, input, understanding). Each dimension is further allocated in contradicting learning style. Hawk and Shaw reviewed most readily used LS instruments (i.e., Kolb instrument, GSD, VARK instrument, Dunn and Dunns PEPS, ILS), which educators use to identify student's LS before instructional designing [31]. The validity of the ILS has been reported by various studies [30, 34–37]. In a recent study, differentiation was applied to improve the mathematic performance of senior secondary school students on the basis of learner information gathered through Felder-Soloman Index of Learning Styles (ILS), [23]. Awofala and Lawani reported high reliability of ILS tool i.e., 0.92 and suggested significant improvement in academic performance when differentiated instruction was applied after using learner's information using ILS [23]. When LS of 40 nursing students were assessed through Kolb experiential model, it positively influenced on teacher's satisfaction and learner's achievement, [38]. But Kolb instrument reliability and validity are questionable [39].

Ross et al. [40] used GSD instrument to identify LS relationship with outcome and found positive association, however instrument is moderately reliable with low validity [41, 42]. The validity of the VARK instrument is not reported by any research other than Fleming's own research study [31]. Dunn and Dunn PEPS is a 100-item commercially available and length tool and the validity of the instrument is being challenged [43]. Students should not be labeled with LS but the main purpose is to understands students learning preferences. Instructional objective ought to train their learners with abilities related to every learning styles category irrespective of their learning styles [18, 44].

Teachers also need to know, how learners get motivated to keep them engaged in learning process and better performance [45]. Motivational orientation towards learning is considered a strong determinant in instructional approaches [46]. Teachers can educate best by understanding their student's needs, reason behind motivation and act upon it [24]. El-Adi and Alkharusi employed a descriptive research on 238 ninth graders and suggested that learners intrinsic and extrinsic motivation is positively related to learning outcome and self-regulated learning [47]. Student's learning is usually derived from two kinds of goal orientations; i.e., mastery/ intrinsic and achievement/extrinsic goal orientation. Teacher's instructional strategy is significantly related to learner's intrinsic and extrinsic motivation [45]. Primary and secondary grade students exhibited positive motivation when school accentuates on intrinsic motivational approach, such as, skill-based learning and better conceptual understanding to improve knowledge [48]. A teacher can play an important role to influence learner's motives, beliefs and goals through interpersonal bond and impact learner's force of motivation [49].

Rawat and Dwivedi suggests that to increase academic performance personalized learning experience need to be provided which is based on learner's profile [50]. In a recent study, the technological system that help develop learner profiles are considered as one of the vital pillars for providing personalized instructions [5]. Thus, researchers admit that development of learning profile for lesson planning has positive impact on learning experience [11, 13–17]. But there is no standard way of development of learner profile that includes all aspects of learner's characteristics including motivation, interests, LS etc., in the literature. The study proposed and evaluated a web-based system to develop learner profile.

7.3 Methodology

7.3.1 Learning Profile System—The Web Portal

The study purposes a web-based system that provides comprehensive information about learner's characteristics and requirements for instructional planning. The use-case diagram of LPS is shown in Fig. 7.1. There are three prospective users of website, admin, teacher and students. The layout of the website (LPS) was kept simple and easy to use. The admin adds the school and Users (Teachers/students) as shown in Fig. 7.2. Then website link will be generated for specific school, which will be provided to school to access LPS. User and its grade need to be assigned by admin. If users (teacher/students) could sign up themselves, the sign-up-request will be sent

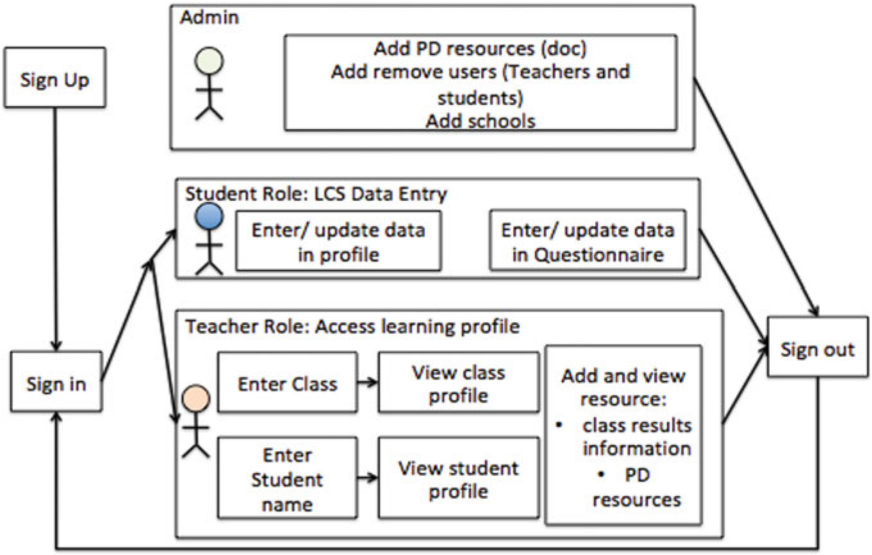


Fig. 7.1 The use-case diagram of LPS. *PD = Professional development, LCS = Learning characteristics of students

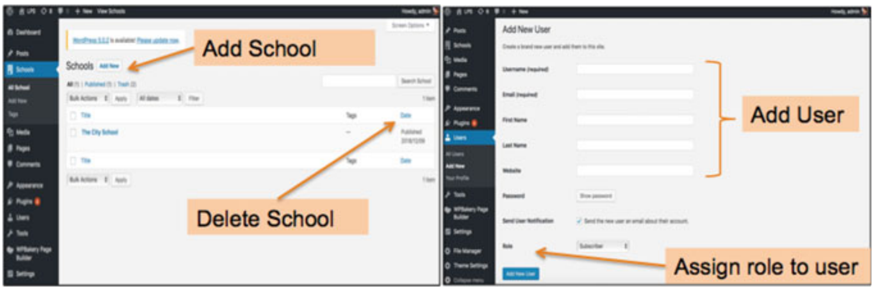


Fig. 7.2 Admin view of the portal

to admin. This allows users to have their own ID through which they could sign in the system as shown in Fig. 7.3.

Students' role is to fill the surveys as shown in Fig. 7.4. Once the surveys are filled, they can submit and sign out and teacher can access their profile by signing in through their account then selecting the class and student name as shown in Fig. 7.5. As illustrated in Fig. 7.6, teachers can also assess the collective class profile.

Fig. 7.3 Sign Up/Sign in forms

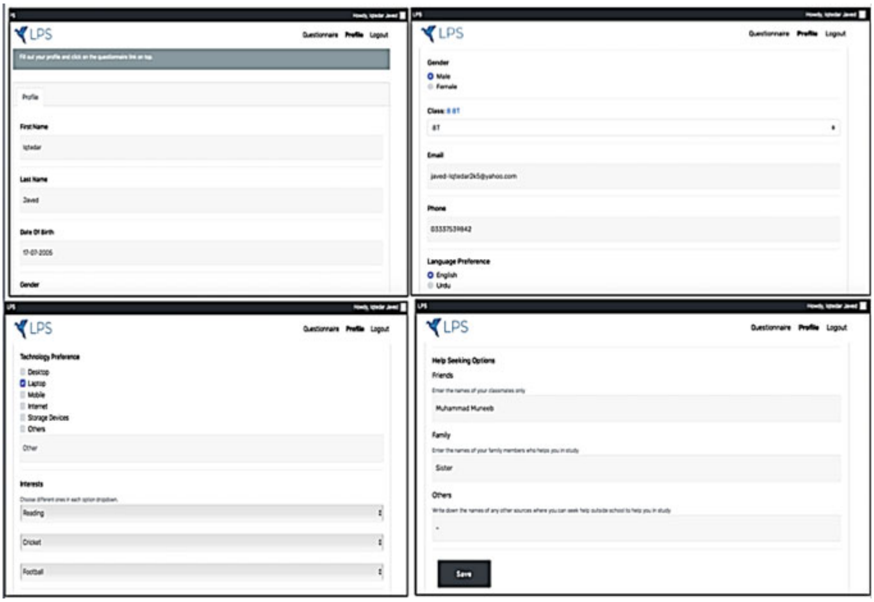


Fig. 7.4 Student's view of the portal

7.3.2 Instrumentation for LPS

The online available tools to develop learning profile lacks information required to comprehend tools, also have nonexistent validity and reliability report in literature. To collect learner's information required for LPS, two instruments were used which are:

1. Index of learning style (ILS) survey comprising 44 items [51]. Validity and reliability of ILS is reported by various studies [30, 34–37].

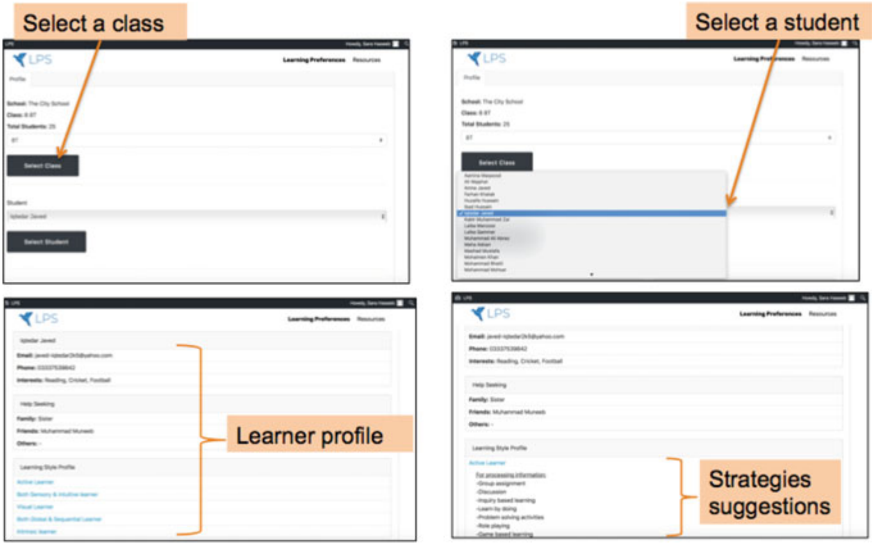


Fig. 7.5 Teacher's view of the portal to access learner's profile

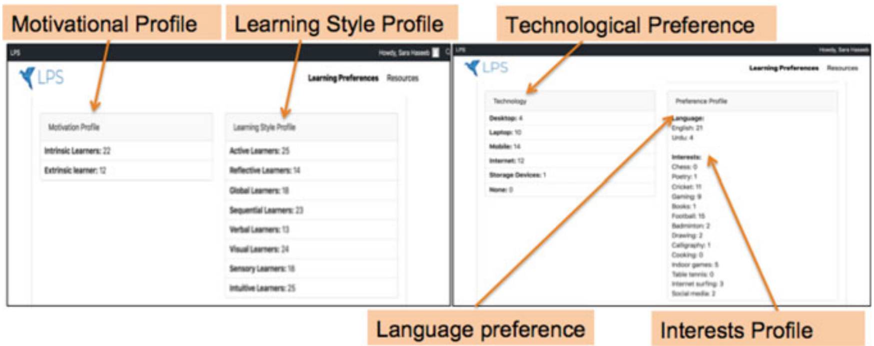


Fig. 7.6 Teacher's view of the portal at the cohort level

2. Students Survey (SS), which is specifically designed for LPS. The SS is comprised of two sections. First section is comprised of the items related to the basic Profile: demographic information, contact information, and preference information as mentioned earlier. Second section consists of 11 items to diagnose motivational goal orientation (MGO).

The following information was collected to develop learner profiles for LPS:

1. Ersonal Data: It comprises questions related to learner demographics i.e., name, age, grade, gender, institution, email, and phone number.

2. Accessibility Data: It includes learner's preference profile i.e., language preference for mode of instruction, the learner's interests, any technology they have available to support their learning, help-seeking (friend they like to work with and support learner needs to study outside their school such as tuition etc.).
3. Learner Preferences: Learner preferences were identified by index of learning style (ILS) survey [51], that comprised of 44-items. It is the self-scoring instrument that assesses students, learning styles on four pairs of dimensions. These dimensions are i.e., visual or verbal, sensing or intuitive, active or reflective, sequential or global. ILS provides information regarding the way learner prefers to receive, process, perceive and understand information. ILS provides a comprehensive picture of learning preferences for instructional strategies.
4. Motivational Goal Orientation: Motivation involves the various reasons that drive learner to work [44, 47]. 11 itemed tools called Students Survey (SS), was developed to identify student's motivational approach i.e., extrinsic goal orientation or intrinsic learner goal orientation based on literature. The literature supports that student's motivation depends on intrinsic vs extrinsic [52], mastery-based learning vs performance-based learning and approach (success) vs avoidance (failure) [13]. Similar to ILS, SS has two inclinations for one-dimension i.e., motivation goal orientation. The bipolar dimensions are intrinsic motivation or extrinsic motivation. The SS was also scored in the same manner as ILS.

7.3.3 Pilot Study

A small-scale trial for pilot study was conducted to ensure the validity and reliability of the instrument using a paper–pencil form. Content validity of the instrument SS is established by having the instrument reviewed by panel of experts as suggested in [53]. The changes were made after carefully considering the provided feedback. After approval of experts, the instrument was made available to the students (N = 60) for a pilot study. Twenty-two semi filled survey forms were exempted from analysis.

The basic profile requires data that is unique for each learner, such as name, age, grade, gender, institution, email, phone number, language, interests and technology preference. Therefore, internal consistency reliability and construct validity of these items cannot be identified or required for the SS validation. Hence the inter-consistency reliability and construct validity of MGO was examined. Literature supports the argument that a large number of participants are not essential for the pilot study, to test the validity and reliability of an instrument [53]. The pilot study was done on 60 secondary grade students of a private school.

The Internal Consistency Reliability

The internal consistency reliability across two motivational aspects was 0.668 of the MGO as shown in Table 1.

Table1 The statistical evidence of reliability of MGO

N	Cronbach's alpha	Mean	SD
38	0.668	8.55	2.127

Construct Validity of MGO

The factor structure using EFA approach provides the evidence of construct validity for the MGO. The sample adequacy was established through Kaiser–Meyer–Olkin and Bartlett's test of Sphericity as shown in Table 7.2. The KMO index of more than 0.50 is considered suitable for EFA [54]. Moreover, Bartlett's test of Sphericity is also less than 0.05. Hence the sample is considered suitable for EFA.

The four-factor solution was estimated using scree test that involves the examination of the eigen values shown in Fig. 7.7. The number of data points above the bend in scree plot clearly shows extraction of four factors. Principal Component Analysis (PCA) was used as an extraction method with Orthogonal Varimax rotation.

Factor one loaded on 5 items and factor two loaded on 6 items. However, item 3 and 8 loads on both factor 1 and 2. Therefore, item 3 and 8 relates to perception of task with intent of performance. Once the items were isolated with respect to the high loadings in the resultant matrices, the factors were descriptively labeled. Table 7.3 depicts the

Table 7.2 Sample adequacy analysis

Kaiser–Meyer–Olkin measure of sampling adequacy	Bartlett's test of sphericity	
0.620	Chi square	131.892
	df	55
	Sig.	0.000

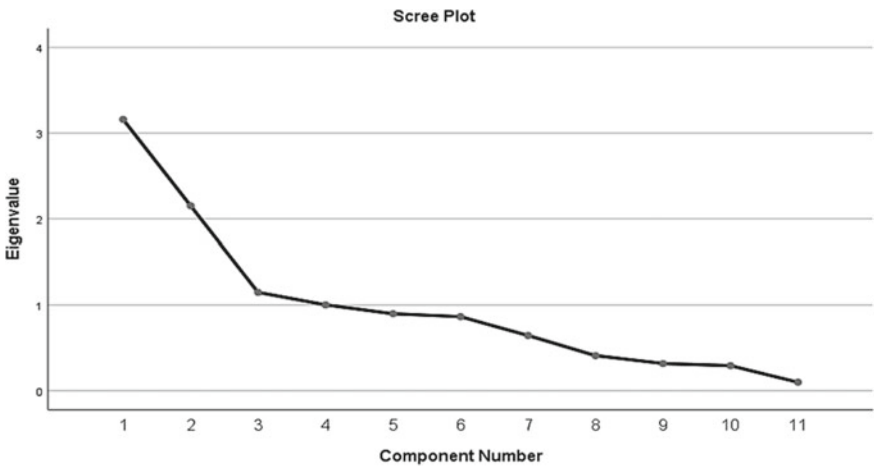


Fig. 7.7 Scree plot for factor analysis extraction of MGO

Table 7.3 Four factors analysis using the student surveys along with the description of the factors

Item no	Factors				Description
	1	2	3	4	
9	0.901				Perception of tasks or learning as an intrinsic or extrinsic learner
10	0.926				
11	0.848				
8	0.665	0.444			Perception of task and intent of performance as an intrinsic or extrinsic learner
3	0.457	0.503			
4		0.533			Intent of performance as an intrinsic or extrinsic learner
5		0.743			
6		0.468			
7		0.704			
1			0.881		Ease in task or learning as an intrinsic or extrinsic learner
2				0.923	Learning vs performance

summary of items in each factor along with description of the factors. The construct reveals the theoretical intent.

The combination of reliability estimations and factor analysis provides the evidence of validity of SS. Once the SS was validated, it was included in the LPS along with ILS and basic profile information items.

7.3.4 Research Design

To evaluate the effectiveness of proposed web-based Learning Profile System, the research design was quasi-experimental with predominantly quantitative nature with some qualitative aspect.

Participants

The participants of the research were learners, recruited using purposive sampling from 7th Grade Urdu (language) teacher and 8th Grade Mathematics teacher at a private school of Capital city of Pakistan, with ages ranging 11 through 14 years.

Thus, Urdu and Mathematics teachers were approached in the selected school. Urdu is the national language of Pakistan. It is also spoken in other South Asian countries such as India, Afghanistan and Nepal. There are 60.6 Million people who speak Urdu as their first language and 40 million as a second [55]. Shah [55] proposed that majority of schools, private and public, are failing their responsibilities in terms of Urdu language learning. Students find mathematics and Language (Urdu) subjects most difficult. Additionally, there is non-existent literature on Urdu learning and its effect on student achievement. Mathematical achievement is directly related to the mathematical anxiety [56]. Zakaria and Nordin[57] suggested that students with high mathematics anxiety in secondary grades have notably lower performance and also implicated that teacher needs to be aware of learner needs and preferences for lesson planning. Berger et al. [58] state that mathematics is vital subject and teachers need to know their learners to able to tailor pedagogies to enhance learner's interests. The teachers of both subjects and grades were also the subject coordinators and had almost same level of education (i.e., MA and M.Ed). The collective sample size was 307 students in the experimented group and controlled group. For Language course, four sections of 7th grade students were the participants of the study and the sample size comprised of 75 students for experimented group of two sections and 74 students for controlled group of two sections. For Mathematics course, four sections of 8th grade students were the participants of the study and experimental group consists of 80 students from 2 sections, whereas 78 students from two sections were in the controlled group. The subject school wanted to keep the class structure intact, thus experimented and controlled group were not made within the class.

Experimental procedure

The experiment took 8 weeks as shown in Fig. 7.8. The course content selected for the experiment was taught in the first term of the annual year however experiment was conducted at the end of the year during last (i.e., 3rd) term. Thus, all the students were familiar with the fundamental concepts of the course content. For two consecutive days, revisionary classes were arranged to revise the course content using traditional approach and then pretests were administered for both subjects (i.e., Urdu Language

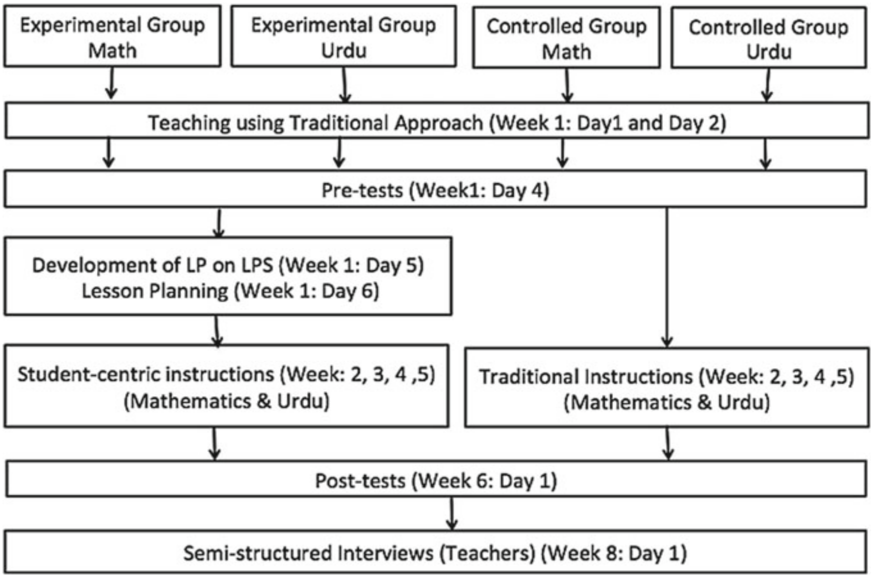


Fig. 7.8 Experimental setup for the study

and Mathematics) on the 4th day with a gap of one day. On 5th day learner profiles of students of experimented groups were composed using Learning Profile System in school's computer lab and LPS based personalized-lesson-plans were developed in collaboration of teachers and researcher. All the participants of experimented group were taught using personalized instructions from 2nd to 5th week. However traditional approach of teaching was used for the controlled groups. To evaluate the effectiveness of the LPS based instructional approach, in 6th week, both experimental and control group students were asked to finish the post-tests. To analyze data, the difference between the scores of the pre- and post-tests was dependent variables, and the lesson plans (i.e., traditional VS LPS bases lesson plan) were the independent variables.

The key purpose of the study was to evaluate the effectiveness of LPS for instructional designing; therefore, teachers were interviewed additionally using semi-structured interviews after one-week gap. In the gap of one week, teachers prepared results of post-tests and had a parent teacher meeting to discuss student progress with parents. The aim of the interviews was to attain the insight of teacher's perception with respect to use of LPS for the instructional designing. The interviews were audiotaped and later transcribed. The transcribed interviews were later categorized under themes through manifest content analysis.

Pre- and post-tests design

To evaluate the impact of LPS based instructional designing, pre- and post-tests were administered. The knowledge assessed were covered in the course that is the lesson delivered in the 4-week lesson implementation for mathematics and 4-week lesson implementation for Urdu administered consisting of carefully chosen learning content form Cambridge Mathematics Curriculum and National Urdu Curriculum. Assessment approaches that were adopted for mathematics were filling in the blanks and short questions and answers. For Urdu, fill in the blanks, short and long question and answers were used as an assessment approach. The topic, type, difficulty and distribution of questions and scoring scheme was the same in pre-test and post-test to ensure the reliability of instrument [53]. Total marks for both pre-test and post-test were 20. Students were given 60 min to complete mathematics pre-test and post-test and 40 min to complete the Language (Urdu) tests. The validity of pre-test and post-tests was established through the traditional idea of content validation. This involves confirming that the test measures certain aspects, requires the focus on curriculum design to meet the needs and abilities of learners and social norms [59]. The approval was obtained from several teachers through a moderation form about the acceptability of pre-test and post-test, which were very much aligned with the curriculum of each subject [60].

Teachers remain in the classroom during both tests for motivation and support, such as helping students understand the asked problem. To keep the same method of assessment for controlled and experimental group, both pre-test and post-test were conducted on paper worksheets. The marked tests were recorded and analyzed using the Statistical Package for the Social Sciences (SPSS).

7.4 Results and Discussion

The conduction of pretest helped evaluate respondent existing knowledge before intervention. This helps to understand the level of improvement achieved by learners after receiving the necessary treatment. The pre-test and post-test were not normally distributed for both control and treatment group. Thus Mann- Whitney U-test equivalent to Independent Sample-test was used to find the significant difference in score between the groups.

The statistical analysis of the pre-test scores for the control and experimental groups for Urdu Language and Mathematics is shown in Table 7.4. For pre-test, the p- value for the Mann–Whitney U-test in Urdu language and Mathematics is $p > 0.05$ that shows children in both groups possessed the same level of knowledge before the treatment was applied (Mathematics groups, $z = -2.006$, $p = 0.045$) and (Urdu language groups, $z = -2.327$, $p = 0.02$). Therefore, level for knowledge before the intervention for all the groups were at the same level.

The quasi-experimental design helps determine the statistical difference between the control and experimental groups after applying the intervention. Table 7.5 provides the statistical analysis of the post-tests scores for control and experimental groups. The results given in Table 7.5 show that there is a significant difference between pre-test and post-test scores obtained from the controlled and experimental group of Mathematics ($U = 1975.5$, $z = -3.997$, $p = 0.00 < 0.05$) in favor of experimental group, was in agreement with the results of recent study done on secondary students in Mathematics [23]. This result shows that learner's academic performance

Table 7.4 Mann–Whitney U-test results of the pre-test scores in each group

Group	N	Mean rank	Sum of ranks	U	*Z*
Experimental group mathematics (EM)	80	72.13	6934.5	2.546E3	−2.006*
Controlled group mathematics (CM)	78	86.68	5626.5		
Experimental group urdu (EU)	75	83.15	6236	2.164E3	−2.327*
Controlled group urdu (CU)	74	66.74	4939		

* $p < 0.05$
** $p > 0.05$

Table 7.5 Mann–Whitney U-test results of the post-test scores in each group

Group	N	Mean rank	Sum of ranks	U	*Z*
Experimental group mathematics (EM)	80	93.81	7504.5	1975.5	*−3.997**
Controlled group mathematics (CM)	78	64.83	5056.5		
Experimental group urdu (EU)	75	88.31	6623	1777.7	*−3.799**
Controlled group urdu (CU)	74	61.51	4552		

* $p < 0.05$
** $p > 0.05$

in mathematics enhances, when student centric learning experience is designed on the basis of learner's information, such as, learning style [23].

When instructions are designed after the development of learner profiles, it had a positive impact on the learning process, learner's comfort level, confidence in their performance abilities and learning outcome [9]. The findings of present study suggest that students perform differently with respect to learning characteristics with positive impact on learning outcome. Therefore, it is necessary to examine learner profile before instructional designing for enhanced learning experience. These findings were in lined with a study done to develop learner profiles using multi-dimensional characteristics analysis by [11] and another study done by [50] where cluster analysis was used for learner profiling in an e-learning system. Rawat and Sanjay recommended that learner profile can enhance academic experience as well as learner outcome [50].

For Urdu Language experimental group, ($U = 1777$), $z = -3.799$, $p = 0.02 < 0.05$), the significant difference is in favor of experimental group which is aligned with previous research [8, 10]. Learners whose teacher differentiated more activities on basis of learner's characteristics, perform better than teachers who differentiated less [61]. Hulme et al. results also suggest that outcome of language intervention produce significant improvement in academic performance [25]. So, it can be concluded that addressing learning characteristics such as learner preferences, interest, preferred language, help seeking profile and motivational profile in instructional designing can help achieve the learning goals and better outcome.

Based on the statistical evidence provided in the tables above, there is an increase in the performance of the learners after the intervention. This suggests that the approach benefited the students in both subject areas (i.e., Urdu Language and Mathematics). The statistical analysis of significant value suggests that the hypotheses (H01and H02) were rejected and these findings are aligned with [61].

Through Mann–Whitney U-test, a significant difference was found in favor of experimental group in both subjects (Mathematics and Urdu), indicating positive impact on learner's outcome when the instructor used LPS for lesson planning. The difference in performance of the groups can be related to a number of factors. The instructional strategies are a vital factor to enhance the interests. In traditional classroom, usually a teacher has to cater several learners at a time and student has passive role that impedes their learning. The findings of Wang, Liang, Lin and Tsai, suggested Junior high school learners with passive learner profile showed the lowest mean score for Mathematics performance in comparison with active learner profile [13].

To attain the objective of study, semi-structured interviews of teachers were also collected to understand the effectiveness of intervention. Several themes emerged through manifest content analysis, which are achievement, teacher's effort, teacher strategies, time management, learner's engagement, motivation and relationship with stakeholders. Teachers mentioned that learning outcome is an important aspect which were enhanced when learning characteristics were addressed using LPS, for example, Urdu Language teacher shared that '[… Because it is important for teacher that students perform better in exams…. it helped improve grades which is concern of teacher, parents… they stayed engaged in class, and were more attentive, so their results have improved…]. Literature supports this as well that students with high engagement profiles are associated with the best mean value of academic achievement [13].

Mathematics teacher also shared that LPS makes it easy to understand learners and help them at an early stage**,** she said: 'It almost takes months to understand a class interests, their behavior, their strengths and weaknesses. This may be the reason that first results of students are usually not good because teachers do not know them well. After first monthly test we get to know learner a bit e.g., a student that answer in class but unable to work in written class or otherwise…. LPS will help teacher know learners from the first lecture, plan lessons with respect to their needs then student's results will not suffer…Students enjoyed the project I gave them with respect to their interests and performed quite well…'. Inguva et al. also state that diagnosis of learning attribute using learner profile makes it easier to know factors required for successful pedagogical approach [62]. Similarly, Rawat and Dwivedi agrees that when learner profiling is done to provide students centered educational experience, it leads to positive learning outcome [50].

Surprisingly, teachers also mentioned, LPS reduced their workload, it reduced the time required to do their task and helped a lot in planning instructions with respect to learner's needs. Urdu teacher said '… I usually teach traditionally when I have limited time to complete course, but website helped me to know my students better, I can quickly integrate several strategies in one lesson…Because of motivational and style profile, it was very easy to assign roles to students for project on topic pollution… I get to know what kind of technology is available at their home, so I made a group for projects accordingly…LPS had several strategies options given with respect to learner's type… I found strategies helpful while lesson planning…It was easy to make results reports where I access learner's profile and was able to access the information to inform parents…'. Literature also relates the workload with a satisfaction level of teachers [63]. Another study used semantics web in education and used software agents to help teachers to distribute their workload by performing their tasks and reported satisfaction [64]. Teachers also mentioned that LPS helped in providing a clear picture about their students to parents as expressed by Mathematics teacher '[…Parents need a clear picture. I usually discussed about each student collaboratively in staffroom to understand learner characteristics and then write comments regarding learning behaviors, strengths and weakness in report cards…]'. The aspect of engagement and motivation surfaced various times in the interview with both teachers. Motivation was expressed in regard to students using the conceptual knowledge in daily life and connecting information to the prior knowledge. Teachers described that when learner's interests were addresses their level of enjoyment, attention enhanced a great deal as described by Mathematics Teacher..'I grouped learners with respect to their help seeking, interests, technology preference profile to do an activity on Edmodo… students were very happy to work with their friends and there were no complaints about home assignment… a parent told me that his son enjoyed his homework and did it all by himself…mathematics required more practiced and revision at home, I noticed that student started to practice more at home once their personal preferences were tackled in class… they did not find their work as burden and it helped improve their progress…'. A qualitative case study on middle school students was matched with these findings that students are more motivated to learn on their own when they feel cared using personalized learning approach [24].

Urdu Teacher also mentioned '…It is usually difficult to keep boys engaged in class specially when content is revised, I motivated students by providing them prompt feedback and positive reinforcement as suggested for extrinsic learner in website…'. The literature supports this aspect of the educational experience. [24] suggested that meeting the needs of middle school learner promotes the sense of enjoyment, engagement, and motivation in learning.

Urdu teacher stated '…I valued the use of conceptual knowledge in daily life, I found Pashto speaking students used more Urdu vocabulary with their friends that they learnt in class.' Hulme et al. study also agreed that language capabilities are crucial not only for social interaction but also for better learning process [25].

Harris and Goodall [65] emphasizes on parent's role in learner's achievements but stated that parents are often difficult to reach, but in present study, Language teacher explained '… I used contact information when I observed a student who was continuously disengaged in the class… She further explained '… I planned activities using website … it was very helpful for my teaching'. Hulme et al. suggested in the recent study that use of technology and language intervention enhances the reading comprehension [25]. An interesting aspect of student teacher, parent-teacher relationship also emerged in the in interviews responses. Teachers explained that when in limited class time, they used their motivational and interest profile and each learner felt personally cherished. This had very positive impact on student's rapport with teacher. These findings are aligned with Ellerbock and Kiefer, who states that enhanced interest in learning leads to positive teacher students' relationship [24].

Math teacher stated: '…I have student information in chunks meaning an unorganized manner… I usually discussed about each student collaboratively in staffroom to understand learner characteristics and then write comments regarding learning behaviors, strengths and weaknesses in report cards…LPS helped know learners better and provide comprehensive report to parent to satisfy them in parent teacher meeting…' This is also suggested by the Harris and Goodall that involvement of parents and understanding their children's learning progress helps improve academic performance [65]. According to Yazdani et al. literature extensively focuses on positive impact on learning experiences of students whose parents and teachers have good relationship and timely involvement of parents in teaching and learning experience [66].

Additionally, Mathematics teacher shared her concerned regarding use of LPS that it required internet availability and power, which is sometimes unavailable by saying'if I have to use the LPS to provide information to concerned parents or administration in a short notice and internet is not available I would not be able to use it… Urdu teacher also mentioned '[…it would be better if I could access the student information off-line somehow, or able to print it…]'.

An important aspect of using LPS was mentioned when teachers shared that students should not know about their learning styles at secondary level otherwise, they would restrict themselves of learning styles. This concern was supported by the reviewed literature, which suggests that the optimal teaching style is a well-adjusted one, in which the pedagogical approach caters to all learning styles. Teachers need to teach in a way so learners are forced to learn through other learning styles as well [34, 44].

Although the results of the present study are promising, but there are several limitations that needs to be taken in account before applying it to other research settings. The time period of intervention was only 8 weeks. Long term retention of knowledge many have been affected as pre-test and post-test were carried out within this time period, thus time period of the study needs to be extended. This may also help understand better perception of teachers towards the use of LPS for lesson planning. Moreover, the present study only validated the Student Survey built-in web-based learning profile system for the secondary grades. The future study can validate the instrument for elementary and post-secondary level. Thus, elementary and post-secondary teachers and students can also get benefits of web-based learning profile system. Additionally, teachers showed their concerns related the internet available for the use of LPS. For further study, LPS can be improved so that it allows teachers to access information off-line and then teachers' perception of issues regarding LPS can be studied. Factors such as limited period of intervention, limited teaching time, mixed ability student and variability between the lesson implementation of same teacher may also influence [67]. Furthermore, in qualitative data, several aspects of learner profiling were indicated by teachers such as engagement, the motivation for self-learning, stakeholder's relationship, influence on teacher's time management and effort. Future studies can focus on the aforementioned aspects and use a qualitative approach to understand the impact of all these aspects with respect to other stakeholders such as school heads, parents and students. In the present study, a purposive sampling method was used because it enables to squeeze a lot of information out of the collected data and is extremely time and cost-effective method. However, probability sampling method needs to be used in future studies to ensure significant representativeness of the larger population of interests.

7.5 Conclusions

The purpose of the study was to develop and evaluate a computer-based platform i.e., Learner Profile System, that provides comprehensive and concise learner profile information to the teachers so that they understand learner's characteristics. This will assist the teacher in understanding their learner's individual requirements for learning, which further aid them in student-centric instructions. The impact of instructional design based on learning profile is then mapped with learner's achievement. Teachers' perception of the use of LPS for the instructional designing was also acquired through a semi-structured interview, which aided this study in understanding the impact of LPS for lesson planning and to improve the LPS system in future.

The findings of the study showed that LPS is a useful tool to develop learner profile for instructional designing. The results showed that there is a potential for

LPS to be beneficial for mathematics and language teaching at the secondary level. By using the web-based learning profile system, it will improve the effectiveness of learning experience and it would lead to quality oriented educational experience. The adoption of LPS for lesson planning can make personalized learning possible in schools. The student will be able to enjoy their learning experience, engagement, improved learning outcomes and lifelong learning. The adoption of LPS for instructional strategies will also lead to job satisfaction for the teachers. It will also be helpful for teachers to develop an in-depth report of student learning characteristics and performance to inform school heads and parents.

References

1. A. Rehmani, Teacher education in Pakistan with particular reference to teachers' conceptions of teaching. (2006)
2. M. Fullan, *Stratosphere*. (Pearson, 2013)
3. C.A. Tomlinson, How to differentiate instruction in mixed-ability classrooms? ASCD (2001)
4. W. Powell, O. Kusuma-Powell, How to teach now: five keys to personalized learning in the global classroom. ASCD (2011)
5. C. Walkington, M.L. Bernacki, Appraising research on personalized learning: definitions, theoretical alignment, advancements, and future directions. (2020)
6. V. Frunză, C. Petre, Obstacles in learning's differentiation and individualization on primary school. Procedia Soc. Behav. Sci. **180**, 573–579 (2015)
7. M. Chamberlin, R. Powers, The promise of differentiated instruction for enhancing the mathematical understandings of college students. Teach. Math. Appl. Int. J. IMA **29**(3), 113–139 (2010)
8. S. Valiandes, Evaluating the impact of differentiated instruction on literacy and reading in mixed ability classrooms: quality and equity dimensions of education effectiveness. Stud. Educ. Eval. **45**, 17–26 (2015)
9. P. Alavinia, S. Farhady, Using differentiated instruction to teach vocabulary in mixed ability classes with a focus on multiple intelligences and learning styles. Int. J. Appl. **2**(4), 72–79 (2012)
10. M. Aliakbari, J.K. Haghighi, On the effectiveness of differentiated instruction in the enhancement of Iranian learners reading comprehension in separate gender education. Proc. Soc. Behav. Sci. **98**, 182–189 (2014)
11. K. Park, H. Ji, H. Lim, Development of a learner profiling system using multidimensional characteristics analysis. Math. Probl. Eng. 2015
12. M.W. Smith, J.D. Wilhelm, Reading don't fix no chevys: literacy in the lives of young men. (Heinemann, 361 Hanover Street, Portsmouth, NH 03801–3912, 2002)
13. Y.L. Wang, J.C. Liang, C.Y. Lin, C.C. Tsai, Identifying Taiwanese junior-high school students' mathematics learning profiles and their roles in mathematics learning self-efficacy and academic performance. Learn. Individ. Differ. **54**, 92–101 (2017)
14. P. Den Brok, S. Telli, J. Cakiroglu, R. Taconis, C. Tekkaya, Learning environment profiles of Turkish secondary biology classrooms. Learn. Environ. Res. **13**(3), 187–204 (2010)
15. P. Lalos, S. Retalis, Y. Psaromiligkos, Creating personalised quizzes both to the learner and to the access device characteristics: the Case of CosyQTI. in *3rd International Workshop on Authoring of Adaptive and Adaptable Educational Hypermedia (A3EH)* (2005)
16. F. Lazarinis, A service-oriented Web application for learner knowledge representation, management and sharing conforming to IMS LIP. Educ. Inf. Technol. **19**(2), 327–344 (2014)

17. T. Ramandalahy, P. Vidal, J. Broisin, Opening learner profiles across heterogeneous applications, in *ICALT 2009. Ninth IEEE International Conference on IEEE Advanced Learning Technologies.* (2009), pp. 504–508
18. R.M. Felder, R. Brent, Understanding student differences. J. Eng. Educ. **94**(1), 57–72 (2005)
19. M. Baeten, E. Kyndt, K. Struyven, F. Dochy, Using student-centred learning environments to stimulate deep approaches to learning: factors encouraging or discouraging their effectiveness. Educ. Res. Rev. **5**(3), 243–260 (2010)
20. J. Jerrard, What does "quality" look like for post-2015 education provision in low-income countries? An exploration of stakeholders' perspectives of school benefits in village LEAP schools, rural Sindh, Pakistan. Int. J. Educ. Dev. **46**, 82–93 (2016)
21. J. Decristan, B. Fauth, M. Kunter, G. Büttner, E. Klieme, The interplay between class heterogeneity and teaching quality in primary school. Int. J. Educ. Res. **86**, 109–121 (2017)
22. M. Spratt, How good are we at knowing what learners like? System **27**(2), 141–155 (1999)
23. A.O. Awofala, A.O. Lawani, Increasing mathematics achievement of senior secondary school students through differentiated instruction. J. Educ. Sci. **4**(1), 1–19 (2020)
24. C.R. Ellerbock, S.M. Kiefer, Fostering an adolescent-centered community responsive to student needs: lessons learned and suggestions for middle level educators. Clear. House J. Educ. Strat. Issues Ideas **87**(6), 229–235 (2014)
25. C. Hulme, M.J. Snowling, G. West, A. Lervåg, M. Melby-Lervåg, Children's language skills can be improved: lessons from psychological science for educational policy. Curr. Dir. Psychol. Sci. **29**(4), 372–377 (2020)
26. N.B. Ishak, M.M. Awang, The relationship of student learning styles and achievement in history subject. Int. J. Soc. Sci. Human. Invent. **4**(3), 3372–3377 (2017)
27. S. Damrongpanit, A. Reungtragul, Matching of learning styles and teaching styles: advantage and disadvantage on ninth-grade students' academic achievements. Educ. Res. Rev. **8**(20), 1937–1947 (2013)
28. M.Z. Ghani, R.A. Wahab, W.S.M. Zain, Dominance learning styles on ADHD student learning behaviors in secondary school. Glob. J. Interdiscipl. Soc. Sci. **3**(3), 133–139 (2014)
29. T.G. Lynch, N.N. Woelfl, D.J. Steele, C.S. Hanssen, Learning style influences student examination performance. Am. J. Surg. **176**(1), 62–66 (1998)
30. M.S. Zywno, Instructional technology, learning styles and academic achievement. Age **7**(1) (2002)
31. T.F. Hawk, A.J. Shah, Using learning style instruments to enhance student learning. Decis. Sci. J. Innov. Educ. **5**(1), 1–19 (2007)
32. S. Avsec, A. Szewczyk-Zakrzewska, Predicting academic success and technological literacy in secondary education: a learning styles perspective. Int. J. Technol. Des. Educ. **27**(2), 233–250 (2017)
33. P.M. Newton, M. Miah, Evidence-based higher education–is the learning styles 'myth' important? Front. Psychol. **8**, 444 (2017)
34. R.M. Felder, J. Spurlin, Applications, reliability and validity of the index of learning styles. Int. J. Eng. Educ. **21**(1), 103–112 (2005)
35. C.C. Hosford, W.A. Siders, Felder-Soloman's index of learning styles: Internal consistency, temporal stability, and factor structure. Teach. Learn. Med. **22**(4), 298–303 (2010)
36. T.A. Litzinger, S.H. Lee, J.C. Wise, R.M. Felder, A psychometric study of the index of learning styles©. J. Eng. Educ. **96**(4), 309–319 (2007)
37. J. Wang, T. Mendori, A study of the reliability and validity of felder-soloman index of learning styles in mandarin version, in *2015 IIAI 4th International Congress on Advanced Applied Informatics (IIAI-AAI)*, (2015), pp. 370–373
38. F. Vizeshfar, C. Torabizadeh, The effect of teaching based on dominant learning style on nursing students' academic achievement. Nurse Educ. Pract. **28**, 103–108 (2018)
39. C. Manolis, D.J. Burns, R. Assudani, R. Chinta, Assessing experiential learning styles: a methodological reconstruction and validation of the Kolb Learning Style Inventory. Learn. Individ. Differ. **23**, 44–52 (2013)

40. J.L. Ross, M.T. Drysdale, R.A. Schulz, Cognitive learning styles and academic performance in two postsecondary computer application courses. J. Res. Comput. Educ. **33**(4), 400–412 (2001)
41. T.P. O'Brien, Construct validation of the gregorc style delineator: an application of LISREL 7. Educ. Psychol. Measur. **50**(3), 631–636 (1990)
42. T.G. Reio Jr., A.K. Wiswell, An examination of the factor structure and construct validity of the gregorc style delineator. Educ. Psychol. Measur. **66**(3), 489–501 (2006)
43. F. Coffield, D. Moseley, E. Hall, K. Ecclestone, Learning styles and pedagogy in post-16 learning: a systematic and critical review. (2004)
44. N. Fang, M.F. bin Daud, S.A. Al Haddad, K. Mohd-Yusof, A quantitative investigation of learning styles, motivation and learning strategies for undergraduate engineering students. Global J. Eng. Educ. 19(1) (2017)
45. J.L. Meece, P. Herman, B.L. McCombs, Relations of learner-centered teaching practices to adolescents' achievement goals. Int. J. Educ. Res. **39**(4–5), 457–475 (2003)
46. C.A. Wolters, M.B. Benzon, Assessing and predicting college students' use of strategies for the self-regulation of motivation. J. Exp. Educ. **81**(2), 199–221 (2013)
47. A. El-Adl, H. Alkharusi, Relationships between self-regulated learning strategies, learning motivation and mathematics achievement. Cypriot J. Educ. Sci. **15**(1), 104–111 (2020)
48. J.L. Meece, E.M. Anderman, L.H. Anderman, Classroom goal structure, student motivation, and academic achievement. Annu. Rev. Psychol. **57**, 487–503 (2006)
49. B.L. Ng, W.C. Liu, J.C. Wang, Student motivation and learning in mathematics and science: a cluster analysis. Int. J. Sci. Math. Educ. **14**(7), 1359–1376 (2016)
50. B. Rawat, S.K. Dwivedi, Discovering learners' characteristics through cluster analysis for recommendation of courses in E-learning environment. Int. J. Inform. Commun. Technol. Educ. (IJICTE) **15**(1), 42–66 (2019)
51. B.A. Soloman, R.M. Felder, Index of learning styles questionnaire. NC State University (2005). http://www.engr.ncsu.edu/learningstyles/ilsweb.html. Accessed 14 May 2010
52. P.R. Pintrich, A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ). (1991)
53. L.R. Gay, G.E. Mills, P.W. Airasian, *Educational research: competencies for analysis and applications, student*, value edn. (Merrill, Pearson, NJ, 2012)
54. J. Hair, R. Anderson, R.L. Tatham, W.C. Black, *Multivariate data analysis*, 4th edn. (Prentice-Hall In, New jersey, 1995)
55. A. Shah, Teaching of urdu: problems and prospects, in *International Multilingual Conference Ethiraj Collage for women Chennai*, (Ethiraj Collage for Women, Chennai, 2016)
56. X. Ma, J. Xu, The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. J. Adolesc. **27**(2), 165–179 (2004)
57. E. Zakaria, N.M. Nordin, The effects of mathematics anxiety on matriculation students as related to motivation and achievement. Eurasia J. Math. Sci. Technol. Educ. **4**(1) (2008)
58. N. Berger, E. Mackenzie, K. Holmes, Positive attitudes towards mathematics and science are mutually beneficial for student achievement: a latent profile analysis of TIMSS 2015. Austr. Educ. Res. 1–36 (2020)
59. M. Gall, W. Borg, J. Gall, *Educational research: an introduction*, 6th edn. (Longman, White Plains, NY, 1996)
60. J.W. Creswell, *Educational research: planning, conducting, and evaluating quantitative* (Prentice Hall, Upper Saddle River, NJ, 2002), pp. 146–166
61. T.H. Eysink, M. Hulsbeek, H. Gijlers, Supporting primary school teachers in differentiating in the regular classroom. Teach. Teach. Educ. **66**, 107–116 (2017)
62. M. Inguva, V. Tuzlukova, P. Sancheti, Foundation program english language learner profile: a case study in Oman. J. Lang. Teach. Res. **10**(6), 1251–1256 (2019)
63. M. Smith, S. Bourke, Teacher stress: Examining a model based on context, workload, and satisfaction. Teach. Teach. Educ. **8**(1), 31–46 (1992)
64. R. Koper, Use of the semantic web to solve some basic problems in education: increase flexible, distributed lifelong learning; decrease teacher's workload. J. Interact. Media Educ. **2004**(1), 2004

65. A. Harris, J. Goodall, Do parents know they matter? Engaging all parents in learning. Educ. Res. **50**(3), 277–289 (2008)
66. N. Yazdani, K.L. Siedlecki, Z. Cao, H. Cham, Longitudinal impact of sociocultural factors and parent beliefs on parent-teacher relationship strength. Element. Schl. J. **121**(1), 1–33 (2020)
67. J.M. Faber, C.A. Glas, A.J. Visscher, Differentiated instruction in a data-based decision-making context. Sch. Eff. Sch. Improv. **29**(1), 43–63 (2018)
68. J.M. Morse, Pragmatic threads in mixed methods research design, in *Handbook of Mixed Methods in Social and Behavioral Research*, eds. by A. Tashakkori, C. Teddlie. (Sage, Thousand Oaks, CA, 2003), pp.189–208
69. W.Q. Oga-Baldwin, L.K. Fryer, Profiles of language learning motivation: are new and own languages different? Learn. Indiv. Differ. **79**, 101852 (2020)
70. NEMIS, *Pakistan Education Statistics 2016–2017*, (2018)
71. J. Pallant, *SPSS survival manual*. (McGraw-Hill Education, UK, 2013)

Chapter 8
Towards an Understanding of Student Digital Ecosystems for Education

Peter Ilic

Abstract Today, it is still unclear to what degree and in what ways students have embraced information and communication technologies for educational purposes. For this reason, curriculum designers remain uncertain what the impact these technologies are having in the modern classroom. At the same time, educators are faced with a diverse array of available devices, which students seem to effortlessly move between. These shifting and blurred boundaries that determine device use have added to the already complex blending of traditional and nontraditional learning environments. All of this creates a significant challenge to those who recognize the inherent positive affordances offered by today's technologies but are unsure of how they can be incorporated into the curriculum. The goal of this chapter is to shed light on this issue and take an initial step towards mapping students' digital ecosystems to enable course design that better fits student learning expectations. Meaningful contextualization of technologies and learning environments requires a clear "map" of the learners' current technological adoption and the learners' perceived usefulness of those technologies to specific learning contexts. In this chapter, methods were employed to obtain a better understanding of the participants' degree of technological adoption and practice in relation to collaborative educational activities. Insight into the structure of Japanese university students' digital ecosystems were developed by first capturing participant activity in log data. Then Kernel-Based Principal Component Analysis (KPCA) was applied to data on read and post activities over one academic year. There were several key findings that may inform curriculum designers. First, the frequency of read access relative to post access fluctuated significantly after the first few activities. Second, there was a consistent decrease in all online activity over the entire academic year. Third, the number of read accesses was always greater than post assesses over all the activities. Fourth, and of particular interest, students appeared to favor mobile and non-mobile devices at different times during the activities, which suggests they are selectively utilizing different affordances. If this is the case, it would be an insight into how they are shifting

P. Ilic (✉)
Center for Language Research, School of Computer Science and Engineering, University of Aizu, Aizu-Wakamatsu City, Fukushima 965-8580, Japan
e-mail: pilic@u-aizu.ac.jp

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_8

between device types depending on the context and purpose. The overall results, as well as implications for education, were discussed, along with suggestions for future research.

Keywords Digital ecosystem · Collaborative learning · EFL · m-learning · KPCA

8.1 Introduction

Leaders in higher education are facing growing skepticism of the value of traditional education systems and calls for greater accountability when these systems do not appear to achieve success. In this challenging time, it is imperative that educational institutions create strategic plans that ensure the best outcomes for students and communities. Efficiently utilizing the affordances offered by today's information and communication technologies (ICT) brings educators closer to this goal but will require a clear understanding of what affordances students perceive in these devices and how they move information effortlessly between them.

Today, it is still unclear to what degree and in what ways students have embraced ICT for educational purposes. For this reason, curriculum designers remain uncertain of the impact these technologies are having in the modern classroom. At the same time, educators are faced with a diverse array of devices available to students, which they seem to effortlessly multitask and move between throughout the day. These shifting and blurred boundaries that determine device use have added to the already complex blending of traditional and nontraditional learning environments. All of this creates a significant challenge to those who recognize the inherent positive affordances offered by today's technologies but are unsure of how they can be incorporated into lessons. For example, one affordance of ICT for education is the opportunity to provide personalized learning. If educators can better understand an individual's digital learning environment, this information can inform the development of personalized learning.

As digital natives, today's university students make use of varied devices, digital tools, and e-resources for learning while combining different subject learning, communication, entertainment, and personal interests, forming their personalized learning approaches. While this study was focused on a specific group of Japanese participants at a university in Japan, this is seen as a first step towards a deeper understanding student digital ecosystem generally. So, the goal of this chapter is to shed light on these areas and take an initial step towards mapping students' digital ecosystems to enable course design that better fits student learning expectations. Meaningful contextualization of technologies and learning environments requires a clear "map" of the learners' current technological adoption and the learners' perceived usefulness of those technologies to specific learning contexts. In this chapter, methods were employed to obtain a better understanding of the participants' degree of technological adoption and practice in relation to collaborative educational activities. Insight into the structure of the students' digital ecosystem was developed by first capturing participant activity in log data. Kernel-Based Principal Component Analysis (KPCA) was applied to data on read and post activities over one academic year. There were several key findings that may inform curriculum designers. First, the frequency of read access relative to post access fluctuated significantly after the first few activities. Second, there was a consistent decrease in all online activity over the entire academic year. Third, the number of read accesses was always greater than post assesses over all the activities. Fourth, and of particular interest, students appeared to favor mobile and non-mobile devices at different times during the activities, which suggests they are selectively utilizing different affordances. If this is the case, it would be an insight into how they are shifting between device types depending on the context and purpose.

8.2 Literature Review

With the invention of new technologies and then the steady merging of these into single devices, such as smartphones, new multi-functional devices are being released annually. While these devices are similar, the latest models may offer new educational affordances not available in previous iterations. There are at least two ways to exploit these affordances. The first is to rely on educators to identify well-known ones and incorporate them based on best practices. For example, cameras in smartphones can act as data collection devices and send that data in the form of pictures to a learning management system to be used for educational activities. The second way relies on the students, as digital natives, to intuitively identify affordances that they feel support their learning. It is this second approach that this research is focused on.

One affordance of ICT for education is the opportunity to provide personalized learning opportunities. If educators can better understand an individual's learning environment, this information can inform the development of personalized learning. University students make use of varied e-resources and tools for learning while combining different subject learning, communication, entertainment, and personal interests, forming their personalized learning approaches [1]. One motivation for this research is to enable course design that better fits student expectations instead of forcing them to adopt tech they do not use in their personal lives. For example, banning smartphones from the classroom inhibits the perception that education is something students can integrate directly into their lives [2] when in reality, the smartphone can help to bridge the gap [3] between school and life outside of school by encouraging learning anywhere and anytime [4, 5]. It has been suggested [6] that using mobile technologies should be of benefit to revising our views of pedagogy, making it much more responsive to students' needs in education. It is this responsive pedagogy approach that will benefit from this mapping of the learners' digital ecosystems. Taking the smartphone as an example, the affordances for learning are ultimately dependent on the views and perceptions of learners. So how learners perceive the possible uses of these digital tools in the context of learning may be very different from those of the educator [7].

Turkle [8] writes about how the new digital technologies of communication provided by devices such as a mobile phone offer the feeling of companionship without the demands of friendship. In a review of the literature, Naismith et al. [9] suggest six mobile learning activity categories. The first is behavioural activities such as delivering content, texting, and feedback response by the learners. Next, there are constructive activities in which learners create knowledge, ideas, or concepts, such as creating and sharing media. Then there are situated learning activities, which take place in natural and authentic contexts, such as providing museum visitors with access to mobile devices to access information on the exhibits. Collaborative activities promote social interaction and communication like texting, e-mail, posting to websites, and synchronous chat. Informal, contextual, lifelong learning activities occur in an individual's everyday life like mobile applications for language learning, bird call identification, and healthcare information. Finally, there is the coordination of learning and teaching, such as mobile access to resources, schedules, assignments, data, and reports.

However, the increased agency that comes with these technologies can create some conflict. The increase in the autonomy of communication means it is more difficult to avoid responsibility, such as responding to a message. In a Finnish study, it was found that teenagers usually expected answers to their text messages within 15–30 min, or else an excuse was expected [10]. Context is central to mobile learning as it is continually created by people in interaction with other people, with their surroundings, and with everyday tools [11]. Learning takes place in meaningful surroundings that are likely outside the classroom and in the student's surroundings or environment at a time appropriate for them [12]. This change in surroundings means that learning and information seeking activities extend into the natural, authentic, and contextual situations of an individual's personal life [13].

Computing technologies have been used to support collaboration for achieving varied learning goals, such as language learning [14, 15]. Asynchronous text-based discussions present several advantages as compared to synchronous discussions [16]: students get more opportunities to interact with each other, and students have more time to reflect, think, and search for extra information before contributing to the discussion. Learners should be engaged in exploration and inquiry [17], which is participatory and embedded in a community of practice [18]. Building a sense of community among students is a challenge, but smartphones increase possibilities to engage in informal learning not tied to a particular physical location like a library, computer lab, or classroom [9, 19].

8.3 Methodology

8.3.1 Participants

The study design was a case study adopted for one academic year to gain a deeper understanding of the processes and outcomes of completing collaborative learning activities by Japanese university undergraduate English as a Foreign Language students. Four case study groups were formed with between five to eight members. All activities and environmental factors remained constant across all the case study groups, and participation in the study was voluntary. Group 1 contained five girls and two boys, group 2 contained eight girls, group 3 contained six girls, and group 4 contained six girls. It was clarified to them that there was no restriction on the type of device allowed to access the course learning management system. The data collection, content, and procedures for each group were identical, and all the interviews took place in the same location with a single interviewer and were of approximately equal length. Although the number of participants was relatively small, the longitudinal design increases the reliability and validity of the findings. The case study is meant to be exploratory in nature to identify patterns that may be researched further in a future study. The disproportionate number of female participants was unavoidable since the university student body was mostly female. While this will undoubtably add some bias to the findings, the activities did not have any overt gender related issues that were predicted to affect the results.

8.3.2 Procedure

The collaborative activities used in this study were in the form of group collaborative learning activities within weekly online modules. These activities consisted of homework questions related to translation issues that are relevant when moving between the Japanese and English languages. These were designed to make the students aware of specific known difficulties in language translation and to encourage authentic use of the target language. One example is the difficulty of translating plurality from English to Japanese. This would serve the dual goal of content knowledge development and target language practice. These activities required collaboration to complete so that they would stimulate some discussion in the target language. For example, the first homework question was, “Find and write a single English word that cannot be translated into a single Japanese word.” This homework required the students to find at least three examples of such words and upload the translation example with an explanation to the course discussion board. This way, the students must understand the translation issue in focus for that week, identify an authentic example from their day, and explain their reasoning in the target language. Frequently they would find examples in authentic contexts, such as on their way to and from school, then record them and upload them through a smartphone. The following week, the results of the online activities would be discussed in class. The homework activities were all collaborative in that they required the individual members of each group to find and upload their answers to the class website and then to decide upon the best answer from their list of group answers. The members in each group communicated through an online forum by posting text messages either with or without supporting media such as images. The workflow of each homework was identical and consisted of collecting or posting initial answers to the homework, commenting at least three times on other group members' posts, agreeing on one best group answer, and posting it to the learning management system (LMS).

There was a total of 16 collaborative activities that the students were required to complete. The procedure for completing these activities can be categorized into two types: supply an answer based on material provided or on material collected. The following are summaries of the 16 assignments.

1. Write a single English word that cannot be translated to a single Japanese word.
2. Write a single Japanese word that cannot be translated to a single English word.
3. Find an interesting, funny, or unusual collocation.
4. Find an English idiom which you feel would be difficult to translate into Japanese.
5. Find a Japanese idiom which you feel would be difficult to translate into English.
6. Choose a notional category that is grammatical in one language but lexical in another.
7. Give examples of these pronoun forms, explain, using English, how they differ.
8. Write one sentence in Japanese with a theme that is unmarked.
9. Identify parts of a given passage.
10. Translate a passage from English to Japanese.
11. Find one example of substitution and one of ellipsis that you see as you travel around Tokyo.
12. Find one Japanese sentence example from around Tokyo for each of the 5 conjunction types.
13. Find one Japanese sentence example from around Tokyo for each of the four collocation types.
14. Find one Japanese sentence example for coherence.
15. Find one Japanese example from around Tokyo for implicature.
16. Find one Japanese example from around Tokyo for theme, cohesion, and pragmatics.

Activities 1, 2, 3, 4, 5, 11, 12, 13, 14, 15, and 16 are material collection activities, which required the students to collect examples and then discuss the answer. It was hoped that the students could utilize the data collection affordances of their mobile devices to capture examples and upload them to the course website for further discussion. The remaining activities, 6, 7, 8, 9, and 10, required the students to discuss material that was provided by the instructor.

8.3.3 Research Design

As this was an exploratory analysis designed to lead into a larger study, it was decided that a longitudinal case study design would provide the best results while causing the least disruption to the participants. The activities were hosted on the Moodle LMS, and the log data comprised the principal source of data used in the analysis. The log data includes access times by hour and day, as well as online activity inside the LMS, such as reading and posting messages. Since the activities required collaboration and the eventual agreement on one group answer, reading and posting information commonly involved following, reading, the answers posted by other group members, and then replying to them with their own posts. This data was extracted from the LMS log data and separated for each student and group to identify each student's online activity and device used throughout the study period. This data was then analyzed using Radial-based Kernel principal component analysis (KPCA) [20]. There are several kernel functions and radial based is a well-known kernel function which has high accuracy. Several functions were tried but the radial based function provided better performance in terms of explanatory power.

KPCA is a technique for non-linear dimensional reduction where objects are mapped to a higher dimensional space before being reduced to a space lower than the observational dimension. The data consists of eight dimensions (variables) that include computer and mobile access for each of the four groups. There are 32 objects formed from the read and post count for each of the 16 homework assignments. KPCA maps the original eight dimensions of data to a space larger than the original eight dimensions. Going larger than the original dimensions gives the inner-product between a pair of objects, not variables, and is known as the Kernel trick. Then Principal Component Analysis can be applied to this inner-product.

The data can be seen in Table 8.1 and consists of the read and post activity counts of the four groups over the 16 homework assignments separated by mobile and non-mobile devices. The data was only divided into these two general categories based on the data to simplify the KPCA procedure. Here mobile is defined as any mobile phone, and non-mobile included desktop or laptop computers. This is not the ideal method of data categorization, but it did allow for the analysis. In the future, this data will be further divided to identify devices at a more granular level.

8.4 Results and Discussion

This section includes a description and discussion of the results of the KPCA for read and post, access for 16 homework activities over one academic year. Table 8.1 includes the results from the homework read and post access counts by both computer and mobile phone. The four case study groups form the columns, with each group subdivided into computer and mobile phone counts. The rows represent the 16 homework assignments subdivided into read and post count. The totals of

Table 8.1 Homework (HW) read and post access counts by computer (C) and mobile (M) device for all groups (G)

Groups mobile (M) and Computer (C) Access												
			G1	G1	G2	G2	G3	G3	G4	G4		
			C	M	C	M	C	M	C	M	Tot.	Tot.
Homework Read and Post Access	HW1	Post	8	16	10	16	21	13	24	8	**116**	552
		Read	34	65	37	63	71	82	72	12	**436**	
	HW2	Post	17	11	12	20	18	8	8	1	95	**386**
		Read	27	40	17	61	51	37	47	11	**291**	
	HW3	Post	15	14	2	19	14	1	7	5	**77**	**330**
		Read	19	43	10	74	41	29	13	24	**253**	
	HW4	Post	11	11	6	IS	13	5	13	11	**88**	**375**
		Read	22	50	14	79	20	42	24	36	**287**	
	HW5	Post	7	17	9	21	14	10	7	12	**97**	**357**
		Read	21	28	8	73	31	46	14	39	**260**	
	HW6	Post	8	12	19	11	11	11	12	8	**92**	**317**
		Read	11	29	16	32	34	51	22	30	**225**	
	HW7	Post	3	19	11	21	3	13	8	8	**86**	**369**
		Read	10	67	19	42	20	63	31	31	**283**	
	HW8	Post	9	15	10	15	6	7	11	**4**	**77**	**241**
		Read	11	38	18	37	11	23	22	**4**	**164**	
	HW9	Post	4	22	15	19	13	9	3	8	**93**	**268**
		Read	9	33	30	26	18	29	6	**24**	**175**	
	HW10	Post	3	18	12	11	6	7	3	5	**65**	**188**

(continued)

Table 8.1 (continued)

Groups mobile (M) and Computer (C) Access												
		Read	5	32	7	27	13	18	7	14	**123**	
	HW11	Post	4	6	15	15	8	6	3	2	**59**	**172**
		Read	8	15	10	28	16	19	4	13	**113**	
	HWl**2**	Post	4	19	17	13	11	8	11	12	**95**	**251**
		Read	3	26	15	16	15	23	19	39	**156**	
	HW13	Post	6	20	7	6	13	9	4	9	**74**	**189**
		Read	2	30	12	10	16	23	6	16	**115**	
	HW14	Post	4	9	15	14	8	16	2	**4**	**72**	**159**
		Read	1	15	8	17	5	27	4	10	**87**	
	HWl5	Post	0	19	11	6	8	12	5	8	**69**	**175**
		Read	0	30	**5**	10	20	22	2	17	**106**	
	HW16	Post	2	1	**5**	9	10	5	8	7	**47**	**115**
		Read	1	4	9	12	16	5	5	16	**68**	
	Post tot.		**105**	**229**	**176**	**234**	**177**	**140**	**129**	**112**	**1302**	
	Read tot.		**184**	545	**235**	**607**	**398**	**539**	**298**	**336**	**3142**	
	Tot.		**289**	**774**	**411**	**841**	**575**	**679**	**427**	**448**	**4444**	
	Post percent		o 36	0 30	0.43	0 28	0 31	0 21	0 30	0 25	0.29	
	Read percent		0.64	0.70	0.57	0 72	0.69	0.79	0.70	0.75	0.71	

read, post, and overall counts are included in the right side columns and bottom rows. Read refers to the action of accessing the LMS without adding posting new information. Post is a similar activity but includes adding new information in the form of comments or examples.

8.4.1 *Access Read and Post*

Figure 8.1 includes the KPCA result of read(R) and post(P) count for all groups over all homework activities (1–16) from Table 8.1. The numbers in the plot represent the homework activity, and the letters indicate either reading or posting. The plot shows four clear clusters, which have been labeled C1 through C4. In addition to these clusters, the data points are clearly separated into post and read. The read counts are all located at the top left half of the plot except for 16R, which is in the bottom half with the posts. The post data points are all located in the right section of the plot. Using the same data as data as Figs. 8.1 and 8.2 shows a graph of the centroid of the

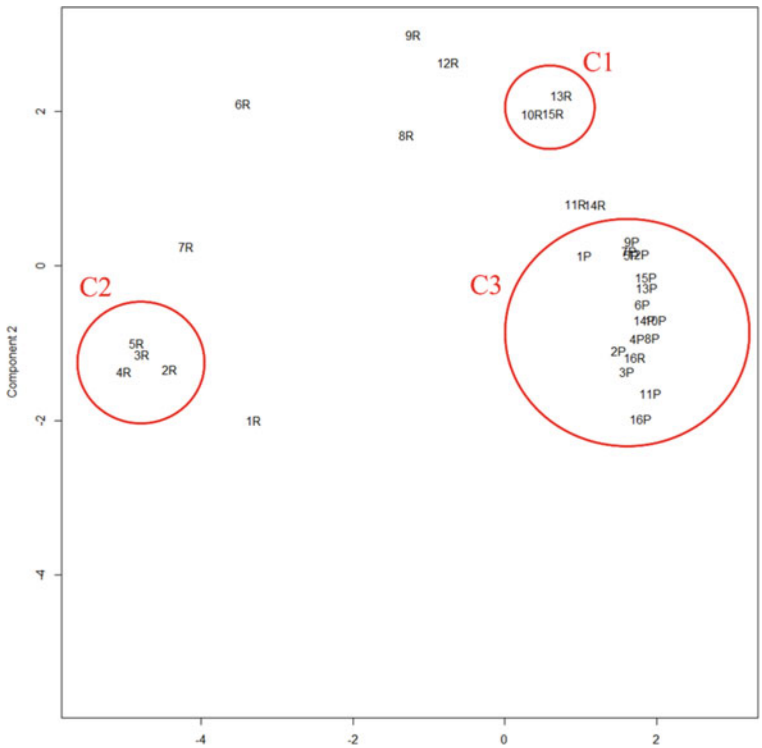


Fig. 8.1 KPCA result of Read(R) and Post(P) count for all groups over all homework activities (1–16)

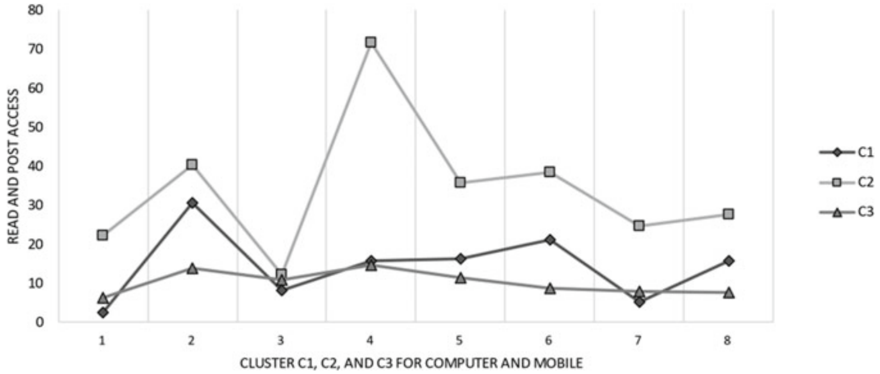


Fig. 8.2 Centroid of clusters 1 through 3 post and read counts for computer and mobile access

clusters C1 through C4 calculated from the averages of data points from each cluster.

The first principal component is interpreted as representing the frequency of access for posting messages. Component one is a negative correlation, so the further to the left of the plot in Fig. 8.1, the lower the count of student access to the website for posting. Table 8.2 includes the results from the KPCA on the data of read and post access in Table 8.1. The values represent the correlation or explanatory power of the first and second principal components. Since it is a negative correlation, the smaller the number in the table, the higher the post access count. Group 2 computer access (G2 C) has the lowest value (−0.3794), and this is supported by the data in Table 8.1, which shows that G2 C has the highest percent of post to total access (0.43) of all the groups. The interpretation of the second component is that it represents the amount of variation in access count across homework assignments. Overall, component two does not have much explanatory power. However, G1 C and G4 M are remarkable because the first value is negatively correlated, and the second is positively correlated. Column G1 C in Table 8.1 has a consistent reduction in values from homework activity one through sixteen. Alternatively, G4 M has a less consistent decline over all of the homework assignments and is positively correlated. In Table 8.2, component two can be translated as the data points near the top of the plot having less variation in post access count while lower points have a higher variation.

Using this interpretation, in Fig. 8.1, cluster C2 is on the left side and includes 2R, 3R, 4R, and 5R with 1R close by. These points represent the first five homework assignments and contain the highest post counts of all the homework assignments, as seen in Table 8.1. At the same time, they have a relatively high rate of variation, as the count values drop suddenly from homework 1 to 5. In addition, 6R and 7R have relatively high post counts and so are located on the left side of the plot. One explanation for this could be that the students learned over these first few activities that only the number of posts made by students were assessed, and the number of access times for reading was not assessed. Each student was required to make a minimum of three posts for the first stage of each homework activity. So, the students

Table 8.2 Read and post access KPCA results for principal components 1 and 2

	G1 C	**G1 M**	**G2 C**	**G2 M**	**G3 C**	**G3 M**	**G4 C**	**G4 M**
PC1	−0.7164069	−0.8093878	−0.3794	−0.9134913	−0.7198006	−0.83401906	−0.6395959	−0.7252279
PC2	−0.4230435	0.1514762	0.1015273	−0.246869	−0.2062848	0.07639891	−0.2235165	0.3173146

may have adapted to the minimum requirements of the course. This suggests that accessing both posting and reading activities may be needed to motivate students to access the site more regularly.

Cluster C1 contains three data points, 10R, 13R, and 15R, and is located on the right upper corner of the plot. These three homework assignments have unusually low post counts that are consistent relative to each other at 65, 74, and 69, respectively. The data point 16R is unusual as it is the only read count among the posts cluster C3. The post count for 16R is exceptionally low in comparison to all other post values and so is not grouped into cluster C1. The consistent decrease in overall activity leading to the lowest post count in the final homework assignment suggests that the students either gradually became less motivated or more efficient. This is an interesting question to investigate in the future. Another explanation is that these specific activities did not require as much communication as the others. Activity 10 is a straightforward translation activity that the students would be familiar with. Activities 13, 15, and 16 require them to find examples in their L1, which they would be more confident working in. If the perceived difficulty is low, this may negatively affect the amount of communication since the students would require less peer scaffolding. This would be another area for future study.

The large cluster C3 is located at the far right and contains all the post data points because the post counts for all homework assignments were all lower than the read counts. This means students accessed the site to get information, perhaps to check for updates on their group members' posts, much more often than posting information. This difference may be investigated in more detail in future research. At the same time, the points in C3 have a clear pattern of variation within the cluster, with 9P at 93 posts and 16P at 47 posts.

The centroids of each of the three clusters are represented in Fig. 8.2. The abscissa represents each of the four groups of computer and mobile access: 1 is group one computer access, and 2 is group one mobile access. The ordinate represents the average access times. Cluster C2 is clearly higher than the other clusters indicating that these data points were much more active, which supports the interpretation of a higher posting count. This is also seen in the data of Table 8.1. In Figs. 8.3 and 8.4, the centroids for computer and mobile access are represented separately. This time the abscissa has only numbers one to four representing the four groups. Here again, cluster C2 is higher than C1 or C2, as is to be expected if the interpretation used is correct, by its position on the left side of the plot in Fig. 8.1. Likewise, the lower counts for C1 and C3 fit with the interpretation of component one as representing post count. One point of interest is the clear preference for mobile devices within group three and the preference for computers in group two. Although the reason for this is not clear, it may indicate a clear preference for one device over another, irrespective of the activity type. Again, this is an interesting point of investigation in future research.

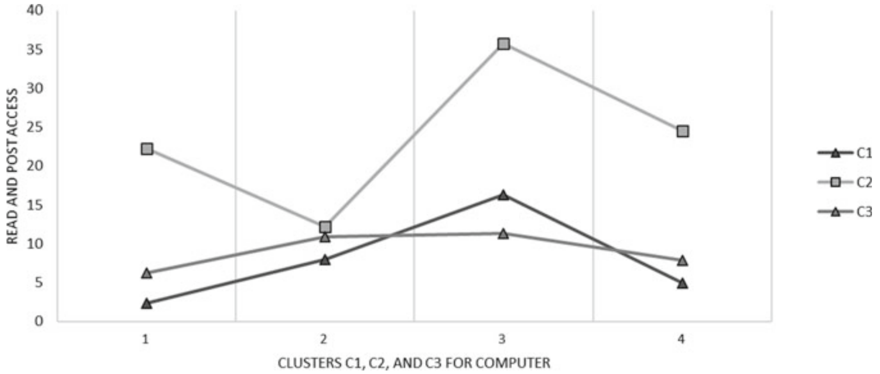


Fig. 8.3 Centroid of clusters 1 through 3 post and read counts for computer

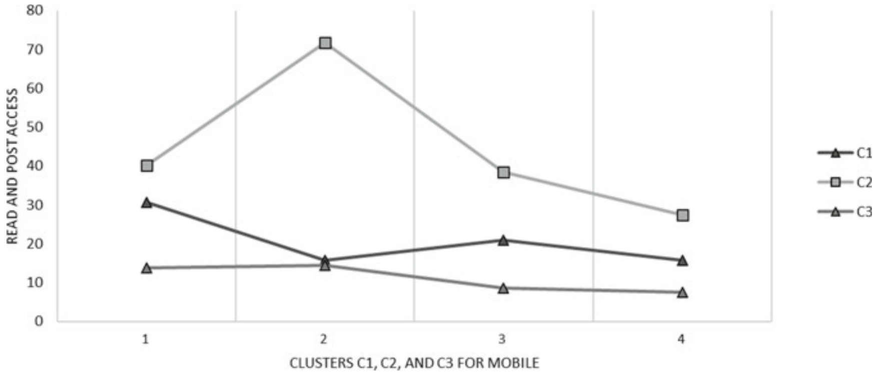


Fig. 8.4 Centroid of clusters 1 through 3 post and read counts for mobile

8.5 Conclusion

This research project was designed as an exploratory study of student behavior as they completed a series of collaborative activities over one academic year. The main goal was to gain insight into the structure and function of the students' digital ecosystem. It was hoped that, as digital natives, the students would have the inherent ability to utilize the technologies available to them in an efficient manner. As such, it was not the goal to provide specific answers to research questions but instead to identify interesting patterns in the data result through KPCA that can inform the design of future research. With this in mind, there were several interesting patterns that the KPCA highlighted, which may have been missed with a more conventional qualitative methodology.

The data on student read and post activity identified several interesting features of the students' behavior. First, there was a clear difference in read and post frequency.

Specifically, the read frequency remained stable relative to post frequency over much of the year. The read count suggests that the students, after an initial period of high activity, learned over the first few homework activities that only the number of posts made by students were assessed, and the number of access times for reading was not evaluated. Each student was required to make a minimum of three posts for the first stage of each homework activity. So, the students may have adapted to the minimum requirements of the course. This suggests that assessing both posting and reading activities may help motivate students to access the site more regularly.

Second, the consistent decrease in overall activity leading to the lowest post count in the final homework assignment indicates that the students either gradually became less motivated with the activities or more efficient at completing them. Another explanation is that these specific activities did not require as much communication as the others. If the perceived difficulty is low, this may have reduced the necessity for communication since the students would require less peer scaffolding.

The third was the dramatically greater read counts in comparison to post counts. This may be explained as students accessing the site to get information, perhaps to check for updates on their group members' posts, much more often than posting information. Presumably, reading allowed the students to consider their group members' answers before committing to upload their own.

Fourth, a point of interest is the clear preference for mobile devices within group three and the preference for computers in cluster C2. Although the reason for this is not clear, it may indicate a clear preference for one device over another, irrespective of the activity type. This could be a valuable insight into how the students are deciding to use the available technology. This is especially interesting as it is closely related to the main goal of this research and suggests they are selectively utilizing different affordances. If this is the case, it would be an insight into how they are shifting between device types depending on the context and purpose.

These findings provide the first step in visualizing, or mapping, students' digital ecosystems and lead to interesting questions to investigate in the future. However, there were limitations inherent in the design of this study. As an exploratory study, it was designed to highlight larger patterns in the collaborative behavior of the students as they used both mobile and non-mobile devices. While several interesting patterns were identified using KPCA, it was not possible to conclusively explain the causes and all ramifications within this study. These points will require several more focused studies designed to answer these specific research questions through targeted questionnaires. It is the goal of the author to work towards this in future research.

References

1. Q. Ma, A multi-case study of university students' language-learning experience mediated by mobile technologies: a socio-cultural perspective. Comput. Assist. Lang. Learn. **30**(3–4), 183–203 (2017)

2. R. Godwin-Jones, Smartphones and language learning. Lang. Learn. Technol. **21**(2), 3–17 (2017)
3. P. Ilic, The effects of mobile collaborative activities in a second language course. Int. J. Mobile Blend. Learn. (IJMBL) **7**(4), 16–37 (2015)
4. J. Byrne, R. Diem, Profiling mobile english language learners. Jalt call J. 10(1) (2014)
5. A. Leis, A. Tohei, S.D. Cooke, Smartphone-assisted language learning and autonomy, in *Handbook of Research on Integrating Technology Into Contemporary Language Learning and Teaching*. (2018), pp. 307–327
6. B. Whalley, et al., Developing active personal learning environments on smart mobile devices, in *Proceedings of the Future Technologies Conference* (Springer, 2019)
7. C. McLoughlin, M.J. Lee, The three P's of pedagogy for the networked society: personalization, participation, and productivity. Int. J. Teach. Learn. High. Educ. **20**(1), 10–27 (2008)
8. S. Turkle, Alone together: why we expect more from technology and less from each other. in Basic Books. (2012)
9. L. Naismith, et al., Literature review in mobile technologies and learning, in *FutureLab Report*. (2004)
10. E.-L. Kasesniemi, P. Rautiainen, Mobile culture of children and teenagers in Finland, in *Perpetual contact*, ed. by J.E. Katz, A.M.A., (Cambridge University Press: Cambridge, 2002), pp. 170–192
11. A. Kukulska-Hulme, et al., The genesis and development of mobile learning in Europe, in *Combining E-Learning and M-Learning: New Applications of Blended Educational Resources*, ed. by D. Parsons, Information Science Reference (an imprint of IGI Global, Hershey, PA, 2011), pp. 151–177
12. L.F. Motiwalla, Mobile learning: a framework and evaluation. Comput. Educ. **49**(3), 581–596 (2007)
13. M. Sharples, D. Corlett, O. Westmancott, The design and implementation of a mobile learning resource. Pers. Ubiquit. Comput. **6**(3), 220–234 (2002)
14. M. Warschauer, Computer-mediated collaborative learning: theory and practice. Mod. Lang. J. **81**(4), 470–481 (1997)
15. D. Nunan, Collaborative language learning and teaching. (Cambridge Univ Pr. 1992)
16. B. De Wever et al., Content analysis schemes to analyze transcripts of online asynchronous discussion groups: a review. Comput. Educ. **46**(1), 6–28 (2006)
17. J. Traxler, Defining, discussing and evaluating mobile learning: the moving finger writes and having writ. Int. Rev. Res. Open Dist. Learn. 8(2) (2007)
18. M. Kearney, et al., Viewing mobile learning from a pedagogical perspective. Res. Learn. Technol. 20 (2012)
19. J. Attewell, *Mobile technologies and learning, in a technology update and m-learning project summary* (Technology Enhanced Learning Research Centre, London, 2004)
20. B. Schölkopf, A. Smola, K.-R. Müller, Nonlinear component analysis as a Kernel Eigenvalue problem. Neural Comput. **10**(5), 1299–1319 (1998)

Chapter 9
Computational Argumentation for Supporting Learning Processes: Applications and Challenges

Carlos Chesñevar, César A. Collazos, and Ana Maguitman

Abstract This book chapter analyzes different applications and challenges of computational argumentation for modeling different aspects of learning processes. Some of the topics included are argument-based recommender systems for educational purposes; argument-based shared knowledge for computer-supported collaborative learning (CSCL) and argument-based opinion mining for eliciting students' knowledge based on information items corresponding to different topics of study. We also identify and discuss salient challenges associated with argumentation in the current state of the art. The chapter is organized to be self-contained, including an overview of the key elements in computational argumentation. Our contribution is intended to provide a reference point for researchers working on intelligent techniques for educational processes who are interested in incorporating argumentation as a metaphor for modeling intelligent decision making in Intelligent Tutoring Systems (ITS), Computer-Supported Collaborative Learning (CSCL) systems, and other related areas.

Keywords Argumentation · Intelligent tutoring systems · Computer-supported collaborative learning · Opinion mining · Recommender systems · Shared knowledge awareness · Learning systems

C. Chesñevar (✉) · A. Maguitman
Departamento de Ciencias E Ingeniería de La Computación (DCIC UNS), Instituto de Ciencias E Ingeniería de La Computación (ICIC CONICET UNS), Universidad Nacional del Sur – Campus Palihue, San Andrés, 800 - 8000 Bahía Blanca, Argentina
e-mail: cic@cs.uns.edu.ar

A. Maguitman
e-mail: agm@cs.uns.edu.ar

C. A. Collazos
Universidad del Cauca - Popayán, Popayán, Colombia
e-mail: collazos@unicauca.edu.co

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_9

9.1 Introduction

Computational argumentation is a discipline that has been gaining increasing importance and wider audiences over the last decades, mainly as a vehicle for facilitating rationally justifiable decision making when handling incomplete and potentially inconsistent information. Argumentation provides a sound model for dialectical reasoning, which underlies discussions or opinion confrontation in social networks. In Collaborative systems, argumentation is an important aspect to help problem-solving situations, considering the cognitive processes of critical information checking, argument elaboration and the taking of multiple perspectives. Argumentation systems are increasingly being considered for applications in developing software engineering tools, constituting an important component of multi-agent systems for negotiation, problem solving, shared understanding, and the fusion of data and knowledge. Such systems implement a dialectical reasoning process by determining whether a proposition follows from certain assumptions, analyzing whether some of those assumptions can be disproved by other assumptions in our premises. In this way, an argumentation system provides valuable help to analyze which assumptions from our knowledge base are giving rise to inconsistency and which assumptions are harmless.

This chapter is structured as follows. In Sect. 9.2 we summarize the main elements which characterize computational models of argument (such as argument, counter-argument, defeat, and the notion of warranted conclusion). We will introduce the basics of Defeasible Logic Programming [1], which will be used for subsequent examples. Then, in Sect. 9.3 we focus on argument-based recommender systems, a sub-area that has received particular attention in the last years. We discuss potential applications of these recommenders for educational purposes. Section 9.4 discusses an alternative approach to argumentation based on opinion mining. We show that this particular view of argumentation processes can help enhance learning processes by identifying reasons pro and con in a very intuitive way. Section 9.5 considers the notion of shared knowledge awareness in the context of argumentation. We show how multiple knowledge bases (associated with different students) can be suitably integrated for collaborative problem solving. Finally, Sect. 9.6 presents the conclusions and discusses some avenues for future research.

9.2 Argumentation in a Nutshell

Argumentation is an important aspect of human decision making. In many situations of everyday life, when faced with new information, people need to ponder its consequences, in particular when attempting to understand problems and come to a decision. Argumentation systems [1–4] are increasingly being considered for applications in developing software engineering tools, constituting an important component of multi-agent systems for negotiation, problem solving, and the fusion of data and knowledge. Such systems implement a dialectical reasoning process by determining whether a proposition follows from certain assumptions, analyzing whether some of those assumptions can be disproved by other assumptions in our premises. In this way, an argumentation system provides valuable help to analyze which assumptions from our knowledge base give rise to inconsistencies and which assumptions are harmless.

In defeasible argumentation, an argument is a tentative (defeasible) proof for reaching a conclusion. Arguments may compete, rebutting each other, so a process of argumentation is a natural result of the search for arguments. Adjudication of competing arguments must be performed, comparing arguments in order to determine what beliefs are ultimately accepted as warranted or justified. Preference among conflicting arguments is defined in terms of a preference criterion which establishes a partial order "$\preccurlyeq$"among possible arguments; thus, for two arguments A and B in conflict, it may be the case that A is strictly preferred over B ($A \succ B$), that A and B are equally preferred ($A \succcurlyeq B$ and $A \preccurlyeq B$) or that A and B are not comparable with each other. For the sake of example, let us analyze the following example about real-world knowledge on spiders. Consider the following sentences:

(1) *If something looks dead, it is usually dead;*
(2) *If something moves when touched, it is usually not dead;*
(3) *If a spider is dead, it is usually not dangerous.*
(4) *If something is a spider, it is usually dangerous.*
(5) Black widow is a spider.
(6) Black widow moves when touched.
(7) Black widow looks dead.

Sentences in italics correspond to defeasible rules (rules which are subject to possible exceptions). Statements (5), (6), and (7) correspond to facts (strict information). Note that different arguments can be constructed:

1. Argument A (based on rules 4 & fact 5): Black widow is a spider. Spiders are usually dangerous. Therefore, black widow is dangerous.
2. Argument B (based on rule 1,3 and facts 5,7): Black widow is a spider. Black widow looks dead. If something looks dead, it is usually dead. If a spider is dead, it is usually not dangerous. Therefore, Black widow is not dangerous.
3. Argument C (based on rule 2, fact 6). Black widow moves when touched. If something moves when touched, it is usually not dead. Therefore Black widow is not dead.

In this particular situation, different arguments arise that cannot be accepted simultaneously (as they reach contradictory conclusions). Note that argument B seems rationally preferable over argument A, as it is based on more specific information. As a matter of fact, specificity is commonly adopted as a syntax-based criterion among conflicting arguments, preferring those arguments which are more informed or more direct [1]. In this particular case, if we adopt specificity as a preference criterion, argument B is justified, whereas A is not (as it is defeated by B). The above situation can easily become much more complex, as an argument may be defeated by

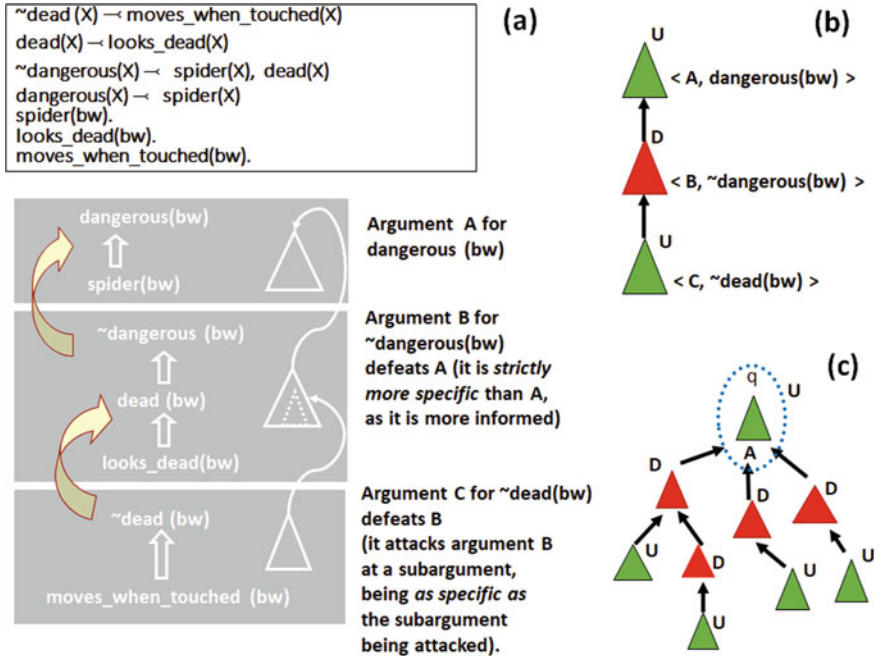


Fig. 9.1 **a** DeLP program for the spider example. **b** The original argument is deemed as "accepted". **c** The dialectical analysis might be complex, resulting in a dialectical tree with several nodes representing arguments and attack relationships among them

a second argument (a defeater), which in turn can be defeated by a third argument, reinstating the first one. As a given argument might have many defeaters, the above situation results in a tree-like structure, rooted in the first argument at issue, where every argument in a branch (except the root) defeats its parent (see Fig. 9.1c).

Defeasible Logic Programming: implementing argumentation as a programming language

Defeasible Logic Programming (DeLP) [1] is a logic-based programming language for modeling incomplete knowledge and providing argument-based inference.[1] It has been applied in different contexts, such as multi-agent reasoning [5], recommender systems [6–9], among others. As most computational argumentation systems, DeLP relies on two kinds of knowledge: *strict* and *defeasible* knowledge. Strict knowledge corresponds to the knowledge that is certain, such as *facts* about the world or mathematical truths (e.g. "all men are mortal"). The strict knowledge is *consistent*, i.e. no contradictory conclusions can be derived from it. On the other hand, defeasible knowledge corresponds to that knowledge which is *tentative*, modeled through "rules with exceptions" (*defeasible* rules) of the form **"if P then usually Q"** (e.g., "if

[1] For an in-depth treatment of DeLP and its features the reader is referred to [1].

something is a bird, it usually flies"). Such rules model our incomplete knowledge about the world, as they can have exceptions (e.g., a penguin, a dead bird, etc.). Syntactically, a special symbol (—<) is used to distinguish "defeasible" rules from logical implications (←).

Argumentation systems like DeLP allow the user to define a knowledge base involving strict and defeasible knowledge. An *argument A* for a claim *c* is basically some "tentative proof" (a derivation using a non-empty set of *defeasible* information) for concluding *c* from the knowledge base (DeLP program). Arguments must additionally satisfy the requirement of *consistency* (an argument cannot include contradictory propositions) and *minimality* (by not including repeated or unnecessary information). Conflicting arguments may emerge in DeLP: an argument *A attacks* another argument *B* whenever both of them cannot be accepted at the same time, as that would lead to contradictory conclusions. Arguments are on their turn compared with each other using a modular criterion (typically specificity), so that it can be established when an argument *defeats* another.

Note that the notion of defeat among arguments may lead to complex "cascade" situations: an argument A may be defeated by an argument B, which in turn may be defeated by an argument C, and so on. Besides, every argument involved may have on its turn more than one defeater. Argumentation systems allow us to determine when a given argument is considered as *ultimately acceptable* with respect to the knowledge we have available by means of a *dialectical analysis*, which takes the form of a tree-like structure called *dialectical tree*. The root of the tree is a given argument A supporting some claim, and children nodes for the root are those defeaters B_1, B_2, … B_k for A. The process is repeated recursively on every defeater B_i, until all possible arguments have been considered. Leaves are arguments without defeaters. Some additional restrictions apply (e.g. the same argument cannot be used twice in a path, as that would be fallacious and would lead to infinite paths).

Figure 9.1a illustrates how a DeLP program for the spider example can be formulated. Note that the symbol "~" stands for strict negation (thus, ~dead(X) means "X is not dead"). In this sample DeLP code "bw" stands for "black widow". The DeLP programming language allows to make queries such as "dangerous(bw)" (standing for "is black widow dangerous?"), which prompts the computation of an *argument* supporting the query. The argument A is found (since bw is a spider, it should be considered dangerous by default). Additionally, a defeater argument B is found which attacks A (black widow is not dangerous as it looks dead), which is on its turn defeated by a third argument C (black window moves when touched, and therefore it is not dead!). All this dialectical process is carried out automatically by the DeLP inference engine (associated arguments can also be displayed using a GUI interface). The associated dialectical analysis is shown in Fig. 9.1b. Arguments with no successful attacks are deemed as ultimately accepted (e.g. argument C). An inner argument is deemed as ultimately accepted if all its attackers are not accepted; otherwise, the inner argument is defeated. Complex situations might arise (e.g. Fig. 9.1c), which are solved by the DeLP inference engine.

9.3 Argument-Based Recommendation in Learning Environments

The Internet is one of the main sources of information and resources for students to explore or learn practically any topic. However, identifying the most useful information or resources can be a difficult task for a student. One of the main difficulties is that there is an overwhelming amount of potentially useful material for learning nearly any topic. Another difficulty lies in the fact that students might not be able to pose appropriate queries to search for relevant content as they may not be entirely familiar with the topic being or to be learned.

Recommender systems can alleviate these problems by providing meaningful recommendations to students. Recommendation in learning environments can be exploited from different perspectives. One approach consists in identifying and suggesting learning objects (e.g., documents, videos, instructional games, etc.) for a specific learning objective. Learning objects are characterized by metadata such as educational resource type, interactivity type and level, content, description, language, and format. When confronted with a problem requiring procedural knowledge (i.e. a sequence of steps to be carried out to solve a task), recommender systems can play a useful role by providing suggestions and hints (e.g. by pointing out possible alternatives or by issuing a warning when a wrong decision has been made). Also, recommenders can be useful during the knowledge acquisition process itself, by engaging learners in specific activities that promote declarative knowledge construction through the exploration of both domain-specific and domain-general knowledge.

A recommender system can adopt a task modeling approach, a user modeling approach, or a combination of both. A task is a piece of work required to achieve an objective. Tasks are usually associated with the need to access information to solve problems, evaluate content, construct meaning, create knowledge and make decisions. A task-based recommender system that supports a student learning process typically monitors the student's work, analyzes its content, seeks for similar content or other students that completed similar tasks, generates recommendations, and incrementally refines the recommendations based on the student's progress on the task at hand and the student's reaction to the suggested resources. Task representations need to be continuously updated as students change their focus during learning activities. This can be captured by analyzing a variety of contextual interaction patterns resulting from clicks, dwell time, cursor movement, scrolling, etc. A learning resource that proved to be useful for a learning task is likely to be useful for a similar task. Hence being able to model tasks and determine when two tasks are similar is key to develop a task-based recommender. A learning task can be modeled by the student's log activity, documents being read or edited, web pages being visited, milestone tasks being accomplished, among other items [10]. Task representations can be stored in a repository and associated with different kinds of resources (learning objects, procedural knowledge, and domain knowledge) that proved to be useful during those particular tasks.

Different from task models, which are changeable, user models are more persistent. Students can be modeled by their declared interest, their long-term browsing history, capabilities, social network communities, and social media interactions, among other features. In [11] various aspects are considered to model the student profile, such as learning style, educational level, preferred language, preferred topic, and preferred format. By modeling students, it is possible to compute similarity scores among students, and hence to recommend items to a target student based on how useful those items proved to be in the past to students with a similar profile.

The most common variants of recommender systems are content-based [12] and collaborative filtering [13]. Content-based recommender systems rely on a representation of a user or an item to find items that match with the user's recommendation needs. For instance, a content-based recommendation for a student currently learning a specific topic in biology requires representing the specific topic or the knowledge the student currently has or seeks to have about the topic to identify material similar to these representations. On the other hand, collaborative filtering algorithms rely on past user's behavior to find other users with similar behavior. The basic idea of a collaborative filtering approach is to provide item recommendations based on those items that were useful to or were liked by similar users. For instance, by modeling a student's skill, it may be possible to identify other students with similar skills to recommend material that proved to be useful to those similar students in the past.

Most existing recommenders are based on machine learning and information retrieval algorithms. As indicated in the literature [6, 7], these approaches are unable to effectively provide informed explanations of the reasons behind a given recommendation. Also, these approaches do not naturally support the kind of analysis of actions and interactions that are crucial in any learning process.

Incorporating Argumentation to Recommend Learning Resources

Argument-based recommenders can be applied to overcome some of the limitations of traditional recommendation systems in learning environments. Content- and collaborative-based recommender systems that use task-modeling or user-modeling approaches can be enhanced by incorporating argumentation technologies, to provide reasoned recommendations and facilitate the exploration of relevant learning resources through a dialectic process. Since the students will receive both a recommendation and a reason supporting it, they will have more confidence in the presented results and they can give the system explicit feedback that can help guide the recommendation process.

The widespread availability of learning resources repositories, coming from different sources and accessed by students with mixed backgrounds, perspectives, and learning abilities offers new opportunities to create argument-based recommendation services. These services can take advantage of the diverse community of students accessing the stored learning resources to implement collaborative-based recommenders. Developing an algorithm for recommending learning resources is challenging because it requires combining many, sometimes conflicting aspects. For instance, a resource may be useful for learning a physics topic for a student with a good mathematics background but it may not be useful for someone who has not developed a good background in mathematics yet. In light of the defeasible nature of students' information needs in learning environments, argumentation is an attractive technology to explore and revise potential recommendations, by generating suggestions of learning resources based on items that proved to be useful in the past during similar tasks and adapting them to the target student.

During procedural knowledge acquisition, students typically create and test solutions in shared learning environments and discuss their potential solutions with teachers and other students while carrying out learning tasks. The creation and discussion could be naturally integrated with a collective dialectic process that provides a context to let learners actively explore different ideas and positions. An argument-based recommender that guides this process will foster the generation of ideas and debate.

Another natural way in which argumentation can help enhance the recommendation of general and domain-specific knowledge is by involving the student in an argumentation process, either with the recommendation system or with other students. During declarative knowledge acquisition, an argument-based recommender will advise the student on which areas to cover, to increase the effectiveness of the learning process. It can also guide students in the process of engaging in specific discourse activities, to express their viewpoints and also to react to other students' perspectives.

Figure 9.2 provides a general picture of how argumentation can be integrated into the recommendation process in a learning environment. Based on a student's current task, similar stored past tasks can be retrieved. As discussed above, stored past tasks will typically be associated with a variety of learning resources, which may include learning objects of different types (e.g., manuals, videos, instructional games, etc.), as well as with procedural and declarative knowledge that proved to be useful for the

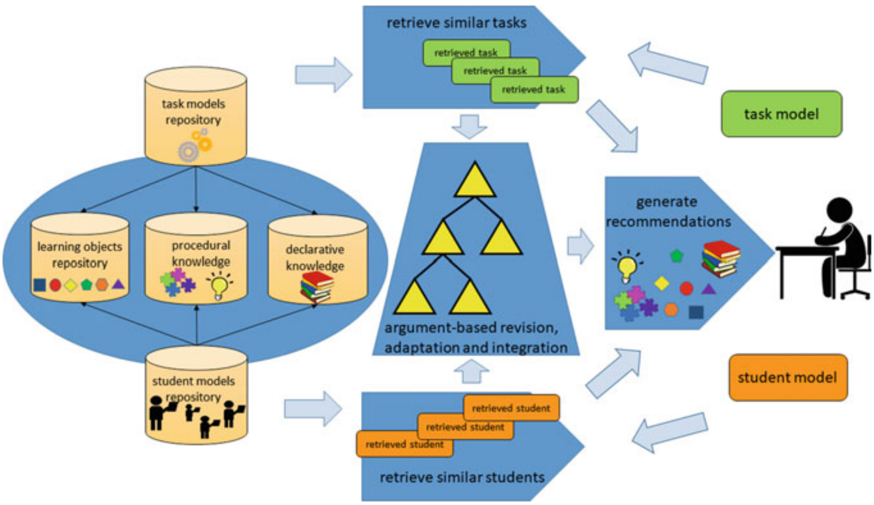


Fig. 9.2 Argument-based recommender systems in the context of educational processes from a high-level perspective

associated tasks in the past. Also, based on the student profile it is possible to retrieve the profiles of other similar students and those learning resources that proved to be useful to those students in the past. Finally, an argument-based approach can be taken to revise, adapt and integrate information coming from similar students and tasks, resulting in recommendations of potentially useful learning resources. We present next a case study illustrating how an argument-based recommendation approach based on Defeasible Logic Programming can be applied in a learning scenario.

A Case Study: Using Defeasible Logic Programming to Model Recommendations about Students' Learning Resources

The process for generating recommendations of learning resources by an argument-based recommender is different from the process adopted by most of the existing recommenders. However, they share the requirement of having access to prior knowledge about a collection of students, tasks, and learning resources, which can be codified as facts of a DeLP program, as illustrated in Fig. 9.3. Facts provide information about the students, tasks, and resources being modeled. Also, rules can be defined to determine if two students or two tasks are similar. To define such rules, similarities between students and tasks can be calculated by applying probabilistic latent semantic analysis [14] or matrix factorization [15], among other techniques. Finally, the DeLP program will contain a set of postulates that describe the conditions under which a learning resource should be recommended to a given student. For instance, a resource is typically recommended to a student if the student likes the resource type. However, even if the student likes the resource type, the resource will not be recommended if there is evidence that the resource was not useful to a similar student in the past. On the other hand, a resource will be recommended if it was useful for a task similar to the current one, albeit it was not useful to a similar student. An additional level of specificity that distinguishes between tasks for which a student finds a resource useful or not could be added if this information is available. This way, the argumentative process will deal with general facts and more specific facts that may be in conflict.

As discussed in Sect. 9.2, rules in a DeLP program are combined to support or reject a conclusion by building arguments. Figure 9.4 shows the arguments that have been computed to determine whether resource r_2 should be recommended to *Peter* while he is completing task t_1. In this example, the root argument of the dialectical tree is *recommend(peter, t1,r2)*, which turns out to be defeated and hence we have no reason to believe that *Peter* will benefit from resource r_2 while completing task t_1.

As another example, assume that the system is evaluating whether resource r_3 should be recommended to *Peter* while he is completing task t_1. Figure 9.5 presents a dialectical tree illustrating how arguments can be built in favor of such a recommendation. The root argument of the dialectical tree is *recommend(peter, t1, r3)*. Although there is a second argument that attacks the root argument, the second argument is in turn defeated by a third argument, concluding that the recommendation under analysis should be made.

Facts about resources and their types, whether the resources were useful for students or tasks and whether a resource type is liked or disliked by a student

resource_type(r1, video)
resource_type(r2, manual)
resource_type(r3, instructional_game)
useful_for_task(t1, r1)
useful_for_task(t1, r2)
useful_for_task(t1, r3)
useful_for_student(sam, r1)
useful_for_student(sam, r2)
~useful_for_student(sam, r3)
likes_resource_type(peter, video)
likes_resource_type(peter, instructional_game)
dislikes_resource_type(peter, manual)

Strict rules determining whether two students or two tasks are similar

similar_student(S1, S2) ← [Computed elsewhere]

similar_task(T1, T2) ← [Computed elsewhere]

Defeasible rules (commonsense knowledge) defining the cases for which resource R should be recommended to student S during task T

recommend(S, T, R) —< resource_type(R, RT), likes_resource_type(S, RT)

~recommend(S,T,R) —< resource_type(R, RT),likes_resource_type(S, RT),
similar_student(S1, S2), ~useful_for_student(S2 ,R)

recommend(S,T,R) —< resource_type(R,RT), likes_resource_type(S,RT), similar_student(S,S1),
~useful_for_student(S1,R),similar_task(T,T1), useful_for_task(T1,R)

Fig. 9.3 A sample DeLP program for modeling recommendations about resources for students

9.4 Opinion Mining and Argumentation: Contrasting Opinions and Viewpoints on the Internet

Opinion mining refers to a number of different techniques (including datamining, sentiment analysis, etc.) which are used in text analysis for automatically identifying opinion and emotion. Opinion mining is a very recent research area, and it provides a powerful resource for educational processes, as it allows students to better understand concepts and ideas which might be associated with different viewpoints.

Argumentation and opinion mining can be combined into an interesting approach presented in [16] which results in **argument-based opinion mining**. In contrast with other logical approaches to argumentation, an argument A for a conclusion C is essentially a set of *statements* that provide reasons to support C. These statements can correspond to different information items available on the Internet (contents from

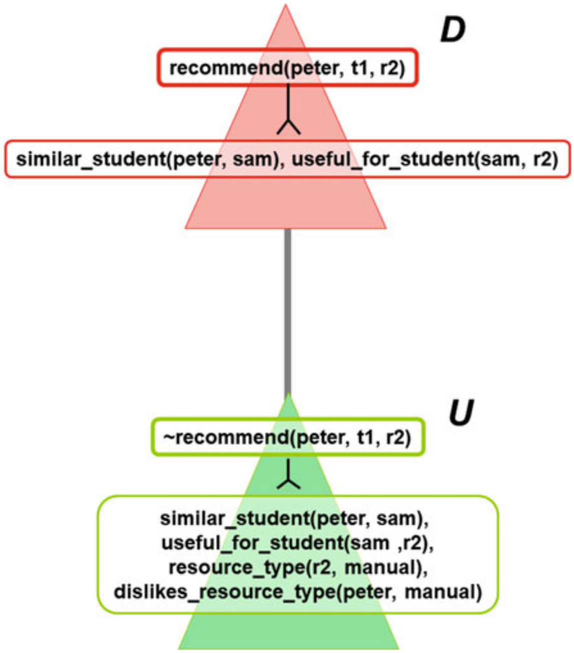


Fig. 9.4 A sample dialectical tree associated with the query "recommend(peter,t1,r2)", where the root argument is deemed as defeated

reviews, tweets in Twitter, etc.). For the sake of example, we will refer to tweets in what follows in order to present the associated framework [17]. We will take a sample topic to illustrate how argument-based opinion mining works. Consider for example the issue "abortion". Some tweets on that topic could be as follows:

Tweet_1 = "government should ban #abortion, it means killing babies"

Tweet_2 = "#abortion is debatable, not all cases are to be equally considered"

Tweet_3 = "#abortion is a right every woman has. Defend it"

Tweet_4 = …

We will refer to the set of topics or issues at hand as the **query Q** to be associated with a given argument (e.g. Q = "abortion" or Q = "abortion, Argentina"). In addition to the notion of query, we will introduce the idea of **context** or **criterion C.** This concept is intended to identify particular properties or features that we would like to consider associated with the query Q. We will aggregate these two elements when defining arguments, and hence will write **(Q,C).** Thus, for example, C1 could be a criterion that indicates that only tweets posted between timestamp T1 and T2 are to be selected. Then (Q,C1) will select only those tweets that contain all the terms of query Q and have been posted in the time period [T1,T2]. Other examples of criteria that can be naturally applied are, for instance, requiring that those tweets were retweeted more than n times, requiring that every user that posted tweets T has at least m followers, etc.

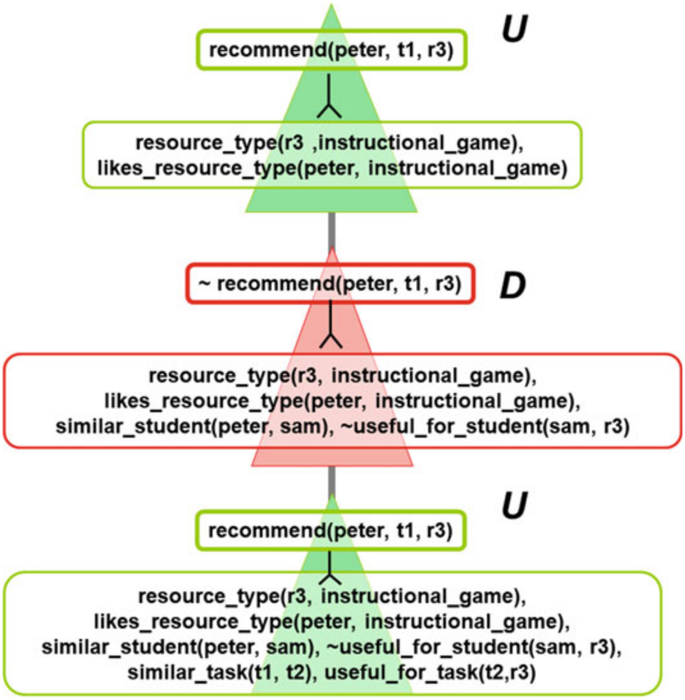


Fig. 9.5 A sample dialectical tree associated with the query "recommend(peter,t1,r3)", where the root argument is deemed as undefeated

Finally, we will also assume a set S of possible **sentiments.** A possible range for S could be *positive*, *negative* and *neutral*.[2] For the sake of example, Tweet_1 could be considered as a negative tweet towards abortion, whereas Tweet_3 corresponds to a positive tweet on that topic. We will generalize the notion of sentiment associated with a single tweet to the notion of *prevailing sentiment* in a bunch of tweets (i.e., the sentiment that prevails, according to some criterion, e.g. percentage). In the same way, we will assume that sentiments might convey conflicting feelings or emotions (e.g. anger vs. happiness; boredom vs. excitement, positive vs. negative, etc.). We will abstract away which is the prevailing sentiment as well as existing conflicts through mapping functions *Sent* and *Conflict*, respectively. Thus, Sent(T) will determine which is the sentiment value associated with a tweet T (as a singleton). As stated before, we will extend the intended meaning of Sent to an arbitrary set of tweets T = {t1,t2….tk}, where every ti denotes a tweet, so that Sent(T) denotes the prevailing sentiment associated with T (e.g. most tweets in T are positive, and hence we deem T as "positive").

[2] This approach is used in some commercial platforms for assessing tweets in terms of a positive, negative or neutral value and the percentage of tweets corresponding to each value (e.g. sentiment 140.com).

Two sentiments Sent1 and Sent2 in *Sent* will be "in conflict" whenever Sent1 differs from Sent2. (e.g. positive will be in conflict with negative; neutral will be in conflict with negative). According to this, we can say that a set of tweets T1 is in conflict with a set of tweets T2 whenever Sent(T1) differs from Sent(T2). We further assume that all possible conflicts are "equally preferred" in the sense that a conflict between positive and negative is as strong as a conflict between positive and neutral; the underlying idea is to identify the situation that the prevailing sentiments in both sets of tweets are not the same.

Characterizing an Argument as a Set of Tweets. Arguments in Conflict and Opinion Trees

For the sake of example, let us assume that we have a set T of 20,000 tweets associated with the query "abortion", and the context is given by "Argentina" and "years 2018–2020" (e.g. we consider only tweets originated from Argentinean accounts posted in the period 2018–2020). Note that in many cases we can easily identify a query because it was used as a hashtag (e.g. #abortion) within a thread of tweets.

In our approach, an **argument** A based on opinion mining for a query Q under a criterion C is a set of tweets associated with (Q,C) with a prevailing sentiment Sent. Thus, following the previous example, for a query Q = "abortion" and a criterion C corresponding to "all tweets in the period 2018–2020", and assuming that the possible sentiments S = {pos, neg, neutral}, then the argument A for Q under C would be the subset of all tweets related to "abortion" restricted to the period 2018–2020. Assuming that e.g. 80% of the tweets have a negative connotation, then the prevailing sentiment Sent = neg.

We have shown how to express arguments for particular queries under a certain criterion, associated with a given prevailing sentiment. Such arguments might be *attacked* by other arguments, which on their turn might be attacked, too. In argumentation theory [3], this leads to the notion of *dialectical analysis*, which can be associated with a tree-like structure in which arguments, counter-arguments, counter-counter-arguments, and so on, are taken into account. The central idea underlying the exploration of possible attacks for a given argument is given by the notion of *specificity*.

Suppose that an argument supporting the query Q = "abortion" is obtained, with a prevailing negative sentiment. If the original query Q is extended in some way into a new query Q' that is more specific than Q (i.e. Q' = Q ∪ {w}, for some particular word w), it could be the case that the argument supporting Q' would have a different (possibly conflicting) prevailing sentiment. For example, more specific opinions about abortion are related to other topics, like for example ethics, social problems or programs, religious issues, etc. To explore all possible relationships associated with arguments returned for a specified query Q and criteria C, we can define a high-level algorithm to construct an **opinion tree** recursively as follows[3]:

[3] The full-fledged description of the algorithm can be found in [16].

Algorithm BuildOpinionTree

Input: query Q, criterion C

Output: Opinion Tree OT(Q) rooted in an argument A for Q under criterion C with prevailing sentiment Sent.

1. We start with an argument A obtained from the original query Q under a criterion C with a prevailing sentiment S, which will be the root of the tree.
2. Next, we analyze within the tweets in A all relevant words that might be used to "extend" Q, by adding a new element (w) to the query, obtaining Q' = Q ∪ {w}.
3. Then, a new argument for Q' under criterion C with prevailing sentiment S' is obtained, which will be associated with a subtree rooted in the original argument A (i.e., the tree resulting from BuildOpinionTree(Q',C)).

It is also easy to see that for any query Q, the algorithm BuildOpinionTree finishes in finite time: given that a tweet may not contain more than 280 characters, the number of contained descriptors is finite, and therefore the algorithm will eventually stop, providing an opinion tree as an output (Fig. 9.6).

A Case Study: The Abortion Issue

As a case study to illustrate our approach, we consider the abortion issue based on information from Twitter in December 2012, when the Michigan legislature was debating several regulations on abortion practices. Consider the query Q = "abortion", and a criterion C = {tweets posted less than 48 h ago}. A root argument is computed for Q and C, obtaining an associated prevailing sentiment (negative). It

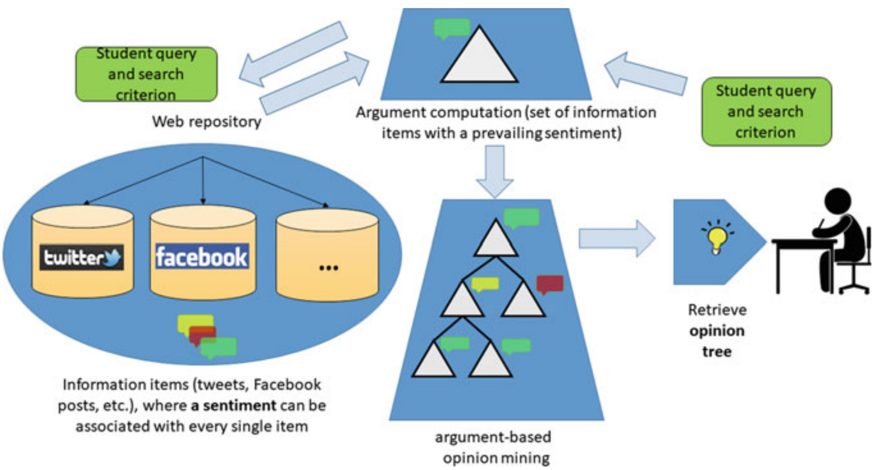


Fig. 9.6 Schematic overview of argument-based opinion mining. Based on a student query and a given context, an argument is computed along with possible conflicting arguments. The whole opinion tree is retrieved as an answer

should be remarked that the algorithm for building opinion trees avoids the repetition of any new descriptor used to extend the query associated with a node. The construction is performed depth-first, so that new descriptors are gradually introduced using a technique specifically designed to guide term selection (outside the scope of this paper, for a detailed description see [16].

Figure 9.7 illustrates how the construction of an opinion tree for the query Q = "abortion" looks like. Distinguished symbols (+, −, =) are used to denote positive, negative and neutral sentiments, respectively. Note that the original query Q has cardinality 1, and further levels in the opinion tree refer to incrementally augmented queries (e.g. {"abortion", "michigan"}, or {"abortion", "murder"}). Leaves correspond to arguments associated with a query Q' which cannot be further expanded, as the associated number of tweets is too small for any possible query Q' U {w}, for some w. Furthermore, we can identify some subtrees in the Opinion Tree rooted in "abortion" which consist of nodes having all the same sentiment. In other words, further expanding a query into more complex queries does not change the prevailing sentiment associated with the root node. In other cases, expanding some queries results in a sentiment change (e.g. from "abortion" into {"abortion", "option"} or {"abortion", "wish"}).

Integrating opinion trees into the learning process allows students to analyze public debate in a more systematic way while at the same time encourages social awareness and an interest in current affairs. Opinion trees help students synthesize complex information and analyze a specific topic from different perspectives. This approach helps improve logical and critical thinking.

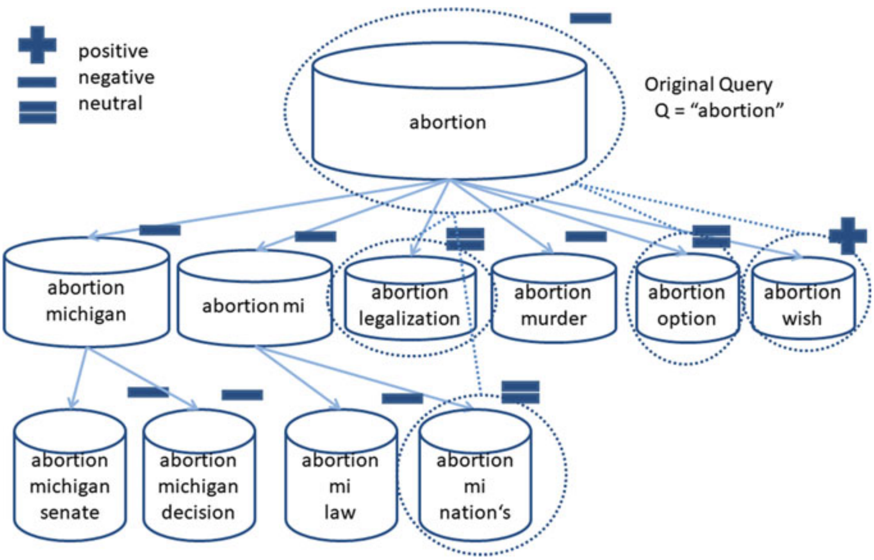


Fig. 9.7 An Opinion Tree for The Abortion Issue (computed from Twitter, 2012). Adapted from [18]

9.5 Shared Knowledge Awareness and Argumentation

Shared Knowledge (SK) concerns the common knowledge constructed by a student group when carrying out a collaborative learning activity in a CSCL environment.[4] In this setting, Shared Knowledge Awareness (SKA) has been defined as the consciousness on the SK that this student group has when performing a specific collaborative task in a restricted moment of time [19, 20]. Indeed, the construction of SK is strongly related to the acquisition of an appropriate level of SKA, as being aware of any knowledge (in particular SK) implies learning something about it.

Students' acquisition of SKA in CSCL scenarios is not a simple task, and a number of questions that should be considered to reach it have been proposed [19]. However, it is difficult to ascertain how to provide mechanisms to model the construction of SKA in a real CSCL system. Indeed, this problem is related to different features, in particular with characterizing the students' dialectical reasoning underlying negotiation processes when looking for an agreement or consensus about a given claim.

In this section, we will illustrate how computational argumentation can contribute when modeling educational processes where different *knowledge sources* (associated with capabilities or domain knowledge corresponding to different students) can be integrated following an argumentative approach. We will consider DeLP as the underlying programming language to provide a support tool for dialectical discussions in a CSCL framework. Indeed, our framework will allow modeling the dialectical analysis carried out by participants in CSCL scenarios, helping them to identify the emerging SK and the explicit specification of its associated SKA. As a starting point, we will consider the individual knowledge constructed by different students when performing a collaborative task (probably expressed in natural language and stored in a generic CSCL platform).

We depart from the assumption that the knowledge required for solving the collaborative task is complex, so that students should be able to integrate different perspectives and conflicting opinions about the task to be solved. Our goal is that participating students can make use of the reasoning and visualization capabilities provided by the argumentation system in order to support part of their SK construction as well as making explicit its associated SKA. Figure 9.8 illustrates the process of acquiring shared knowledge awareness through argumentation. As a result of this process, students will be able to identify what we will call *Argument-Based Shared Knowledge* (ArgSK): students are aware of how different conflicting pieces of knowledge are related to each other, why some of such pieces should be deemed as warranted (and some others should not), and how their own individual knowledge may be in conflict with other participants' knowledge.

A Case Study: Solving a Printer Configuration Problem Collaboratively[5]

Consider the following case study: Computer Science students from three different universities U_1, U_2 and U_3 (located in different cities) have to solve an activity

[4] CSCL stands for "Computer Supported Collaborative Learning".

[5] This example was originally presented in [20].

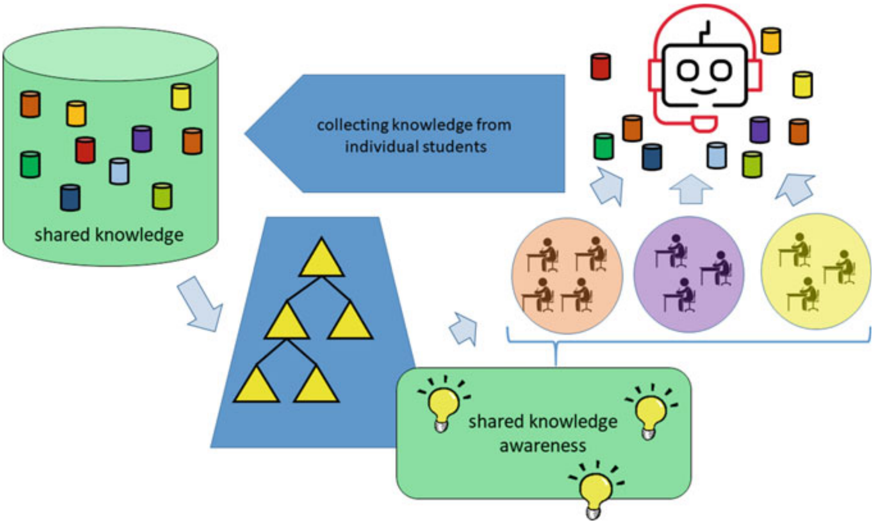


Fig. 9.8 Schematic overview of argument-based shared knowledge awareness. Based on knowledge from individual students an intelligent agent builds shared knowledge, which is combined with a dialectic process to acquire shared knowledge awareness

collaboratively in a CSCL scenario. The activity is structured using the *JIGSAW* technique [21] and includes the task T of *detecting good and bad features in different configurations of a personal computer model called "pcu" (acronym for "PC for universities")*, which is the computer model available in the computer labs of the three universities (e.g. the three labs have pcus with the same configuration, devices, etc.). The students are divided into small groups of three people, each of them belonging to a different university. Following the JIGSAW technique, each member of the group will be responsible for analyzing a different piece of knowledge when constructing his/her individual knowledge. Let us focus on one jigsaw group G formed by three students, namely S_1, S_2 and S_3. As stated before, we will assume that S_1, S_2 and S_3 are using a particular CSCL system to solve T, as they are located in different cities. For the sake of example, the students must learn about different topics related to pcus as follows: (1) S_1 is assigned the topic "input/output devices"; (2) $S_2$is assigned the topic "memory devices"; and (3) S_3 is assigned the topic "processors".

Let us assume that students have already constructed their individual knowledge and they are coming back to the group G to solve T. At this moment, S_1, S_2 and S_3 have to present a well-organized report to other members of G about the topic each of them has studied. The immediate goal is to construct SK and SKA in order to solve T. As a part of their SK and SKA, students are offered to re-cast their knowledge using an argumentative formalism (such as DeLP), where arguments and their acceptance statuses can be computed automatically.

Following our proposal, an automated argumentation platform is integrated with the CSCL scenario. It includes a knowledge base K (empty at the beginning), an inference engine for computing arguments and a suitable front-end for posing queries and visualizing results. First, each student S_i exchanges (separately) messages with an intelligent agent about what he/she knows, and the intelligent agent writes down this in terms of rules and facts. Following our example, suppose that student S_1 has acquired knowledge about printers (as they are I/O devices). He/she has learned the following: *hp1020 and hp1018 are models of laser printers. Laser printers work ok if the computer has a good RAM memory. Inkjet printers usually work ok with any kind of computer*. Besides, S_1 has checked the computer model "pcu" (the object of study) and has seen that there was a printer connected, namely the hp1020. In the same way, S_2 has studied memory devices. He/she has learned that *a RAM memory of 256* Mb *or more is usually good enough for a computer, unless you want to use it with a laser printer, since in such a case a RAM of 256* KB *has slow access, which is usually not a good feature.* In addition, S_2 has checked the computer model "pcu" and has seen that the computer had 256 Mb of RAM memory (note that S_2does not know anything about processors or printers, he just knows that they appeared as related concepts when learning about memory devices). Concerning S_3, he/she has individual knowledge about processors. He/she has learned that *if a computer has a processor double-core, then the processor is usually fast. Pentium processors result in slow access time for RAM memory. An exception are Pentiums with the special swap technology, which do not have this problem.* He/she has checked the computer model "pcu" and has seen that it has a Pentium processor with "swap technology".[6]

At the end of all the dialogues between S_1, S_2 and S_3 with the intelligent agent, the knowledge base K stores the sum of the three students' individual knowledge, which could have been written down by the intelligent agent as follows:

Facts about the computer in the lab

printer(pcu, hp1020) % *fact from student S1*
has_ram (pcu,256) % *fact from student S2*
processor (pcu,pentium) % *fact from student S3*

Defeasible rules (Commonsense knowledge)—C stands for an arbitrary computer

Knowledge about printers coming from S_1

[6] Names and values used here are fictitious. They are just considered for the sake of the example and not necessarily according to a real-world situation.

printer(C, laser) $\prec$ *printer(C, hp1020)*

printer(C, laser) $\prec$ *printer(C, hp1018)*

printer_ok(C)$\prec$ *ram_memory(C,good), printer(C, laser)*

printer_ok(C)$\prec$ *printer(C, inkjet)*

Knowledge about RAM memories coming from S_2

ram_memory (C, good)$\prec$ *has_ram (C,X), X > = 256*

ram_slow_access(C) $\prec$ *has_ram (C,X), X = 256, printer(X,laser)*

~ram_memory (C,good) $\prec$ *ram_slow_access (C)*

Knowledge about processors coming from S_3

processor(C, fast) $\prec$ *processor(C,double_core)*

ram_slow_access (C)$\prec$ *processor(C,pentium)*

~ram_slow_access (C) $\prec$ *processor(C,pentium), has_processor(pentium,swap_tech)*

Now, consider that as part of task T to solve (detecting good and bad features in different configurations of a "pcu"), S_1, S_2 and S_3 are discussing about the piece of knowledge "*printer_ok(pc)*", which stands for the claim *"is it ok to have a printer connected to the computer pcu?"*. By analyzing the individual knowledge provided by each S_i separately, the members of G cannot infer anything (except from the facts provided). However, if they *jointly* consider all the information stored in K (which accounts for part of their SK) they can rely on DeLP to automatically compute a dialectical tree rooted in the above claim, which will include all possible combinations of arguments and defeaters related to the claim. This way, they can guarantee that those pieces of knowledge subject to dialectical discussions will be part of the SK only if they are warranted on the basis of the joint knowledge of the group, thus avoiding a dialectical discussion based on incomplete and biased perceptions of reality. Hence, if the claim results to be supported by a warranted argument, then the above piece of knowledge can be part of the argument-based shared knowledge (ArgSK) for the group on the basis of rational and justified information.

In this particular example, S_1, S_2 and S_3 will obtain a warranted argument supporting the claim "*printer_ok(pcu)*" (as the warranted argument *Arg1* supports it), and they will add the claim to their ArgSK. Note that the claim is deemed as warranted by the underlying argumentation system, based on the dialectical tree shown in Fig. 9.3. Besides, S_1, S_2 and S_3 will visualize the dialectical tree shown in Fig. 9.3 (left), which explicitates a rational justification of the obtained results. Indeed, it can be seen that there exists an argument *Arg1* supporting *"printer_ok(pcu)"*, which can be obtained by combining knowledge from $S_1$and S_2. The argument is based on knowing that "pcu" has enough RAM memory to support hp1020, the laser printer connected to it. However, *Arg1* is defeated by *Arg2*, which supports the claim

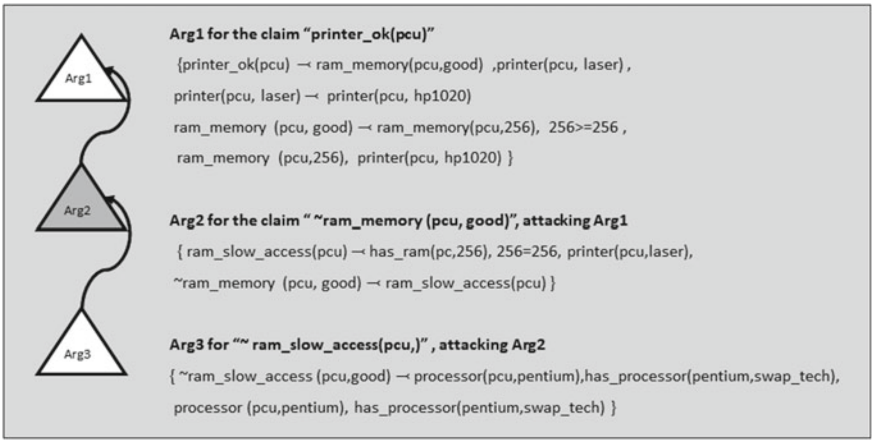


Fig. 9.9 Outline of the dialectical analysis obtained for the claim "is it ok to have a printer connected to the computer pcu?". Left: Arg1 is warranted and ultimately prevails, as it is defeated by Arg2, which is on its turn defeated by Arg3. Right: the argument contents provided by the argumentation engine in DeLP

"~ram_memory (pcu, good)" (the student who studied memory devices provided a defeasible rule which states that 256 Mb usually do not suffice for a laser printer to run ok). But this argument *Arg2* is on its turn defeated by *Arg3* standing for "*~ram_slow_access(pcu)*" (the student who studied processors provided a defeasible rule which states that computers with Pentium processors with swap technology, as it is the case here, do not have problems with RAM of 256 Mb). This way, the visualization of the tree will be linked to the ArgSKA associated with the claim under consideration, helping S_1, S_2 and S_3 to be aware of their own SK. Later on, S_1, S_2 and S_3 will be able to use the piece of warranted knowledge (the fact that the printer connected will work ok) when going further on the resolution of T (Fig. 9.9).

9.6 Conclusions and Related Work

In this chapter we have analyzed the role of computational argumentation as a metaphor for handling incomplete and potentially contradictory information. The task of contrasting alternative arguments and determining which ones are to be ultimately accepted is core to many educational processes in which critical thinking is involved. Even though argumentation has been central to education for many centuries in Western civilization, it has not been until recently that more evolved computational models for argumentation have been developed. We contend that these models can provide effective alternatives for new conceptualizations that improve and empower analytical thinking for both students and teachers.

In the last years, argumentation has had considerable growth and consolidation, establishing itself as a discipline in its own right within the research community in Artificial Intelligence. Argument-based recommender systems (one of the applications discussed in this chapter) have received particular attention when context-based information is taken into account [22–24]. Another important aspect that needs to be considered in the learning environment is the notion of trust. Students or instructors may trust certain learning resources because other users trusted by them recommend those resources, or simply because they trust the resources' sources. Trust is subjective, not always symmetric or transitive, context dependent, dynamic, and defeasible. Hence, as discussed in [25], trust can be naturally modeled using an argumentative framework, playing a useful role at the moment of integrating the notion of trust to support any learning process.

Recent research [26, 27] has been focused on integrating persuasion and computational argumentation in a unified system, leading towards a so-called Automated Persuasion System (APS). Persuasion is an activity that involves one party trying to induce another party to believe something or to do something. It is an important and multifaceted human facility. As the authors point out, persuasion is present in many human activities (such as a doctor persuading a patient to drink less alcohol, a road safety expert persuading drivers to not text while driving, or an online safety expert persuading users of social media sites to not reveal too much personal information online). An automated persuasion system (APS) is a system that can engage in a dialogue with a user (the persuadee) in order to persuade the persuadee to do (or not do) some action or to believe (or not believe) something. To do this, an APS aims to use convincing arguments in order to persuade the persuadee. Computational persuasion is the study of formal models of dialogues involving arguments and counterarguments, user models, and strategies, for APSs. The authors claim that a promising application area for computational persuasion is in behavior change (particularly in the context of healthcare organizations, where there is much interest in changing behavior of particular groups of people away from actions that are harmful to themselves and/or to others around them). In our opinion, education is also an area where APS could play an important role (as students need typically to be persuaded of carrying out different goals as part of educational processes—e.g., carrying out some particular kind of exercise, mastering some skill, etc.).

Along this chapter, we have carried out an analysis of the impact and possibilities of computational argumentation from different perspectives, based on some common elements of argumentation provided in Sect. 9.2 (including a brief account of Defeasible Logic Programming). In Sect. 9.3 we showed how argumentation and traditional recommender systems can be unified into argument-based recommender systems, in which recommendations associated with the outcome of a particular query on a certain domain can be backed up by arguments that have emerged as ultimately accepted after performing a dialectical analysis. Then, in Sect. 9.4 we moved into mining opinions from user content knowledge (particularly information in Twitter). We showed that argumentation can provide the backbone for an enhanced model in which arguments are given by sets of information units (e.g. tweets) that have a prevailing sentiment. Such arguments could also be contrasted using a dialectical analysis, identifying so-called “opinion trees” (an alternative form for representing dialectical analysis). Finally, in Sect. 9.5 we analyzed the concept of shared knowledge awareness in a group of students. We showed that for solving a particular problem (e.g. making a printer work), students might need to combine pieces of information from their own knowledge, and that potential conflicts and inconsistencies might arise. Once again, argumentation comes out as a solution for such situations, allowing students to be aware of their “shared knowledge” that contributes to finding a solution for a given problem.

In summary, we have shown that computational argumentation can indeed provide a powerful model for recasting and enhancing traditional educational processes (particularly those in which incomplete and potentially inconsistent information is at hand, and different, alternative viewpoints have to be assessed and contrasted). We think that the three alternatives explored in this chapter (argument-based recommendation, argument-based opinion mining and argument-based shared knowledge awareness) illustrate the power of argumentation as a backbone for developing new, different intelligent techniques and approaches for educational purposes. Even though many advances have been achieved, the most promising results in this direction seem still to be seen in the future.

Acknowledgements This research was supported by Projects PICT 2014-0624 and PGI 24/N051(Universidad Nacional del Sur and ANPCyT, Argentina).

References

1. A.J. García, G.R. Simari, Defeasible logic programming: an argumentative approach. Theory Pract. Logic Programm. 4.1+ **2,** 95–138 (2004)
2. P. Besnard, A. Hunter, *The Elements of Argumentation* (The MIT Press, 2008)
3. I. Rahwan, G. Simari (Eds.), *Argumentation in Artificial Intelligence.* Springer (2009)
4. S. Modgil, F. Toni, F. Bex, I. Bratko, C. Chesñevar, W. Dvorak, M. Falappa, X. Fan, S. Gaggl, A. Garcıa, M. González, T. Gordon, J. Leite, M. Mozina, C. Reed, G. Simari, S. Szeider, P. Torroni, S. Woltran, The added value of argumentation, in S. Ossowsky (Ed) The Law, Governance and Technology Series (LGTS), “Agreement Technology Handbook” vol.8, 357–404 (2012)
5. M. Nicolas, S. Parsons, I. Rahwan, Argumentation in multi-agent systems: context and recent developments. *International Workshop on Argumentation in Multi-Agent Systems.* Springer, Berlin, Heidelberg (2006)
6. C. Chesñevar, A. Maguitman, G. Simari, Argument-based critics and recommenders: a qualitative perspective on user support systems. Data Knowl. Eng. **59**(2), 293–319 (2006)
7. C. Chesñevar, A. Maguitman, G. Simari, Recommender systems based on argumentation, in “*Emerging Artificial Intelligence Applications in Computer Engineering*”. Maglogiannis et al (eds). *Frontiers in Artificial Intelligence and Applications*, IOS Press, vol. 160, pp. 53–70 (2007)
8. C. Briguez, M. Budán, C. Deagustini, A. Maguitman, M. Capobianco, G. Simari, Towards an argument-based music recommender system. COMMA **2012**, 83–90 (2012)
9. Briguez, E. Cristian et al., Argument-based mixed recommenders and their application to movie suggestion. Expert Syst. Appl. **41**(14), 6467–6482 (2014)

10. N.K. Tselios, N.M. Avouris, M. Kordaki, Student task modeling in design and evaluation of open problem-solving environments. Educ. Inf. Technol. **7**(1), 17–40 (2002)
11. P. Rodríguez, S. Heras, J. Palanca, J.M. Poveda, N. Duque, V. Julián, An educational recommender system based on argumentation theory. AI Commun. **30**(1), 19–36 (2017)
12. M.J. Pazzani, D. Billsus, Content-based recommendation systems, in *The Adaptive Web*, pp. 325–341. Springer, Berlin, Heidelberg (2007)
13. J.B. Schafer, D. Frankowski, J. Herlocker, S. Sen, Collaborative filtering recommender systems, in *The Adaptive Web*, pp. 291–324. Springer, Berlin, Heidelberg (2007)
14. T. Hofmann, Probabilistic latent semantic indexing, in *Proceedings of the 22nd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, pp. 50–57 (1999)
15. Y. Koren, R. Bell, C. Volinsky, Matrix factorization techniques for recommender systems. Computer **42**(8), 30–37 (2009)
16. K. Grosse, M.P. González, C. Chesñevar, A. Maguitman, Integrating argumentation and sentiment analysis for mining opinions from Twitter. AI Commun. **28**(3), 387–401 (2015)
17. C. Chesñevar, A. Maguitman, E. Estévez, R. Brena, Integrating argumentation technologies and context-based search for intelligent processing of citizens' opinion in social media, in *Proceedings of 6th International Conference on Theory and Practice of Electronic Governance*, ICEGOV '12, pp. 171–174. ACM Press (2012)
18. Chesñevar, C. Iván, A. Gabriela Maguitman, M.P. González, Empowering citizens through opinion mining from twitter-based arguments. *Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance* (2014)
19. C. Collazos, L. Guerrero, J. Pino, S. Ochoa, Introducing knowledge-shared awareness. *Proceedings of IASTED'02*, USA, pp.13–18 (2002)
20. M. González, C. Chesñevar, C. Collazos, G. Simari, Modelling shared knowledge and shared knowledge awareness in CSCL scenarios through automated argumentation systems. CRIWG **2007**, 207–222 (2007)
21. E. Aronson, N. Blaney, C. Stephin, J. Sikes, M. Snapp, *The Jigsaw classroom* (Sage Publishing Company, Beverly Hills, CA, 1978)
22. J. Teze, S. Gottifredi, A. García, G. Simari, An approach to generalizing the handling of preferences in argumentation-based decision-making systems. Knowl. Based Syst., 189 (in press) (2020)
23. J. Teze, L. Godo, G. Simari, An argumentative recommendation approach based on contextual aspects. SUM **2018**, 405–412 (2018)
24. M. Leiva, M. Budán, G. Simari, Guidelines for the analysis and design of argumentation-based recommendation systems. IEEE Intell. Syst. **35**(5), 28–37 (2020)
25. C.E. Briguez, M. Capobianco, A.G. Maguitman, A theoretical framework for trust-based news recommender systems and its implementation using defeasible argumentation. Int. J. Artif. Intell. Tools **22**(04), 1350021 (2013)
26. A. Hunter, Towards a framework for computational persuasion with applications in behaviour change. Argument Comput. **9**(1), 15–40 (2018)
27. L. Chalaguine, A. Hunter, A persuasive chatbot using a crowd-sourced argument graph and concerns. COMMA **2020**, 9–20 (2020)

Chapter 10
Revealing Latent Student Traits in Distance Learning Through SNA and PCA

Rozita Tsoni, Evangelos Sakkopoulos, and Vassilios S. Verykios

Abstract Distance Learning has moved almost completely online, gaining ground in an educational setting of constantly increasing demand. Physical distance poses barriers in the implementation of such a transition, however, most of these barriers can be surpassed by implementing a Learning Analytics process around the educational process. The chapter presents a novel approach that is based on a rich spectrum of metrics of Social Network Analysis that can capture complicated interaction of social students' behavior, along with academic performance indicators, in a process that aims to reveal the latent characteristics of students participating in the discussion fora of their Distance Learning postgraduate course.

Keywords Higher education · Distance learning · Learning analytics · Social network analysis · Principal component analysis

10.1 Introduction

In the past decade, a large score of the learning and teaching activities have been transferred online. Recent technological and socio-economic developments on top of unpredictable global events pose even more imperatively the need for Open and Distance Learning. Restrictions for preventing Covid-19 infection led more than 1.5 billion enrolled students from all over the world (approximately 90% of the global student population) to experience interruption of education [52]. A massive, urgent transition of the conventional teaching and learning on the web increased the need

R. Tsoni (✉) · V. S. Verykios
School of Science and Technology, Hellenic Open University, Patras, Greece
e-mail: rozita.tsoni@ac.eap.gr

V. S. Verykios
e-mail: verykios@eap.gr

E. Sakkopoulos
School of Information and Communication Technologies, Department of Informatics, University of Piraeus, Piraeus, Greece
e-mail: sakkopul@unipi.gr

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_10

for monitoring students' online behavior. Therefore, Learning Analytics (LA) was brought into the spotlight as the most promising tool to diminish the spatial and temporal distance between learning stakeholders.

Even without the massive disruption of Covid-19, there is an obvious upcoming change in the Higher Education setting. New models of teaching and learning have moved conventional systems from being able to service a small number of participants to massive, open courses, replacing a part of tutor's assistance and evaluation with automated or peer assistance and evaluation, resulting in a fewer percentage of students completing the courses successfully [28]. Higher education has emerged toward increased specialization and individualized instruction, while attention shifts from institutions and programs to individual students who aim to construct skill sets according to the new demands of the job market [15].

As a result, the complexity of the field is growing since personalization comes along with massive demand and large heterogeneity. Numerous students' communities are formed in large-scale courses offered by top-rated universities. Moreover, learning cannot be seen apart from social interaction whether this is happening implicitly or explicitly. Therefore, having a clear picture of tutors' and learners' interaction is vital to maintain and improve the quality of Distance Education. While teaching does not necessarily lead to learning [29], there is a constant need for feedback to evaluate the engagement of the learners and the effectiveness of the learning process [38]. In Distance Education tutors in online classes, without adequate information, may be misled by an unnoticed mismatch between ideal and actual class dynamics, from a social learning perspective [22]. Engagement and productive dialogue are important conditions for successful teaching. Network Analysis can identify where productive dialogue takes place [46]. Ferguson and Shum [17] found that educational success was correlated to the quality of learners' educational dialogue and students' satisfaction [37].

LA has the potential to: *"dramatically impact the existing models of education and to generate new insights into what works and what does not work in teaching and learning"* [41] Moreover, recently, the analysis of the existing evidence for LA indicates that there is a shift towards a deeper understanding of students' learning experiences [53]. LA focuses on the specific problem of understanding and optimizing factors that lead to a successful educational experience for all learners [31]. The implication of LA and the evaluation of its impact on learning is one of the key challenges of the educational field [45]. Also, one key principle in the "*Global guidelines for ethics in LA*" is to consider whether access to knowing and understanding more about how students learn brings with it a moral obligation to act [42].

There are many ways in which LA can impact education. A taxonomy of the LA types depending on their result is described by Downes [16] and contains descriptive analytics, diagnostic analytics, predictive analytics, prescriptive analytics, generative analytics, and deontic analytics. Additionally, in a research concerning the implementation of LA in countries identified seven major factors that should be taken into account: power, pedagogy, validity, regulation, complexity, ethics, and affect [18].

Our main stand in this context is to use LA for descriptive and diagnostic purposes mostly with a focus on identifying how the social behavior of students as it is ascribed in their interactions with their fellow students and their tutors affects their learning. In our previous work [48, 51], qualitative conclusions were drawn by posing different research questions from well-established educational theories and using social network visualization and polarity analysis to answer them. In that respect, centrality measures and their distribution were studied in two-mode networks, and their projection onto one-mode networks, were extensively investigated [47].

In this chapter, we present a novel approach that is based on a rich spectrum of metrics of Social Network Analysis (SNA) that can capture complicated interaction of social students' behavior, along with academic performance variables, in a process that aims to reveal the latent characteristics of students participating in the discussion fora of their Distance Learning postgraduate course. Hopefully, actionable knowledge will be produced, helping tutors and educational stakeholders to base their decisions on the learners' needs even when these needs are not clearly stated.

This chapter is structured as follows: In Sect. 10.2 certain concepts and metrics mainly concerning Network Analysis are discussed. Additionally, the Hyperlink-Induced Topic Search (HITS) algorithm is presented along with a brief description of the Principal Component Analysis (PCA) and the Hierarchical Cluster Analysis techniques providing a complete report of the analytical tools used in the research. In Sect. 10.3 relevant work, concerning forum interaction and students' online behavior, is briefly presented. The following Sects. 10.4 and 10.5 describe the data and the experimental method used in our research. Results are presented and discussed in Sect. 10.6, providing educationally sound interpretation and understanding. In the final section conclusions, limitations, and future work are discussed.

10.2 Background: Definitions, Algorithms, and Methods

Our LA approach consists of two main steps. We can consider them as an analysis and a meta-analysis step. During the first step of our proposed methodology, we apply Network Analysis. Below we discuss relevant metrics, along with algorithms and methods that were used in this context. We also touch upon and introduce PCA and clustering, which are built around our primary analysis technique and used as a meta-analysis phase to build on the primary findings of SNA.

Network analysis includes concepts and metrics that allow the representation of the interaction between actors in the form of a network where each node represents an actor and the edge between two nodes represents connections (some kind of association). Here, we deal with networks containing either a single or a multiple type of nodes. When the nodes are of one kind the network is unimodal (or one-node network). Multimodal networks consist of different types of nodes. For example, forum participation can be expressed in two ways. In a one-mode network, where each node represents a participant, the edges indicate the interaction among them. In other words, a link indicates a comment or a reply to each other's post. Alternatively, the forum community can be imprinted as a two-mode network where nodes might represent participants or discussion threads. There, a link always connects two nodes of a different type. A participant-node is connected directly only with thread-like nodes and vice versa. In the analysis that follows the representation of students' networks is bimodal as this allows for a more thorough view of the interaction, providing richer information than the projected one-mode network [47].

The reciprocity of the interaction among different nodes is associated with the feature of directivity. A network can be either directed or undirected. In a directed network, when a node i, is connected to a node j, the node j is not necessarily connected to node i. Thus, the adjacency matrix of the network is not necessarily symmetric. The links between a person and his/her followers in a social network site are an example of directed edges between the person and their followers because they are not reciprocal. Therefore, a network of Twitter accounts and followers is a directed network. On the contrary, an undirected network corresponds to a symmetric adjacency matrix. Thus, for every pair of nodes i, j, $\alpha_{ij} = a_{ji}$. A friendship network is undirected because of the mutuality of the relation.

Starting to explore a network *G*, the first and simplest metric describing a node is its *degree*. It is the sum of the number of edges connected to this node. In a bimodal network that represents a discussion forum activity, the high degree of a participant shows that s/he has posted in a lot of discussions but does not provide us any information about the number of the people he interacted with. The degree rises if the person posts in more discussions even if always the same person participates in them. In a directed network the *in-degree* is the number of incoming edges, and the *outdegree* is the number of outgoing edges. Forum interaction can be represented as a bimodal directed network where all edges come out of person-nodes and point to discussion-nodes. Therefore, the indegree of person-nodes and the outdegree of discussion-nodes are always zero.

The *Weighted degree* metric counts the number of edges but also adds up the number of times a person has posted in a certain discussion in a bimodal network.

Closeness centrality shows how many "hops" are needed so that a node can reach other nodes. The concept of geodesic distance is necessary to define closeness centrality. Geodesic distance is the number of edges that contain the shortest path between two given nodes. Closeness centrality is inversely proportional to the total geodesic distance from a node to all other nodes of a network [19]. Since closeness centrality depends on the networks' magnitude (the number of nodes and edges that contains), it is strongly affected by the network's type. In a bimodal network, for a given person ***A*** to reach another person ***B*** a discussion node has to intercede between them. Therefore, the distance between any two nodes cannot be less than two. The closeness centrality of a vertex is defined as:

$$C(x) = \frac{N-1}{\sum_{x \neq y} \mathrm{d(x, y)}} \quad (10.1)$$

where x, y are two vertices in the network G, $d(x, y)$ denotes their distance, and N is the number of nodes in the graph. Thus, a node with low closeness centrality is a central node in the network. In other words, if the sum of the distances is large, then the closeness is small and vice versa [33].

Harmonic closeness centrality which is, likewise the Closeness centrality, a measure of nodes' proximity was proposed by Marchiori and Latora [32]. Harmonic closeness centrality can be computed in a not necessarily complete network because in case that there is no path between x, y the value of $\frac{1}{d(y,x)}$ equals zero.

It is defined as:

$$H(x) = \sum_{y \neq x} \frac{1}{d(y, x)} \tag{10.2}$$

A nodes' *betweenness centrality* is a metric indicating the node it is contributing to connecting other nodes. This measure provides information about the "importance" of a node that despite the fact that it is a low degree node, it happens to be in a strategic location within the network. Nodes with high betweenness centrality act as bridges linking sub-groups of nodes that otherwise might be disconnected. In a discussion forum network, tutors have high betweenness centrality holding together the learning community [47].

Betweenness centrality of a given node i is proportional to the total number of geodesics between two given nodes j and k, which include node i. A node i with high betweenness centrality is part of many paths of its network. In general, when more ties are added in a network with a given number of nodes, betweenness centrality decreases [4]. Betweenness centrality can be expresses as:

$$BC(x) = \sum \frac{\sigma_{(v,w)}(x)}{\sigma_{(v,w)}} \tag{10.3}$$

where x denotes a given node, σ denotes the count operation, $\sigma_{(v,w)}(x)$ is the number of shortest paths (between any pair of nodes v, w in the graph) that passes through the target node x, and $\sigma_{(v,w)}$ the total number of shortest paths that occur between any pair of nodes of the graph. The target node would have a high betweenness centrality if it appears in many shortest paths [34].

Eigenvector centrality is a node's metric strongly affected by its neighbor's characteristics. It is defined as follows: given the adjacency matrix A of the network G, an eigenvector for this matrix is a vector v that satisfies the matrix–vector equation Av = av for some scalar value a (the eigenvalue). This would give the equation:

$$ECx_i = \frac{1}{\lambda} \sum_{j \in M(i)} x_j \tag{10.4}$$

where λ is a constant and $j \in M(i)$ means that the sum is over all j such that the nodes i, j are connected (where $M(i)$ denotes the set of all the nodes that are directly connected with node (i). Eigenvector centrality indicates a node's influence which signifies its strategic position in a network. Highly influential nodes are connected with other nodes of high influence, adding value to each other.

Eccentricity is a distance measure that is considered to be much simpler than closeness centrality [39]. In a given network G the eccentricity $e_{G(v)}$ of a node v is the maximum distance between node v and node u over all the nodes of the network. From the definition below (Eq. 10.5) it is obvious that a node with high eccentricity is a distant node.

$$e_{G(v)} = max\{dist_G(v, u) : u \in V\} \tag{10.5}$$

A more advanced approach to investigate nodes' strategic position and influence is through a sophisticated approach, the so-called HITS algorithm. HITS, also known as *Hubs and Authorities* is a link analysis algorithm initially created to rank web pages [26] on the internet. The algorithm assigns two values in each node: a hub value and an authority value. A high value of hub means that the node points to high authorities i.e., nodes with valuable information. Respectively, a node with high authority is being pointed by good hubs in a mutually reinforcing relationship. The computation of these values is based on an iterative process that follows the principle of repeated improvement as a good hub adds value to an authority and subsequently, the authority adds more value to the hub in a repeated process that converges to a final result. The degree of convergence e (epsilon) determines the ending point of the iterative algorithm that is the maximum divergence between two sequential results. Initially, for each node p we set $x^{<p>} = 1$ and $y^{<p>} = 1$ for the ranking process to begin (where $x^{<p>}$ denotes the hub and $y^{<p>}$ the authority of the node. The function that updates the weights for hubs and authorities (hub and authority update rules respectively) are:

$$x^{<p>} \leftarrow \sum_{q:(q,p)\epsilon E} y^{<p>} \tag{10.6}$$

and

$$y^{<p>} \leftarrow \sum_{q:(q,p)\epsilon E} x^{<p>} \tag{10.7}$$

A directed edge (p, q) indicates the presence of a link from p to q. In a directed bimodal network of participant-to-thread interaction, an edge is always directed from a participant-node to a thread-node. Thus, participant-nodes have non-zero outdegree and always zero indegree. Additionally, thread-nodes always have zero outdegree and non-zero indegree. Therefore, participants are hubs with zero authority and threads are authorities with zero hubs.

The metrics that were briefly described above imprint different properties of each node in a network. Students' interaction and behavior within an online learning community is a multidimensional problem. The network metrics shed light into the social aspect of learning. The online presence and the academic performance are revealed by the number of views and the grades of the students. There are many other features that affect the learning process such as personal and cultural information. However, the scope of the proposed methodology is to provide an accurate description of the learners based on the available data, preserving students' privacy and, at the same time, capturing a large range of their characteristics. To overcome the problems posed by the multidimensionality that was created from the incorporation of network metrics in our analysis it is useful to apply a method for dimensionality reduction. Exploratory Factor Analysis is a method that can prevent biased and skewed results, which are difficult to interpret and, additionally, can reveal hidden aspects of this multidimensional problem. Thus, most relevant metrics and variables were used in a Principal Component Analysis. PCA provides variables reduction, maintaining the majority of information. As an orthogonal linear transformation that projects the data to a new coordinate space, it produces main components that can be expressed as a linear combination of the initial variables weighted by their variance. The components that emerge are represented in a new orthogonal dimension revealing patterns and latent characteristics, that were not obvious in the first level of the analysis. Additionally, we can create graphs using the eigenvectors as new uncorrelated variables.

To further leverage the new normalized variables developed by PCA's factor scores, a clustering process is proposed. Hierarchical Cluster Analysis can provide additional information about students' behavior based on their latent characteristics. Thus, the method of between-group linkage using the Euclidean distance will be used in the new orthogonal space that PCA produced.

10.3 Related Work

Forum participation and interaction is a field of interest in education research because it reflects the relationships in the learning community and it can indicate issues where action must be undertaken by the learning facilitators. In Distance Learning it is crucial for the students to be and feel supported and, at the same time, to increase their autonomy. Descriptive and predictive models can help tutors to focus their attention on students at risk and prevent poor learning results. The activity of the students in the discussion fora was used for academic performance prediction by Chiu and Hew [10] along with views and posts count. Their research demonstrated greater predictive power in views count than in posts counts. Crossley et al. [11] shown that students had significantly better achievement than their peers when they made at least one post of 50 words or more. Furthermore, students who produce more on-topic posts, posts that are more strongly related to other posts, or posts that are more central to conversation presented a better completion rate. Sun et al. [44] compared the forum interaction between who participated in pre-defined groups and students in self-selected groups. It was found that there is a significant difference between the strength of the ties that students formed that led them to the conclusion that the course design approach is affecting students' community structure. Chiru et al. [9] proposed a model for counting the strength of students' connection with certain discussion topics and with other participants, called the participant-topic and the topic-topic attraction.

In the field of Social Network Analysis visualization and metrics contribute to providing a deeper sight into the community structure, revealing relations and participants with a strategic role. Network Analysis of forum activity was considered in two successive studies in Hellenic Open University (HOU) [24, 30] aiming to create students' profiles based on their online participation in order to provide useful feedback to their tutors. Network representation through time reveals the evolution of students' community and along with polarity analysis can provide insights into the social aspect of their learning behavior [49]. In a literature review by Cela et al. [7] the most common metrics were found to be centrality and density, leading to the conclusion that Social Network Analysis, particularly when combined with content analysis, can provide a detailed understanding of the type of interactions between the members of the network, allowing the optimization of the course design. Hernández-García et al. [22] highlighted the need for tailored tools for advanced and in-depth analysis that will allow the effective confrontation of the problems that commonly appear in Distance Learning.

De-Marcos et al. [14] used network metrics to conduct PCA and also, they examined the correlation between those metrics and academic achievement. An analysis of the data retrieved from a social networking site that was delivered to students providing gamified activities and enabling social interaction and collaboration, showed a moderate correlation between most centrality measures and learning achievement. Thus, they concluded that structural metrics can be used as predictors of the learning outcome.

Tools and applications have been developed focusing on social network analysis and community detection [2, 3, 5, 8, 12] with different features [43] that can be used in educational research.

SNA was found to be more revealing concerning students' interactions and their location in the learning community [54]. This result is consistent with the research of Traxler et al. [46] that found that centrality measures were more reliable indicators of the grade than non-network measures such as post count. In a pedagogy-oriented work, Jan and Vlachopoulos [23] explored social network features as indicators of the structure of communities of practice and communities of inquiry. Their study substantiates the proposed Integrated Methodological Framework based on SNA as an effective framework for structural identification of community-based learning. A collaborative forum-based learning design, including pre-learning and post-learning activities, was proposed by Amano et al. [1]. In order to discover relevant structures in social networks generated from student communications Rabbany et al. [36] introduced a toolbox which automatically discovers relevant network structures, visualizes overall snapshots of interactions between the participants in the discussion forums, and outlines the leader and peripheral students.

While LA can be applied in a broad range of educational fields providing answers to a variety of students' related problems [25] research questions that contain structured hypotheses are not always the case. The computational, data-driven research is gaining ground, especially when Machine Learning techniques are used. In the so-called "black-box" approach data lead to the hypothesis creation, revealing hidden aspects of the problem. On the contrary, the "white-box" is a theory-driven, hypothesis-testing statistical analysis. Taking into account the multidisciplinary and the special characteristics of the educational research Sharma et al. [40] proposed a combined method, the grey-box approach where data collection, feature extraction, feature selection, prediction, and interpretation form a pipeline that can be fine-tuned with specific research needs. Pedagogical criteria lead Gkontzis et al. [21] to divide the academic year of students into six periods before applying Machine Learning techniques for academic performance prediction.

Prabhakar and Zaiane [35] presented a framework using a hybrid particle swarm optimization to form student groups based certain attributes (like age, grade etc.). They argue the algorithm that they proposed can cluster students into dynamic learning groups and could be used for automated grouping in MOOCs. PCA was used to investigate the relation between the use of web2.0 tools and students' performance [20]. Certain activities were identified as indicators of students' success even though no significant correlations between learning styles and performance were found.

10.4 The Hellenic Open University Dataset

The HOU is the only Higher Education Institute that offers full Distance Learning courses at undergraduate and postgraduate level in Greece. Moreover, it is the only university in the country that admission does not require written exams. Students that meet some basic requirements can enroll, even if they live in remote geographical areas, as they do not have any obligation of physical presence, except for some laboratory courses held during summer vacation time in certain programs. These two characteristics are considered to be the main assets of the openness culture that this university represents. However, all study programs offer the opportunity of face-to-face meetings, mainly for advisory and motivational purposes. Communication between students and their tutor can be achieved via synchronous teleconference meetings and telephone calls, SMS text messages, e-mails, or through the discussion forum of the course. Peers officially interact only through the discussion forum although they usually create groups in social media to communicate outside of the formal learning environment. Forum interaction takes place with no external motivation. Students do not gain extra credits and forum-related assignments are not usually assigned. They post online only if they feel that they want to communicate with their peers for any reason. Thus, discussion forum topics may vary from general questions or statements to specific course-related questions.

Graduate programs at the School of Science and Technology, are usually consisted of courses that last an academic year. Each academic year students can attend up to five OSS (Group meeting for consulting) and have to hand over up to six written assignments in each course. These assignments are obligatory and the average grade (it has to be above 5/10) determines whether a student would be permitted to sit on the final exams or not. In some courses, there are quizzes and online tests available that can contribute a percentage of the final grade, but this feature usually varies.

A compulsory course offered in the first year of studies was chosen for the experimental evaluation of the proposed methodology because it represents the beginning of students' learning experience and their first contact with Distance Learning for a large number of them. In the academic year, 2019–2020 students were divided into seven groups. Each group had a different tutor-consultant in charge. Two of the groups participated in face-to-face meetings held in the two bigger cities of Greece (Athens and Thessaloniki) and the five other groups had their synchronous meetings online (we will refer to them as e-groups). Students had to choose whether to participate in online or in face-to-face meetings at the beginning of the academic year for the groups to be formed. Data were drawn from the forum that was accessible from students and tutors of all groups, hosted in Moodle platform at the School of Science and Technology of the HOU in the academic year 2019–2020. Assignments' grades, final grades, views, and forum data were included in the dataset used for the analysis.

A high priority is the data mining and data management process to comply with the newly established General Data Protection Regulation. Privacy protection applies in all stages of data processing: data preprocessing, data analysis, and data publishing [27]. Thus, data went through the process of anonymization and a reference number was assigned to each student.

10.5 Data Analysis Process

The preliminary steps of the analysis included descriptive statistics and the creation of new data tables with binary variables (e.g., pass/fail, participant/non-participant). This is the stage of the formation of a detailed description of the participants, attaching additional features to the nodes, in order to follow the analysis of the interaction network.

There is a threefold benefit of using Social Network Analysis in educational data. Firstly, the visualization of the network, that allows the investigation of the relations in the forum community, the type and the strength of the bonds between participants, and the positions of its members. Secondly, metrics about each participant and the complete network accurately determine the features of the participants and the structure of their community. Different roles and attributes that constitute meaningful information about the participants' behavior can be identified. Thirdly, metrics that were derived from SNA provide rich information and can be used for further analysis (Fig. 10.1).

The main characteristics of the students' community that emerged from the descriptive analysis are presented in Table 10.1. Hereupon, the overall academic performance of the students was seen in the context of different features that possibly affect it. The final grade is considered to be the most typical metric of students' performance. Students of HOU in order to pass the course have to have a minimum score of 50% in the final exams. Additionally, in case of failure or absence, they have a second chance in the re-examination. Therefore, a cross-tabulation was conducted between students' final achievement (the binary variable "pass or fail") and three variables ("meeting group" depending on which of the seven groups a student belongs, "e-group" which is the binary grouped variable of the groups that have online meetings and the groups that have face to face meetings, and "forum participant" that is also a binary variable depending on whether a student participated in the forum or not). Results revealed a statistically significant difference ($p < 0.01$) in students' success for the students that participated in the forum, while the results did not vary significantly within different groups or whether students were participating in the online meetings or the face-to-face meetings.

Therefore, data were modified to fit Gephi's requirements into nodes' and edges' tables and were loaded in the application. Force Atlas algorithm was used to achieve

Table 10.1 Basic information about the students

Number of students	175
Number of academic staff	10
Forum participants (students)	49
Number of students in the online meeting groups	135
Number of students in the f2f meeting groups	40
Forum participation rate	28%
Number of posts	1309
Number of threads	179
Average number of posts per participant	22.2

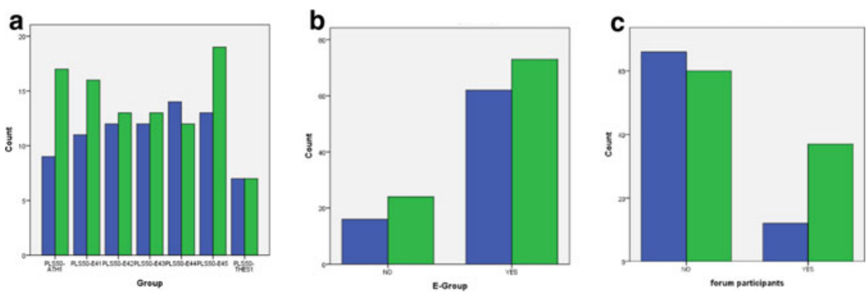


Fig. 10.1 **a** Students' achievement per meeting group, **b** Students' achievement: online and face to face groups, **c** Students' achievement: forum participants and participants (green: pass, blue: fail)

a readable visualization with no overlapping nodes and a minimum number crossing edges based on gravity, repulsion, and inertia [2]. Subsequently, certain partition and ranking methods were applied to assign different colors and magnitude to nodes and edges according to chosen variables and allowing multiple visualizations of the same network, highlighting different features each time (Figs. 10.2 and 10.3).

Fifteen variables were chosen to be included in the PCA that constitutes the next step of the analysis. The grades of the 6 written assignments (variables: WA_1, WA_2, WA_3, WA_4, WA_5, WA_6), the final grade, the number of views, and seven more network metrics (degree, weighted degree, betweenness centrality, harmonic closeness centrality, eigenvector centrality, hub, and eccentricity). Although in the first steps of the analysis all of the participants were included, for PCA the academic staff was excluded for two main reasons:

(a) Students and tutors belong to different groups of participants, with different features and behavior. The scope of this research is to investigate students' actions and reveal latent characteristics that hopefully will be used to improve the educational process. The investigation of tutors' behavior demands a different methodological approach.

(b) Seven of the variables chosen for the analysis do not apply in the case of tutors.

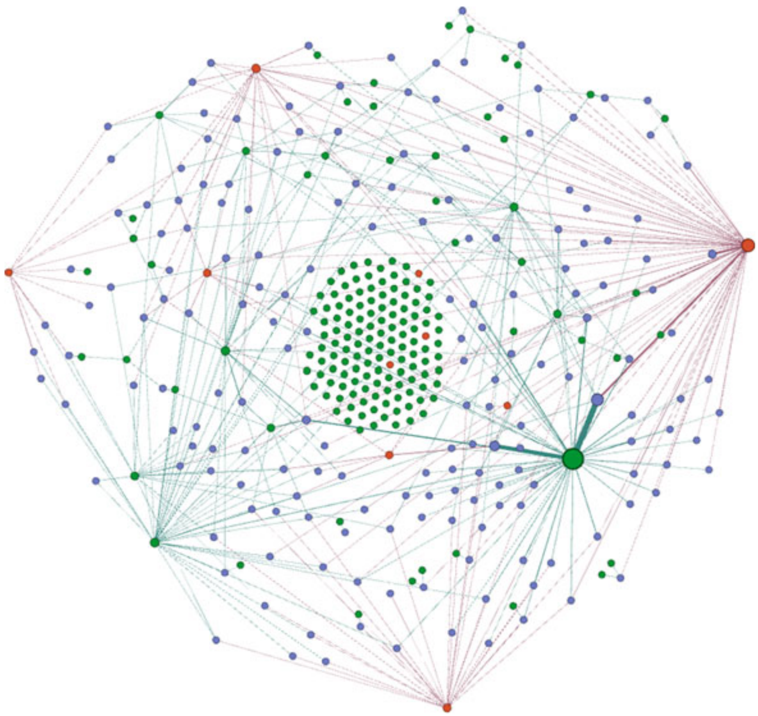


Fig. 10.2 The participants' network annotated by the node's type and weighted degree (purple nodes: threads, green nodes: students, orange nodes: tutors)

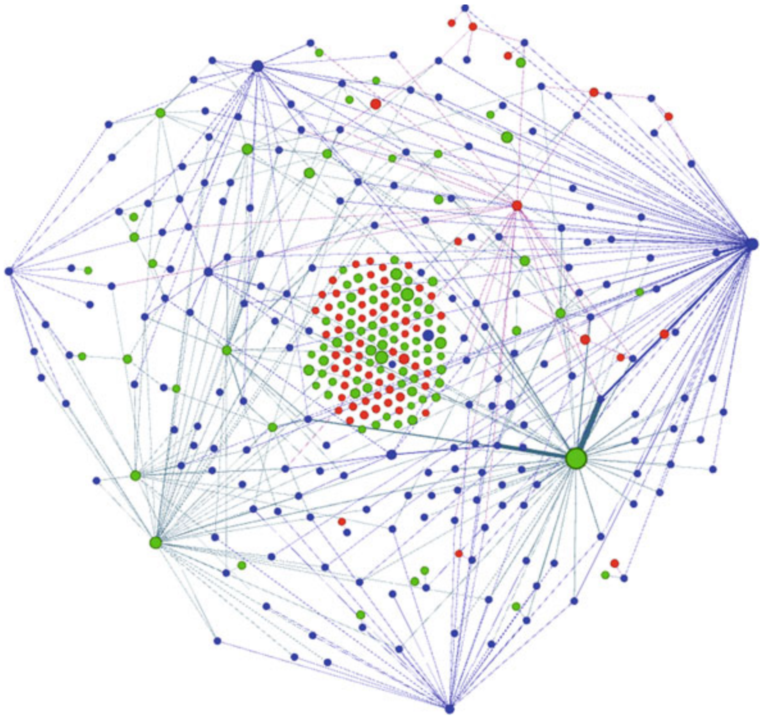


Fig. 10.3 The participant's network annotated by final exam's result and views count

As a last step of the proposed methodology, the factor scores that emerged from the PCA were saved as variables and were used to conduct hierarchical cluster analysis and graphical representation. Briefly, the methodological steps that describe our experimental evaluation are technically the following:

i. Retrieve log files from forum activity in Moodle Platform
ii. Anonymize data
iii. Clear data and keep only every event's id. Each student is represented by a unique id number
iv. Create edges files and nodes files with nodes annotation
v. Import data to Gephi
vi. Run Force Atlas algorithm for network formation
vii. Run statistical measures for the bimodal network
viii. Use partition to format the network
ix. Export results containing network measures
x. Use the new dataset for further analysis: descriptive statistics, cross-tabulations, distributions, correlations, clustering, and principal components analysis

10.6 Explicit and Latent Characteristics of the Students' Community

The results can be grouped into four levels deriving from the methodology, presented above:

a. Descriptives and Cross tabulations
b. SNA with Gephi software and metrics distribution
c. Correlations
d. PCA and clustering

10.6.1 The Descriptive Features of Students' Community

The main characteristics of the students' community that emerged from the descriptive analysis are presented in Table 10.1. Hereupon, the overall academic performance of the students was seen in the context of different features that possibly affect it. The final grade is considered to be the most typical metric of students' performance. Students of HOU in order to pass the course have to have a minimum score of 50% in the final exams. Additionally, in case of failure or absence, they have a second chance in the re-examination. Therefore, a cross-tabulation was conducted between students' final achievement (the binary variable "pass or fail") and three variables ("meeting group" depending on which of the seven groups a student belongs, "e-group" which is the binary grouped variable of the groups that have online meetings and the groups that have face to face meetings, and "forum participant" that is also a binary variable depending on whether a student participated in the forum or not). Results revealed a statistically significant difference ($p < 0.01$) in students' success for the students that participated in the forum, while the results did not vary significantly within different groups or whether students were participating in the online meetings or the face-to-face meetings.

10.6.2 Social Network Analysis and Distributions

The second level of analysis provided information-rich graphs along with important metrics about the social aspect of learning. The first network's graph (Fig. 10.2) presents the interaction network that contains two types of nodes. Participant-nodes and threads-nodes (purple dots). Participants can either be students (green dots) or tutors (orange dots). There is also a ranking in the nodes' magnitude by their weighted degree (min 10-max 30) that indicated their overall participation. It is obvious that some central nodes gather around them lower degree nodes. Also, there is a very distinct group of disconnected nodes in the center of the network. These are the students who don't participate in the forum community.

In Fig. 10.3 a different partition has been implemented. Green nodes represent students that passed the course, orange nodes represent students who failed and blue nodes represent tutors of discussion threads. Nodes' magnitude depends on views ranking (min 10-max 30). The majority of active students passed the course. On the other hand, some of the inactive students have high views count. That means that although they don't participate in the forum community by posting or replying to the discussion, they read the posts of their peers.

Network metrics provide a more accurate image of the interaction. In Table 10.2 the characteristics of the ten more active forum participants (by descending value of weighted degree) are presented. The most active participant is a student with a significantly higher number of posts than all the other participants. It is worth noticing that even though Std_18 has posted far more messages and had much more views than the second more active participant (Tutor_1), two important network metrics tell a different story. The betweenness centrality of Tutor_1, which indicates the mediative role of a node, is higher. Also, the eigenvector centrality of Tutor_1 is greater than the eigenvector centrality of Std_18, meaning that Tutor_1 has a more strategic position in the network, therefore, is a highly influential node.

Participants' Degree (Fig. 10.4) and Weighted Degree follow a power-law distribution. Additionally, most participants have a relatively low Betweenness centrality, indicating that there are a few nodes (Tutor_1, Std_18, Std_51) in a mediative role in students' collaboration community (see Table 10.1).

Most of the participants had up to 1000 views during the academic year. However, there was a small number of participants with higher views number. It is worth noticing that a specific student had over 5000 views at the same time where the average number of his/her peers, including the academic staff, was approximately 430 views. The larger number of participants with low views count is consistent with the relatively low forum participation rate (Table 10.1). The visualization of

Table 10.2 Characteristics of top ten more active forum users

Participant	Degree	Weighted degree	Harmonic closeness centrality	Eigenvector centrality	Betweenness centrality	Views	Final grade
Std_18	57	483	0,49	0,76	6.939,39	5139	8
Tutor_1	68	209	0,55	0,92	11.505,06	1652	N/A
Std_51	42	68	0,46	0,55	5.176,13	1771	8
Std_46	21	63	0,39	0,25	1.604,65	791	7,7
Tutor_5	23	56	0,40	0,25	2.679,92	1510	N/A
Std_43	21	41	0,39	0,23	2.152,22	1006	0
Tutor_6	28	40	0,39	0,27	2.421,97	605	N/A
Tutor_9	10	30	0,35	0,13	461,89	602	N/A
Std_9	7	27	0,33	0,07	731,39	629	6,7
Tutor_7	8	26	0,32	0,05	569,19	956	N/A

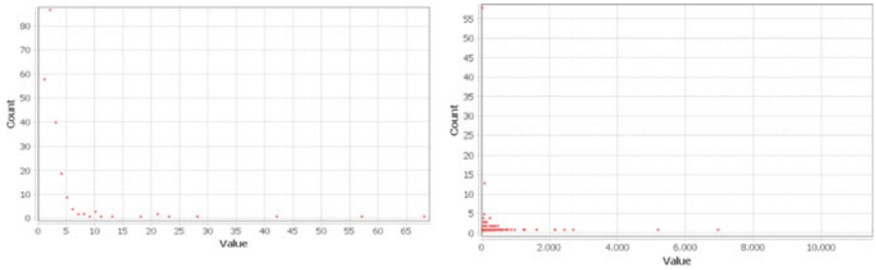
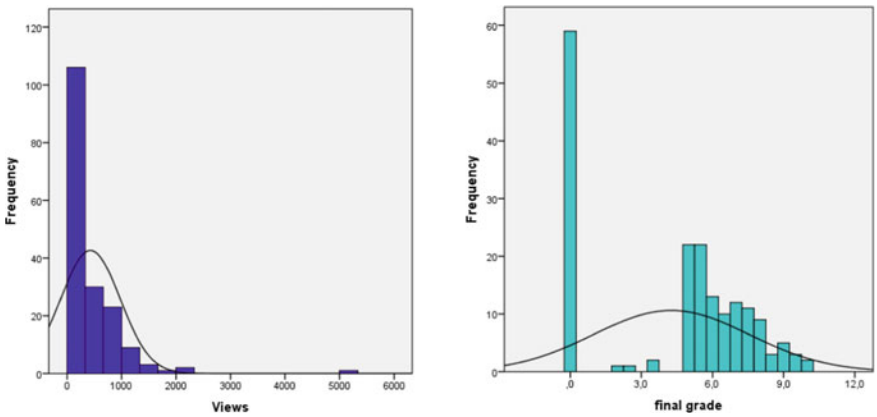


Fig. 10.4 Degree Distribution (Left), Betweenness centrality Distribution

the views counts also follows a Power Law distribution. The distribution of the final grade was also visualized (Fig. 10.5).

The final grade is the highest of the grades of the final exams and re-examination. 59 students are appearing to have a final grade equal to zero. This number represents the students who did not show up in any of the two examinations. The majority of them (61%) did not hand over written assignments 4, 5, and 6, proving that they practically dropped out of the course earlier, in the mid academic year. Additionally, some of the students fail to achieve an average grade of 5/10 in the 6 written assignments resulting in their exclusion from the final examination.



Mean=429,38
Std. Dev.=545,619

Mean=4,27
Std. Dev.=3,29

Fig. 10.5 The distribution of views count (left), and the distribution of students' final grade (right)

10.6.3 Correlations

In the next level of the analysis, the correlation of students' grades with variables that describe their online activity and their position in the forum community revealed some interesting results. There was a strong positive correlation between the grades of the 2nd WA ($r = 0{,}597$, $p < 0{,}05$) and the final grade and a moderate positive correlation between the grades of the 1st ($r = 0{,}496$, $p < 0{,}05$), 3rd ($r = 0{,}451$, $p < 0{,}05$), 4th, ($r = 0{,}466$, $p < 0{,}05$), and 5th WA ($r = 0{,}487$, $p < 0{,}05$), and the final grade. This result signifies that the 2nd WA is the most representative of the final achievement. There was no significant correlation between the grade of the 6th WA and the final grade ($p > 0{,}05$). This, seemingly contradictory, result can be justified by the course's restrictions on participation in final exams. Many students who have ensured the right of participating in the final exam (that is an average grade of 5/10 in the WA) already in the 5th WA, minimize their effort in the 6th WA.

The views number also is moderately correlated to the final grade of the students ($r = 0{,}298$, $p < 0{,}05$). The position of the participants in the communication network does not seem to affect their final grades. It has to be noted that there were no structured learning activities given to the students that included forum interaction. In this sense, forum interaction is not directed linked to their academic performance. The instructional design significantly affects the expected results of SNA. In other words, a discussion forum where students have to complete certain learning tasks is expected to reflect the academic characteristics of the participants. However, in this case, where the discussion forum that is used for communication not restricted by topic, and does not yield grading rewards, the network structure reveals social characteristics rather than academic.

Although the final grade isn't related to network measures, the third (WA_3) and the sixth written (WA_6) assignment are. The WA_3 is moderate negatively correlated ($r = -0{,}360$, $p < 0{,}05$) to eccentricity. Thus, most peripheral nodes had lower grades in the third written assignment than their most central peers. Interestingly, the sixth written assignment, although does not reflect the final achievement, is positively correlated with two important indices of the network: eigenvector centrality ($r = 0{,}287$, $p < 0{,}05$) and betweenness centrality ($r = 0{,}302$, $p < 0{,}05$). As was mentioned above, the WA_6 differs from the previous assignments because of the exam's participation restriction. Therefore, two polar groups of students were formed. The high-graded students who already established the minimum 5/10 and chose to minimize their effort, and the low-graded students who are at risk of losing the right to participate in the exams, so they maximize their effort. As a result, they address to the discussion forum their questions, trying to get all the help that they need to raise their grades. High betweenness centrality indicates interaction with many different inner groups and high eigenvector centrality signifies communication with highly influence participants, where, in most cases, are tutors answering questions.

Table 10.3 KMO and Bartlett's Test

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0,754
Bartlett's Test of Sphericity	Approx. Chi-Square	4190,699
	Df	105
	Sig	0,000

10.6.4 Factor Analysis and Clustering

Variables concerning students' performance (WA_1, WA_2, WA_3, WA_4, WA_5, WA_6, and final grade) along with variables related to students' online activity (views) and their position in the communication network (Degree, Weighted Degree, Eccentricity, Betweenness centrality, Harmonic closeness centrality, Hub and Eigenvector centrality) were imported for Principal Component Analysis. Firstly, a Kaiser–Meyer–Olkin (KMO) and Bartlett's test was conducted to investigate the adequacy of our dataset for factor analysis through PCA. KMO score (Table 10.3) can be considered as middling suitable for PCA. Bartlett's test results (Table 10.3) indicate that factor analysis can be used in these variables, as there are interrelated to a significant level.

Three major components were found, explaining approximately 79% of the total variance of the sample (Table 10.4). In Fig. 10.6 the scree plot of the eigenvalues of each component is presented. Only three of the eigenvalues are greater than 1, the rest of them explain a very small proportion of the variance, less than each initial variable explained, hence they can be rejected.

In order to explain and interpret the results of PCA in the educational context the rotated component matrix is used (Table 10.5). Varimax with Kaiser Normalization was the rotation method that converged in four iterations. Each of the three components is most highly correlated with a different group of variables that reflects another aspect of students learning presence. Component 1, which explains 43,65% of the variance, is highly correlated with metrics that concern forum interaction (views, degree, weighted degree, betweenness centrality, hubs, and eigenvector centrality). This component is about the social status of the students in the learning community that is expressed through the discussion forum. It sums up indicative features of the influence, the collaboration, the extroversion, and the participation of peers. Component 2, which explains 25,73% of the variance, is highly correlated with all the grading variables (WA_1, WA_2, WA_3, WA_4, WA_5, WA_6, and Final

Table 10.4 Total variance explained

Component	Initial eigenvalues		
	Total	% of Variance	Cumulative %
1	6,548	43,651	43,651
2	3,859	25,725	69,375
3	1,452	9,679	**79,054**

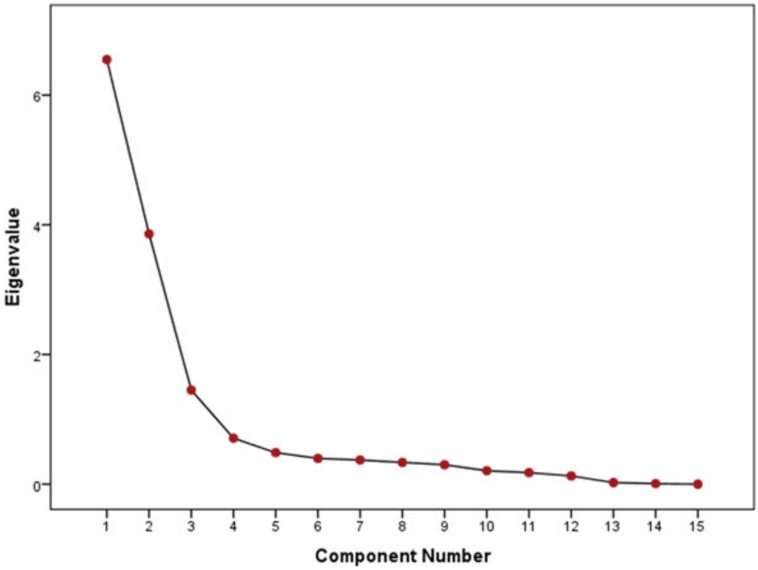


Fig. 10.6 Scree Plot

Table 10.5 Rotated component matrix

Variable	Component 1	Component 2	Component 3
WA_1	0,009	**0,698**	0,209
WA_2	0,030	**0,772**	0,144
WA_3	0,084	**0,798**	0,070
WA_4	0,086	**0,886**	0,003
WA_5	0,105	**0,847**	0,080
WA_6	0,165	**0,753**	-0,076
Final grade	0,087	**0,826**	0,046
Views	**0,734**	0,414	0,035
Degree	**0,950**	0,086	0,232
Weighted degree	**0,925**	0,031	0,032
Eccentricity	0,138	0,151	**0,923**
Betweenness centrality	**0,969**	0,060	0,106
Harmonic closeness centrality	0,345	0,109	**0,879**
Hub	**0,977**	0,062	0,160
Eigenvector centrality	**0,967**	0,072	0,188

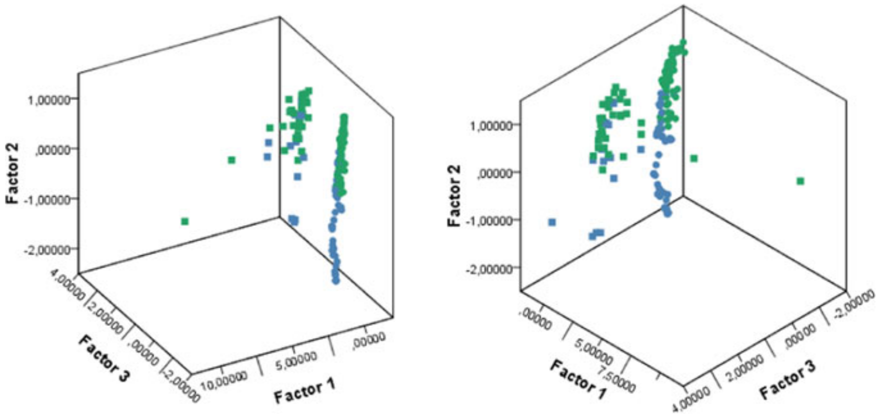


Fig. 10.7 The 3D scatterplot of the three main components from two different angles (Partition: Green: Pass, Blue: Fail, Square: Forum Participant, Round: Non-participant)

grade). Thus, it reflects the academic profile of the students. Finally, component 3 that explains 9,68% of the variance, is highly related to two network measures: eccentricity and harmonic closeness centrality. These measures denote peripheral nodes in the network, therefore component 3 indicative for students who participate but tend to stay aside, in a loose engagement with the discussion community.

The visualization of students' eigenvectors can provide further explainable information. In Fig. 10.7, two different views of the three-dimensional graph are presented. Nodes are parted by color and by shape. The color defines whether the student passed (green nodes) or failed (blue nodes) the course. The shape separates forum participants (square nodes) from non-participants (round nodes). As it is shown in both graphs, the two main clusters corresponding to the two different groups of students. Those that participate in the forum community and collaborate online and those who see the educational process as a personal experience and do not have an online social presence. This result highlights the online social presence as the most important difference within students' behavior.

The clusters that emerged from the Hierarchical Cluster Analysis (Fig. 10.8) denoted two main groups that concentrate the majority of the students and three other clusters with outliers who present some notable features. Hence, cluster 1 contains the students with a low online presence (non-participants in the forum and low views count). Custer 2 contains students who participated actively in the forum community. Cluster 3 contains students who followed a common path: initially participated and handed over the first one or two written assignments gaining high grades, however, at a later point, they dropped out of the course. Clusters 4 and 5 contain one node. Their profile explains their position in a different group as it is about the two most active students in the forum community. Both of them have excellent grades and over 1500 views. Additionally, they hold a central position in the network with high values in nearly all centrality measures. However, they are placed in different groups therefore

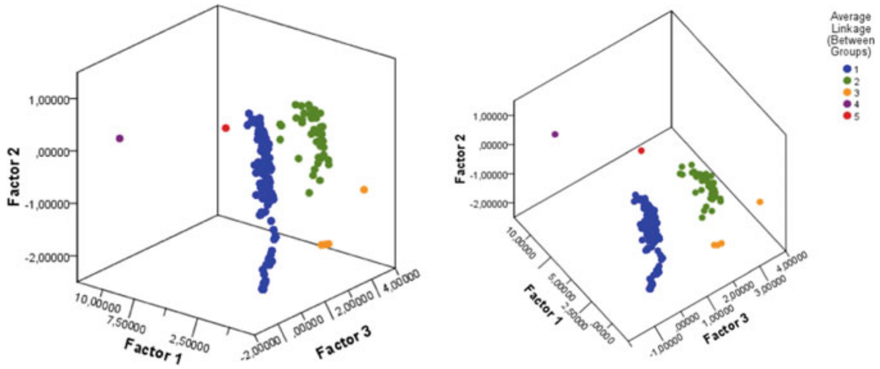


Fig. 10.8 The 3D scatterplot of the three main components from two different angles colored by clustering group

there has to be a non-negligible difference between them. Their main difference relies on the number of views (5139 for cluster 4 and 1771 for cluster 5) and in their weighted degree especially compared to their degree (57 and 483 respectively, for cluster 4 and 42 and 68 respectively, for cluster 5). The difference between these numbers in a bimodal participant-thread network is the following: The first student (cluster 4) posted in 57 threads 483 times. That means that he/she posted approximately 8,5 times in each thread, while the second student (cluster 5) posted approximately 1,6 messages per thread. That explains why cluster 5 is located near the clusters of his/her peers and cluster 4 is relatively isolated.

10.7 Conclusions

The abrupt shift of many conventional institutions that moved their courses online without a thorough educational design, led Distance Education experts to make the distinction between Distance Education and "what is being practiced during the interruption of education, which can better be described as emergency remote education" [6]. A new challenge is therefore created for Distance Education institutions to lead the way towards "real" Distance Education rather than urged online courses, through quality students' support. Thus, in an intriguing period for Higher Education, where Distance Learning is coping to establish its effectiveness, LA can provide answers to a series of aspects of teaching and learning such as students' support, instructional design, policymaking, and educational leadership. While technology is increasingly providing tools the appropriate methodology to incorporate them in educational research and implementation is needed. This chapter describes a methodology that was implemented in data from a postgraduate distance learning course for revealing latent students' characteristics, aiming to improve the educational process. Data from the online platform were analyzed and the network of students' interaction was created. It was shown that a combination of network metrics along with academic performance indices provided a detailed insight into the learning community and for individual students as well. Some of the results became obvious in the first steps of the analysis. However, PCA revealed three main factors: the "social status" factor, the "academic performance" factor, and the "loose engagement" factor.

The difficulties arising from the lack of physical presence in Distance Education can be addressed by effectively leveraging available data. Although several Learning Analytic approaches have been proposed, they usually focus separately on academic performance indices or in social network metrics. Additionally, SNA is used as the final step of the analysis, restricting its contribution in producing metrics to describe students' community. Instead, we proposed a methodology that goes beyond simple description and uses SNA as a pre-processing step to retrieve metrics that would enrich our dataset preparing it for PCA and Clustering. This way, the clusters that emerge group students by latent traits, allowing tutors to focus on features that matter the most in the learning process. In our experiments, among others, cluster analysis identified a group of students in danger of dropping out who need further support (cluster 3), outliers that could disturb the collaborative spirit in the forum community (cluster 4), and also students who need external motivation to improve their effort levels (cluster 1).

As was mention above, educational research is a complicated, multi-dimensional field with various aspects that cannot all be captured by log file data. Therefore, we consider that the lack of personal, socio-economical, and cultural data along with data from previous learning experiences is the main limitation of our research. This is a difficult barrier to overcome, not only for practical but mainly for privacy reasons.

A student's learning experience rarely starts and ends in one course. An integrative, complex, and holistic view is needed to understand the dynamics outside of a specific course that influence learning performance [13]. Therefore, we plan for the future to test this methodology in different datasets to compare results and discover patterns. Additionally, time series analysis and content analysis of the discussions should provide a deeper understanding of the interaction that takes place within the educational context.

References

1. K. Amano, S. Tsuzuku, K. Suzuki, N. Hiraoka, Learning together for mastery by using a discussion forum, in *2019 International Symposium on Educational Technology (ISET)*, pp. 165–169. IEEE (2019)
2. M. Bastian, S. Heymann, M. Jacomy, Gephi: an open-source software for exploring and manipulating networks. Icwsm **8**(2009), 361–362 (2009)
3. V. Batagelj, A. Mrvar, Pajek-program for large network analysis. Connections **21**(2), 47–57 (1998)
4. S.P. Borgatti, M.G. Everett, Network analysis of 2-mode data. Social networks **19**(3), 243–270 (1997)
5. S.P. Borgatti, M.G. Everett, L.C. Freeman, Ucinet for windows: software for social network analysis. Harvard, MA: Analyt. Technol., 6 (2002)

6. A. Bozkurt, I. Jung, J. Xiao, V. Vladimirschi, R. Schuwer, G. Egorov, ... & V. Rodes, A global outlook to the interruption of education due to COVID-19 Pandemic: navigating in a time of uncertainty and crisis. Asian J. Dist. Educ. **15**(1), 1–126 (2020)
7. K.L. Cela, M.Á. Sicilia, S. Sánchez, Social network analysis in e-learning environments: a preliminary systematic review. Educ. Psychol. Rev. **27**(1), 219–246 (2015)
8. J. Chen, J. Fagnan, R. Goebel, R. Rabbany, F. Sangi, M. Takaffoli, ... & O. Zaiane, Meerkat: Community mining with dynamic social networks, in 2*010 IEEE International Conference on Data Mining Workshops*, pp. 1377–1380. IEEE (2010)
9. C.G. Chiru, T. Rebedea, A. Erbaru, Using pagerank for detecting the attraction between participants and topics in a conversation, in *WEBIST* (1), pp. 294–301 (2014)
10. T.K. Chiu, T.K. Hew, Factors influencing peer learning and performance in MOOC asynchronous online discussion forum. Australasian J. Educ. Technol. **34**(4) (2018)
11. S. Crossley, M. Dascalu, D.S. McNamara, R. Baker, S. Trausan-Matu, *Predicting success in massive open online courses (MOOCs) using cohesion network analysis* (International Society of the Learning Sciences, Philadelphia, PA, 2017)
12. M.G. Csardi, Package 'igraph.' Last accessed **3**(09), 2013 (2013)
13. S. Dawson, S. Joksimovic, O. Poquet, G. Siemens, Increasing the impact of learning analytics, in *Proceedings of the 9th International Conference on Learning Analytics & Knowledge*, pp. 446–455 (2019)
14. L. De-Marcos, E. García-López, A. García-Cabot, J.A. Medina-Merodio, A. Domínguez, J.J. Martínez-Herráiz, T. Diez-Folledo, Social network analysis of a gamified e-learning course: small-world phenomenon and network metrics as predictors of academic performance. Comput. Hum. Behav. **60**, 312–321 (2016)
15. R. DeMillo, New ecosystems for higher education and what they mean for accreditation and assessment. *WASC Concept Papers, Second Series: The Changing Ecology of Higher Education.* WASC (2013)
16. S. Downes, Ethical codes and learning analytics. Hum. Artif. Intell. Soc. Future (2020)
17. R. Ferguson, S.B. Shum, Social learning analytics: five approaches, in *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, pp. 23–33. ACM (2012)
18. R. Ferguson, D. Clow, D. Griffiths, A. Brasher, Moving forward with learning analytics: expert views. J. Learn. Analyt. **6**(3), 43–59 (2019)
19. L.C. Freeman, A set of measures of centrality based on betweenness. *Sociometry*, pp. 35–41 (1977)
20. C. Giovannella, F. Scaccia, E. Popescu, A PCA study of student performance indicators in a Web 2.0-based learning environment, in *2013 IEEE 13th International Conference on Advanced Learning Technologies*, pp. 33–35. IEEE (2013)
21. A.F. Gkontzis, S. Kotsiantis, D. Kalles, C.T. Panagiotakopoulos, V.S. Verykios, Polarity, emotions and online activity of students and tutors as features in predicting grades. Intell. Decis. Technol., 1–28 (2020)
22. Á. Hernández-García, I. Suárez-Navas, GraphFES: A web service and application for Moodle message board social graph extraction, in *Big Data and Learning Analytics in Higher Education*, pp. 167–194. Springer, Cham (2017)
23. S.K. Jan, P. Vlachopoulos, Social network analysis: a framework for identifying communities in higher education online learning. Technol. Knowl. Learn. **24**(4), 621–639 (2019)
24. V. Kagklis, A. Karatrantou, M. Tantoula, C.T. Panagiotakopoulos, V.S. Verykios, A learning analytics methodology for detecting sentiment in student fora: a case study in distance education. Europ. J. Open Dist. E-Learn. **18**(2), 74–94 (2015)
25. A. Klašnja-Milicevic, M. Ivanovic, Learning analytics-new flavor and benefits for educational environments. Inform. Educ. **17**(2), 285–300 (2018)
26. J.M. Kleinberg, R. Kumar, P. Raghavan, S. Rajagopalan, A.S. Tomkins, The web as a graph: measurements, models, and methods, in *International Computing and Combinatorics Conference*, pp. 1–17. Springer, Berlin, Heidelberg (1999)
27. K.H. Kyritsi, V. Zorkadis, E.C. Stavropoulos, V.S. Verykios, Privacy issues in learning analytics. Blended Online Learn., 218 (2018)

28. D. Laurillard, E. Kennedy, T. Wang, How could digital learning at scale address the issue of equity in education? Learning at scale for the global south. *Quezon City, Philippines: Foundation for Information Technology Education and Development* (2018)
29. A. Lionarakis, The theory of distance education and its complexity. Europ. J. Open Dist. E-Learn. **11**(1) (2008)
30. E. Lotsari, V.S. Verykios, C. Panagiotakopoulos, D. Kalles, A learning analytics methodology for student profiling, in *Hellenic Conference on Artificial Intelligence*, pp. 300–312. Springer, Cham (2014)
31. K. Mangaroska, M. Giannakos, Learning analytics for learning design: a systematic literature review of analytics-driven design to enhance learning. IEEE Trans. Learn. Technol. **12**(4), 516–534 (2018)
32. M. Marchiori, V. Latora, Harmony in the small-world. Physica A **285**(3–4), 539–546 (2000)
33. L. Metcalf, W. Casey, Cybersecurity and applied mathematics. Syngress (2016)
34. C. Perez, R. Germon, Graph creation and analysis for linking actors: application to social data, in Automating *Open Source Intelligence*, pp. 103–129. Syngress (2016)
35. S. Prabhakar, O.R. Zaiane, Learning group formation for massive open online courses (MOOCs). *International Association for Development of the Information Society* (2017)
36. R. Rabbany, M. Takaffoli, O.R. Zaiane, Social network analysis and mining to support the assessment of on-line student participation. SIGKDD Explor. **13**, 20–29 (2012)
37. Y.B. Rajabalee, M.I. Santally, Learner satisfaction, engagement and performances in an online module: Implications for institutional e-learning policy. Educ. Inform. Technol., 1–34 (2020)
38. C. Reffay, T. Chanier, How social network analysis can help to measure cohesion in collaborative distance-learning, in *Designing for Change in Networked Learning Environments*, pp. 343–352. Springer, Dordrecht (2003)
39. J.S. Sereni, M. Krnc, R. Škrekovski, Z.B. Yilma, Eccentricity of networks with structural constraints. Discussiones mathematicae, 1–22 (2018)
40. K. Sharma, Z. Papamitsiou, M. Giannakos, Building pipelines for educational data using AI and multimodal analytics: a "grey-box" approach. Br. J. Edu. Technol. **50**(6), 3004–3031 (2019)
41. G. Siemens, Learning analytics: envisioning a research discipline and a domain of practice, in *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, pp. 4–8 (2012)
42. S. Slade, A. Tait, Global guidelines: ethics in learning analytics (2019)
43. C. Sternitzke, A. Bartkowski, R. Schramm, Visualizing patent statistics by means of social network analysis tools. World Patent Inf. **30**(2), 115–131 (2008)
44. B. Sun, M. Wang, W. Guo, The influence of grouping/non-grouping strategies upon student interaction in online forum: a social network analysis, in *2018 International Symposium on Educational Technology (ISET)*, pp. 173–177. IEEE (2018)
45. J.P.L. Tan, E. Koh, Situating learning analytics pedagogically: towards an ecological lens. Learn. Res. Pract. **3**(1), 1–11 (2017). https://doi.org/10.1080/23735082.2017.1305661
46. A. Traxler, A. Gavrin, R. Lindell, Networks identify productive forum discussions. Phys. Rev. Phys. Educ. Res, **14**(2), 020107 (2018)
47. R. Tsoni, E. Sakkopoulos, C.T. Panagiotakopoulos, S.V. Verykios, On the equivalence between bimodal and unimodal students' collaboration networks in distance learning. J. Intell. Decis. Technol. (2021)
48. R. Tsoni, V.S. Verykios, Looking for the "more knowledgeable other" through learning analytics, in *Proceeding of 10th International Conference in Open and Distance Learning* **10**(3A), 239–251 (2019)
49. R. Tsoni, E. Paxinou, E.C. Stavropoulos, C. Panagiotakopoulos, V. Verykios, Looking under the hood of students' collaboration networks in distance learning. *The Envisioning Report for Empowering Universities* (2019)
50. R. Tsoni, C. Samaras, E. Paxinou, C. Panagiotakopoulos, V.S. Verykios, From analytics to cognition: expanding the reach of data in learning, i*n Proceedings of CSEDU* (2019)
51. R. Tsoni, E.C. Stavropoulos, V. Verykios, Leveraging learning analytics with the power of words. *The Envisioning Report for Empowering Universities*, 24 (2019)

52. UNESCO, COVID-19 Educational disruption and response (2020). https://en.unesco.org/covid19/educationresponse
53. O. Viberg, M. Hatakka, O. Bälter, A. Mavroudi, The current landscape of learning analytics in higher education. Comput. Hum. Behav. **89**, 98–110 (2018)
54. N. Yusof, A.A. Rahman, Students' interactions in online asynchronous discussion forum: a social network analysis, in *2009 International Conference on Education Technology and Computer*, pp. 25–29. IEEE (2009)

Chapter 11
Smart Technology in the Classroom: Systematic Review and Prospects for Algorithmic Accountability

Maria Ovchinnikova, Daniel Ostnes, Arian Garshi, Malin Wist Jakobsen, Jørgen Nyborg-Christensen, and Marija Slavkovik

Abstract Smart technologies, which include but is not limited to artificial intelligence (AI) algorithms, have emerged in the educational domain as a tool to make learning more efficient. Different applications for mastering particular skills, learning new languages, and tracking their progress are used by students. What is the effect on students from using this smart technology? We conducted a systematic review to understand the state of the art. We explored the literature in several subdisciplines: wearables, child psychology, AI and education, school surveillance, and accountability. Our review identified the need for more research for each established topic. We managed to find both positive and negative effects of using wearables, but cannot conclude if smart technology use leads to lowering the student's performance. Based on our insights we propose a framework to effectively identify accountability for smart technology in education.

Keywords Education · AI technologies · Surveillance · Wearables in classroom · Accountability

11.1 Introduction

Today children and students are exposed to more technology than at any other point of history [1]. This applies to the use of technology for both entertainment and education. Smart technology is a generic term used to denote technology that is one or all of: ubiquitous, invisible and capable of some type of artificial intelligent behaviour. It is the use of smart technology in education that we are concerned with

M. Ovchinnikova · D. Ostnes (✉) · A. Garshi · M. W. Jakobsen · J. Nyborg-Christensen · M. Slavkovik
Department of Information Science and Media Studies, University of Bergen, Fosswinckels gate 6, 5007 Bergen, Norway

M. Slavkovik
e-mail: marija.slavkovik@uib.no

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_11

here. Smart technology has mostly been evaluated in terms of how efficient it makes learning, how easy it is to use, and how entertaining the applications are.

However, as the use of smart technology is becoming widespread, there is also a need to study the impacts that these technologies may have on students. We choose to work with the term smart technology rather than artificial intelligence (AI) because the use of the term AI is very inconsistent and poorly defined: at times technology that is not AI is called such and at others technology which is AI is not called by its name. Topics that are of interest to education include ambient computing technology, wearable technology and surveillance technology, and fit nicely under smart technology but not under AI. Under smart technology in education, we consider learning applications, software, and tutoring systems as well as different types of wearables that can track student's activity and surveillance technology that is used. How ethical is it to use technology with undocumented impact for students while they are in a class? Is this technology necessary? Is its efficiency for the learning process sufficient justification for its use? We are here concerned with the state of the art in smart technology in the classroom and its algorithmic accountability.

We aim to understand the state of the art in accountability in the context of smart technology use in education, and to accomplish this goal, we conduct a systematic literature review. Since it is difficult to cut a clean timeline as to when smart technologies begin to be used in education, we have decided to 'cast a wide net'. This means we do not put any time limits on publication dates of articles to consider. Having found very little discussion on the accountability of smart technology, we consider articles on artificial intelligence used in education, articles on wearables, articles on use of surveillance in schools and also articles from psychology that treat the topic of surveillance use in schools. We use the insights from the review to understand and outline the perspective for algorithmic accountability of the smart technology used in classrooms.

Articles were identified and collected from Web of Science,[1] Google Scholar,[2] and ACM FaccT Conferences.[3] Our systematic review methodology is based on: (a) proper definition of search strings, (b) article relevancy, (c) topic relevancy, (d) success in producing results for the research questions. The articles ultimately selected for review were split among the co-authors with each reader writing a small summary of the article. The articles were then shared among the readers and their summary was written down following a group discussion. The literature review has shown that the majority of work on the use of smart technology in education mainly focuses on the innovative uses for revolutionizing learning. Comparatively little attention is paid to the possible negative side-effects of constant monitoring. Major areas of concerns in the literature were found to be breach of privacy, surveillance culture and the neglect of self-monitoring practices. The systematic review has also shown relatively little work in accountability in the domain of smart technology

[1] https://apps.webofknowledge.com/.

[2] https://scholar.google.com/.

[3] https://facctconference.org/.

use in education. Students can be young children, which are a vulnerable group and depend on guardianship or authorities to decide for them.

Parents and teachers cannot be expected to understand technical details of all the smart technology that can be used in the classroom. It is therefore important to properly establish rules of accountability in the use of wearable technology in education. The consequences of the use of wearables in the classroom are important to identify, and this includes identification of accountable parties to mitigate harm.

This report is structured as follows: We introduce our methodology in Sect. 11.2, showing our query designs and discussing the limitations of our review. Section 11.3 covers the topic of AI technologies in education, what advantages and disadvantages it brings into the learning process. Section 11.4 presents the concept of surveillance in school. We then look at the psychological effects of being under surveillance, and what issues this might cause in Sect. 11.4.4. Section 11.5 presents the literature on the use of wearables in schools. In each of these sections we summarize the main points from the literature, make our observations and include a discussion as a last subsection called "issues".

In Sect. 11.6 we present the topic of accountability as studied in the field of AI. Using the observations from the previous sections we discuss the needs and possibilities for accountability of smart technology in the classroom. This discussion is aimed to be used as a pointer to researchers who are interested to champion the work in accountability for smart technology in education. Lastly, we draw our conclusions and outline directions for other future work in Sect. 11.8.

11.2 Methodology

The systematic review was conducted by focusing on five topics of interest: AI in education, surveillance in school, wearable technology in school, psychological effects of surveillance, and accountability in AI. We discuss our approach to finding the relevant publications and its limitations. As we discussed in the Introduction, we considered all articles regardless of year of publication. Furthermore, we did not eliminate the so called 'grey literature', e.g., technical reports, opinion papers, governmental reports, etc., from the collected articles. Because the topic of the survey is of interest to many different stakeholders, evaluations are not always done by academic institutions, but they can nonetheless contain important insights.

11.2.1 Query Design

For each of our topics of interest, we designed string queries to produce relevant results. Journal pages and databases that were queried include: Google Scholar, Web of Science and ACM FAccT Conference Papers (2018, 2019 and 2020). Google

Scholar effectively produces results that can be sorted by citation index and publication years. Web of Science is common for scientific and technical articles, hence its inclusion.

The ACM FAccT Conference is a cross-disciplinary conference that focus on fairness, accountability and transparency in socio-technical systems and is thus included for its relevancy to work on accountability. Our queries have the following structure:

[wearables AND school]
["place in schools" wearable technology]
[wearables AND (school OR education OR children)]
[(accountability AND (AI OR artificial intelligence OR autonomous systems))]
[(algorithm OR algorithmic OR algorithms) AND (accountability OR accountable OR accountabilities)]
["effects of surveillance" AND "school" AND "learning" AND "children"]
[(surveillance AND school (school OR education OR students OR student))]
[((camera OR CCTV OR fingerprint OR "facial recognition" OR "metal detector") AND (monitor OR monitoring OR surveillance OR spy OR spying) AND (school OR kindergarten OR university OR college OR education OR student))]
[Biometrics school]
[Biometrics]
[Social issues wearables]
[Issues wearables]
[cctv school]
[("AI" OR "artificial intelligence") AND "education" AND "learning"]
[Intelligent tutoring systems]

Querying through Google Scholar produced results in English, and were sorted by relevance and high citations, but no specific year limit was set. As this is a wide project of multiple fields and mature topics, it is important not to exclude older work that either defined key aspects, or newer work that pushed the state of the art. Google Scholar includes books, direct citations and other reports, hence the queries produce many more results. Some older citations may also be excluded due to lack of tagging to match the produced queries. Web of Science produce lots of content for social sciences and computer science and also calculate an impact factor. The results of WoS are not as vast compared to Google Scholar, thus well-defined queries produce accurate results that were effectively sorted. The ACM FAccT Conference is a computer science conference with focus on Fairness, accountability and transparency in socio-technical systems. All papers produced in the years 2018, 2019 and 2020 have been screened from and identified.

The articles we found were assessed for their relevance through screening title and abstract. We considered a total of 1581 articles. Screening resulted with 84 core articles. We identified additional 15 articles following references. Exclusion of articles occurred either through the preliminary process of identifying core articles, or full reading of the article proved to be unfit for this projects scope. We reviewed

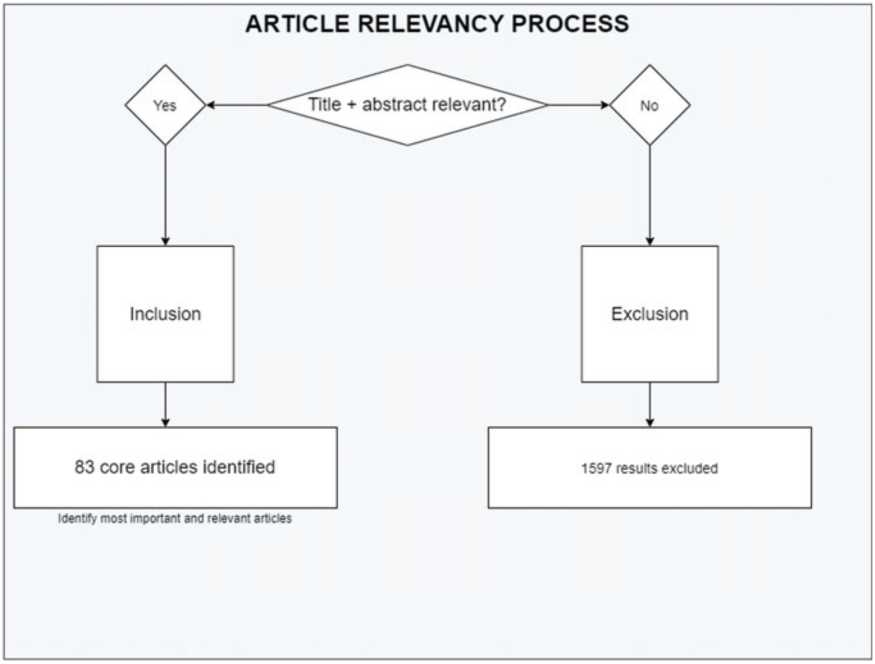


Fig. 11.1 Flowchart of article selection process

99 articles in detail. Figure 11.1 visualize the article relevancy process and feature the article distribution from where they were found.

11.2.2 Query Limitations

We are concerned with the state of the art in accountability of smart technology in the classroom. As this is an emerging topic, research targeting our specific goals are limited. For this reason, we also explored literature that intersects with our topic. We looked at keywords such as "AI", "Surveillance", "Wearables", "Classroom", "Accountability", "Behavior", "Consequences", etc. We acknowledge that there might be some literature that we missed due to the restriction on queried keywords in addition to the volume of research papers that we were able to review.

11.3 AI in Education

In this section we focus on the articles from our survey that reflect on and analyse the use of artificial intelligence in education. We have identified three types of AI technologies used in the classroom and summarise the work reporting on them in turn. First, we look at what advantages AI technologies bring into education. We then discuss the possible issues of accountability and ethics raised using this technology.

11.3.1 AI Technologies Used in the Classroom

There are various ways to use AI in learning: students use virtual classrooms and gain new skills through various applications and educational online games. AI modules and Educational Data Mining techniques can track students' performance in order to provide a better learning experience based on students' needs [2]. The development of such tools and technologies as teaching robots, intelligent tutoring systems (ITSs), and adaptive learning systems significantly change the learning process [3]. The systematic literature review identified three different AI technologies that are being often used in learning: Intelligent Tutoring Systems (ITSs), intelligent support for collaborative learning, and intelligent virtual reality [4]. The benefits that these technologies bring are also discussed.

Intelligent tutoring systems. [5] defines the Intelligent Tutoring System (ITS) as a computer program that is designed to incorporate techniques from AI to provide tutors that know what they teach, who they teach and how to teach. ITSs can perform one or more tutoring functions such as asking questions, assigning tasks, offering hints, providing feedback, or answering questions. These systems also use student input to model the student's cognitive, motivational or emotional states in a multidimensional space [6, 7]. The research on ITS have successfully delivered techniques and systems that provide personalized support for problem-solving activities in a variety of domains (e.g., programming, physics, algebra, geometry, SQL) [8]. Intelligent tutoring systems are able to offer considerable flexibility in the presentation of material and a greater ability to respond to idiosyncratic student needs. In addition, ITSs have been shown to be highly effective at increasing students' performance and motivation [9, 10].

Intelligent support for collaborative learning. The concept of collaborative learning refers to "an instruction method in which students at various performance levels work together in small groups toward a common goal". Thus, the success of one student helps other students to be successful since students are responsible for one another's learning as well as their own [11]. In order to increase the level of the success of the group as well as learning, some approaches based on AI technologies can be useful: for example, virtual agents and adaptive group formation [4]. Virtual agents can play the role of a tutor or a virtual peer which, according to Baylor, increases the motivation of the learners [12]. As for adaptive group formation, this approach helps to form a group best suited for a particular collaborative task using information about participants, for example, students' cognitive level [13].

Virtual reality. Virtual reality (VR) can be seen as an interactive computer-generated experience taking place within a simulated environment. Its primary effect is to place the user into the simulated environment using a head-mounted display. VR requires hardware and software that furnish a sense of immersion, navigation, and manipulation [14].

The main purpose of the use of VR in education is to explore and train practical skills, technical skills, operations, maintenance, and academic concerns [15].

Pantelidis [16, 17] claims that VR grabs and holds the attention of students. They find VR technology exciting and challenging to walk through an environment in three dimensions and interact with it. In addition, VR can more accurately illustrate some features and processes as well as change the way a learner interacts with the subject matter. Using VR in learning encourages active participation rather than passivity.

Hussein and Nätterdal [18] show that there are a variety of possibilities to use VR in education for different purposes. In medicine, VR can allow users to perform tasks that carry safety concerns or cannot be achieved in real life, hence people are able to practice more. In fields of architecture and design, VR technology encourages users to be creative. The use of VR is also able to create interactive environments to teach kids about basic science facts and small lab simulations. Thus, virtual reality provides more opportunities for practice and training.

11.3.2 Issues

Even though applications and learning concepts that are based on AI technologies can have a significant positive effect on education, the use of AI in education brings issues for teachers, students, and researchers [19].

One of the issues mentioned is the need for a comprehensive public policy on AI development. Such public policy will give an opportunity to spread AI research. Today most of the AI products in education come from the private sector. If there is no partnership between state and private companies, public policy will not be able to cope with the speed of innovation. There is a need for such a partnership in order to be able to enhance AI training and research [19].

There is also a concern that AI&Education research does not provide an educational clear pedagogical alternative, besides individual tutoring. There is a specific view of the role of the computer in education: it is considered as a cognitive tool, which performs lower-order tasks and allows the user to concentrate on the more important higher-order thinking. In that case, developing such tools does not really need AI technology to be involved [20].

One of the biggest issues for AI in education is privacy and data collection. People are concerned about how and when their data is collected, and most important for what purposes. Data collection becomes even more complicated in the context of young learners, who, in legal terms, cannot yet provide express consent regarding the collection and use of their personal data [19].

Another issue that AI brings into education is that teachers might not be ready for such technologies. For educators, the use of new applications and ITSs systems in their teaching programs requires a rapid revision of what is taught and how itis presented to take advantage of evolving knowledge in a field where technology changes every few years [21].

11.4 Surveillance in School

Surveillance refers to the continuous observation of a place, person, group or activity in order to gather information, influence and manage individuals. Surveillance in schools has previously been largely the task of the teachers, hall monitors as well as simple attendance lists and grading systems. Technologies such as closed-circuit television (CCTV) cameras, webcams, automated fingerprint identification systems, facial recognition, and metal detectors have seen an exponential growth of use in schools [22].

In 2014, the US market for surveillance cameras, access control equipment and notification systems for schools and colleges was roughly 768 million USD. A large contributor of justification for such spending is the fear of rapid school shootings. For instance, after the 2012 Sandy Hook Elementary School shooting, the schools of Virginia were awarded 6 million USD to pay for video monitoring systems, metal detectors and other security upgrades [23]. Such intense surveillance is argued to create prison-like conditions, especially for students in low-income areas [24].

We are interested in which technologies exist and how they are currently used by schools and educators. Although the surveillance of students is an international matter, the assessment of such technologies is based on their use in the United States and the United Kingdom due to the abundance of gathered data and research in the regions. Since surveillance can have a measurable effect on the surveyed, we include literature from psychology that specifically considers surveillance in the classroom.

11.4.1 Video Surveillance

CCTV cameras collect images through cameras and transfer the footage to a monitoring where they are available to be reviewed [25]. They present one of the most common surveillance methods in the schools internationally. An estimated 85% of secondary schools in the United Kingdom, and two thirds of high schools in the United States use some form of CCTV systems [26].

The motivation of implementing CCTV is primarily crime prevention and detection as well as to detect vandalism, bullying, smoking, monitoring staff performance and to prevent intrusions by strangers [27]. However, it is common for schools to be careless about the privacy of students and have been found to not be incompliance with the data protection act of 1998 [28].

The rampant use of CCTV has led to students comparing their school to a prison [29] and has raised paranoia to a degree that some students speculated that there were cameras in the toilets, that some cameras were hidden and could record their voice [29, 30].

11.4.2 Internet Surveillance

Ever since the Internet gained popularity in the 1990s, classrooms have been connected to the internet to provide students with universal access to networked communications technologies. However, this has changed the classroom exponentially with the increased level of surveillance [31].

The motivation of implementing internet surveillance systems has been concerns about online pornography, chat rooms, hate engendering websites, websites that sought to encourage experimentation with drugs and bomb creation, copyright violations, cyberbullying, piracy and hacking [32, 33].

A number of private companies track the students on their personal social media accounts [34]. The monitoring systems flag concerning phrases through the use of machine learning and artificial intelligence and alert school officials informing about the incidents.

Filtering software is also a tool that is used to block access to online content that is deemed to be harmful. The Queensland Government's Department of Education used school filtering software to block various social media websites, arguing that they did not offer educational value [35].

A frequently reported problem is the fact that school filters block access to sites that the students need to visit to complete in-class assignments, causing frustration nand disengagement from the learning material [31, 36].

Research shows that some students intentionally engage in punishable online behavior, which can be understood as an escape from tedious routine through publicly testing boundaries. This act is seen as an important part of identity formation [37].

11.4.3 Biometric Surveillance

Biometrics is the science of establishing the identity of an individual based on the physical, chemical or behavioral attributes of the person [38]. Biometric technologies are used for surveillance in schools in the form of automated fingerprint identification systems, palm vein scanners, iris scanning devices and facial recognition software [39].

This field is expanding rapidly, and schools represent a significant market that uses such technology. In 2011, 2000 secondary schools and 2000 primary schools in the United Kingdom had adopted some form of biometric technology. Three years later in the same country, it was estimated that 1.28 million secondary schools were fingerprinted [40]. The motivation for the use of fingerprint identification has been registration, library book lending, cashless catering systems and personal lockers [39].

The use of fingerprinting for identification seems intuitive in the sense that the body parts in question are merely patterns in the skin and are probably not integral to people's sense of uniqueness.

It may even be less threatening to privacy than other surveillance methods such as scanning systems that produce an image of the naked body or manual frisking searches. However, the routine use of our body as a password may add new dimensions to our experience of embodiment in ways unimaginable to present generations [41].

The use of fingerprinting technology was one of the first applications of machine pattern recognition and is well established with powerful recognition systems that can match fingerprints with millions of matches per second. However, this process is very complex and is not a fully solved problem. Besides the possibility to hack such systems, it also is possible to present fake fingers to the sensors and be able to steal other people's identity [42].

Metal detectors are another popular form of biometric surveillance used in schools. Biometric surveillance is one of the ways that the American schools are trying to solve the problem of weapons in schools. Six percent of public schools in the country are conducting daily or random metal detector searches of students [43]. Metal detectors have been argued to represent a source of fear by reminding students that their peers may be carrying weapons. Using metal detectors alienates students and decreases the student's confidence in the school [44]. This fear could lead to students taking protective measures to defend themselves and paradoxically cause more violence.

11.4.4 Psychology of School Surveillance

In order to determine if using wearable AI surveillance gadgets cause lower performance in students, we must look at the psychological effects of being under surveillance, and what issues this might cause. The literature review uncovered a worrying lack of research regarding the psychological effects of surveillance in the classroom, and what implications this have for student performance. AI powered surveillance gadgets and their effects on students as a psychological topic are suffering from serious neglect. However, there are studies on motivation, creativity and the consequences of being watched that can shed some light of the possible psychological consequences of this new technology, and its application in the classroom.

Surveillance, Reward and Motivation. One important aspect of how surveillance affects student performance, is to consider its effect on students' motivation [45–49]. These papers investigate the effects of surveillance on intrinsic and extrinsic rewards and motivation. An extrinsic reward is a tangible and visible reward given to an individual for achieving something. This is the opposite of an intrinsic reward, which is an intangible award of recognition, such as a sense of achievement or satisfaction from completing a task.

Intrinsic motivation refers to behaviour that is driven by intrinsic rewards, and the motivation for this behaviour arises withing the individual because its naturally satisfying to them. This contrasts with extrinsic motivation, where one engages in a behaviour in order to gain external rewards or avoid punishment.

Lepper and Greene [47] did a study of 80 preschool children (4–5 years old), where the children were to complete puzzles. Participants were divided into three conditions, the expected reward condition, the unexpected reward condition, and the no reward condition. There were three surveillance conditions. In the non-surveillance condition, the television camera had its lens removed and was faced away from the table where the subject was doing the puzzle, and there was no mention of the subject being under surveillance. In the low-surveillance conditions the light that indicated that a subject was under surveillance was turned on for one of the six puzzles. In the high surveillance condition the light was turned on during four of the six puzzles. Three weeks after the individual experimental session was completed, the researchers measured the student's intrinsic interest in solving puzzles, by having children choose between the target activity (solving puzzles) and a variety of other activities. [48] did the same experiment and found that the same results applied to college students.

Results [45, 47, 48] show that the expectation and receiving of an extrinsic reward for engaging in an activity produced decreased intrinsic interest related to engaging in that activity. Surveillance produced an even greater additional decrease in later interest in an activity, and it also reduced participants autonomy [46, 47]. Autonomy refers to self-government over one's own actions, and the feeling of autonomy decreases under surveillance. Intrinsic motivation was greater in the no-surveillance conditions. One interesting finding from these experiments is that it made little difference whether the surveillance was constant or only occasional [46, 47]. It also interesting to note that if subjects were informed that the surveillant was watching because he was personally interested or curious as to how people would approach an activity it neither challenged personal autonomy nor undermined intrinsic motivation [46].

> The knowledge that one's performance at a task is being observed and evaluated by someone else, even when there is no explicit expectation of any tangible reward for engaging in the activity, appears sufficient to decrease later interest in the task [47].

Several studies have also looked at how intrinsic motivation is a precursor to creativity and that extrinsic motivation has a detrimental effect on it [49–51]. These studies suggest that surveillance is the killer of intrinsic motivation and creativity.

How Surveillance Influences Student Behaviour. Several studies show how different aspects of surveillance can affect students' behaviour online [52, 53], self-monitoring [48], cheating and pro-social behaviour [54], moral judgements [55] and children's experience of trust, risk and responsibility [56, 57].

Dawson [52] investigates how online surveillance of students affect their behavior. Through surveys, Dawson studies the extent to which students perceived they changed their own online behaviour as a result of institutional surveillance techniques. The results showed that "all students with browsing behaviour, range of topics and writing style is influenced by the various modes of surveillance".

This change in behaviour is explained through the fact that "when people are objectively self-aware—aware of themselves as an objector as viewed by another—they are likely to regulate themselves controllingly (i.e., as if they were concerned about an other's evaluation of them) [58]. One interesting finding is that students unaware of the specific surveillance measures enacted by the institution performs a high level of self-regulation [52].

Williamson [59] and [60] investigates the ClassDojo application, which is a school based social media platform that incorporates gamified behaviour shaping functions. The app has been marketed as promoting positive psycho-logical concepts such as growth mindsets and character development [59]. However, the problem with this application is that it "requires teachers to monitor students constantly, catching students performing particular behaviours, generating, storing and analysing data through its software as this occurs" [60].

11.4.5 Issues

The research shows that the use of surveillance technologies is rapidly growing [26]. Schools use tragedies such as school shooting (in the United States), bullying and suicidal students as mascots to justify the implementation of increasingly invasive surveillance systems to track and identify students both during and after school [23, 34, 61]. Private companies that sell surveillance technology are earning massive amounts of money to track student in social media with seemingly little regard for their privacy [27] while fingerprint scanners and CCTV cameras track every movement and action of the students while they're at school [40]. The negative reaction about the prison-like state, alienation and paranoia that students have reported to feel during school [24, 29, 30, 44] raises major concerns about how wearables which are arguably even more invasive than the technologies that are covered in this section may affect the students trust in their schools and their sense of liberty.

11.5 Wearables in School

Wearable technology can be defined as *items worn with acceptable function and aesthetic properties, consisting of a simple interface to perform set tasks to satisfy needs of a specific group* [62]. As wearable technologies create opportunities in educational, it is important to understand their affordances and issues.

Technology is getting smaller and is being created in everything and everywhere, even in toys [63, 64]. With that in mind, we introduce the fourth main theme of our systematic review, accountability of wearables in school. We have gathered around

20 scientific articles surrounding the theme of wearables in education, from the web of science and google scholar.

The articles we have collected are only dated 2014 and onward. This is so they are relevant and holds the technical state of the art. The articles will be categorized after common themes found in the articles.

11.5.1 Possibilities of Wearables in an Educational Environment

Learn from learning. The gathered articles state that there are multiple possibilities regarding using wearables with students in an educational domain. An emerging theme found in 2 of the 20 articles was about how we can learn from [65, 66]. As one can use wearables to gather information about how well students learn and how to utilize the technology for better learning environment. Geršak et al. explore the possibilities of wearables in a classroom environment through a case study of learning geometry using movement [65]. Goh et al. summarized potential uses for portable tech in a classroom to improve learning and teaching practice's [66].

First person view and simulation. Introducing new technologies in an educational domain creates new methods of learning. Virtual reality wearables can be used to achieve a first-person view of learning new skills [67]. Examples could be showing how to perform surgery or simulating riskier scenarios [68]. Another way is to enhance the learning experience in general, for example with the use of google glass as Coffman and Klinger explored in their conference paper [67].

Helping students with disabilities. [69] explores the possibility of student engagement through wearables such as Fitbit, GoPro cameras, Google Glass and Oculus Rift. The author also presents how students with physical disabilities can benefit from this new technology. For example, students with visual impairments can use google glass to help students navigate when walking, or using GPS connected wearables so parents get notified when students are out of "bounds" from where they should be e.g., school. This possibility is also explored by Gilmore et al., where parents have used devices to monitor students within geo-technological fences [70]. Another possibility of using this GPS technology is explored in the article by Freeman et al., where the classroom is sensor tagged so visually impaired students achieve more independence with wearing smart watches [71].

Health. Wearing Fitbit or other training wearables can be a motivation for being healthy, by tracking activities and setting personal fitness goals [72]. In their feasibility study, [73] show that wearables can be used as a motivation for students to stay healthy. [74] focus on young people's use of Fitbit.

They discovered that daily steps and calorie burning target did not engage young people's engagement more than a few weeks. These different results show us that more research is needed to conclude whether wearables can be used as a psychical education motivation or not [72–74].

11.5.2 Issues

As there are multiple opportunities using wearables as a tool in education, it is important to highlight the issues surrounding them.

Safety of the students. [69] explore how using wearables can affect student safety. Data gathered from wearable devices can make information about students too available compared to students not using wearables, as the data usually contains sensitive information. Sensitive information like location, what they do, how long they are at certain locations. Another safety aspect to consider is students who use wearables due to health reasons, for example, drug infusion pumps [75]. Mills et al. [75] explores a case where a drug infusion pump was hacked and "it was possible to remotely change the amount of drug administered". This is not necessarily a wearable device such as a Fitbit, but as new technology becomes available it might be the next step when it comes to unsecured devices.

Distraction and dependence on technology. Students using wearables in a classroom environment might become too dependent on this new technology, as students might not be able to apply the same knowledge for real-life scenarios when not using the wearables as in school [76]. Another issue with wearable sis how they might be a distraction for other students in a classroom environment [77].

Surveillance of Young children. [64] highlight the dangers with having technology in everything through sensors children are interacting with. Showing the dangers on how something simple such as toys can have weaknesses that can be exploited. Another danger of using wearable technology with such young children is that the surveillance of children might become normalized. As parents are usually accepting of wearables as they are easy to use and the children like them [78]. As [79] explore the dangers on how wearable technology have authentication issues. Thus, introducing surveillance dangers to young children.

Erosion of enjoyment. Wearables can be seen as a form of extrinsic motivator resulting in either an extrinsic reward or punishment for the student. When students are under constant evaluation, the motivation for doing any task is inherently extrinsic, and the students might be awarded with praise or punished for bad results. One negative effect of extrinsic motivation is that it can lead to the erosion of enjoyment in tasks that were previously extrinsic. The results from [47] clearly shows how the student's enjoyment of playing with puzzles eroded, after being in the surveillance group for this study, which sets us to expect the same effects in this new technology enhanced context.

Autonomy. The real danger of widespread adoption of wearable AI surveillance gadgets, from a psychological perspective, is that they will undermine a whole generations intrinsic motivation to learn. This will also be detrimental to a student's autonomy, as the constant surveillance will influence how they interact with the world around them, as shown by [52]. Dawson [52] showed that when students are under surveillance, they restrict their actions which negatively impacts their autonomy. For people to feel autonomous they need to feel that they are in control of their own lives. This control is reduced when they are under surveillance.

11.6 Algorithmic Accountability Background

Algorithmic accountability is a multidisciplinary theoretic field [80] and examines an algorithm's influence, mistakes or biases [81]. Algorithms are defined as instructions fed to a computer [80, 82] and in this systematic review, algorithms or algorithmic systems refer to AI based technology that is used in an educational environment by young students. Issues may arise with the use of AI in education [19–21, 64, 69, 75–79] hence the importance properly defining accountability and identifying stakeholders in an artificial technology devices' lifetime. Accountability can be defined as *a relationship between an actor and a forum, in which the actor has an obligation to explain and to justify his or her conduct, the forum can pose questions and pass judgement, and the actor may face consequences* [83].

One can argue that companies must assume ethical responsibilities for their creations instead of outsourcing the ethical concerns to those directly related to the implementation of the technology. So, who is accountable for the use of technology? This is not an easy question to answer, and researchers argue whether designers, users, stakeholders, or all the mentioned are the ones accountable [84–89]. By defining accountability and describing factors related to it, we hope to find ways to describe responsible parties and create more transparency in the use of artificial intelligence in education.

Decision-making algorithms must represent moral values and societal norms related to its operational context in order to ensure accountability. Requirements for accountability in artificial intelligence are guiding of actions (making decisions and forming belief), and explanation (assigning decisions to a broader context and classifying them onto moral values) [84]. Dignum [84] investigates how researchers should approach AI system design and how complex that can be. Current machine learning and deep learning technologies are not able to link decisions to input in meaningful ways, which means we are not able to understand their choices.

Problems such as who is to blame when a self-driving car runs over someone must be in place in a responsible AI system and mention how participation is essential; one must understand different cultures and lifestyles, therefore a framework that is effective across cultures must be put in place. The author proposes the ART principles: accountability, responsibility, transparency. Investigations into each of these principles are essential to develop a responsible AI system [84].

Orr and Davis [86] provide an analysis of ethical responsibility in artificial intelligence through interviews of field experts. The problems of ethics in AI are clearer than the ethical responsibility. Interviewees revealed that practitioners involved in design and development are the obvious choice as the accountable party as they are the creators of the product. However, the subjects argue the designers are but a single node in a more complex system.

Regarding accountability norms, the interviews reveal a relationship between the nodes where one has power (legislators, organizations, clients) and the others have technical expertise (practitioners). Hence, it is not possible for practitioners to operate in full discretion, but they must display independent results. Three stages are identified as nodes in the system, and put together they represent the process of defining, development, and deployment:

1. Organizations define parameters.
2. Practitioners develop hardware and software.
3. Deployment to users and machines.

The literature [81, 84, 86, 89–92] indicates the importance of understanding ethics as a collaborative process that is developed through practices and negotiations for the future of AI and the importance of accountability norms in case systems go wrong. Decisions must be clear and made under a set of rules that define legal fairness and transparency, identifying accountable collaboration between computer science, law and relevant fields [85]. Torresen [93] presents the importance of control mechanisms in systems to ensure collaboration between stakeholders, designers, and users [86]. Hence, there is need for a regulatory institution to oversee proper implementation [94].

The ACM Europe Council Party Committee (EUACM[4]) and ACM U.S. Public Policy Council (USACM[5]) have together described and codified a set of principles to ensure fair use in technological systems: Awareness, access and redress, accountability, explanation, data provenance, auditability, and validation and testing [90].

> Accountability rejects the common deflection of blame to an automated system by ensuring those who deploy an algorithm cannot eschew responsibility for its actions [90].

Martin [87] argues that firms who develop algorithms are responsible for the ethical outcomes of their technologies. If some algorithm acts to influence people, then the companies should be accountable for the influence of their technology. By visualizing the delegation of responsibilities in algorithmic design, the author concludes that the creator of the algorithm decides the structure and allocation and should thus be held accountable.

Derived from this logic, inscrutable algorithms constructed as difficult to understand and hard to explain, will prove greater accountability for the designer as it excludes the involvement of users in the decision role [87]. This is defined as the accountability gap [95]. If an algorithm does impose ethical concerns, they either implicitly or explicitly take a stand on an ethical issue. Designers should therefore leave ethical issues for the users or create algorithms that are transparent and easy to understand [88].

Although algorithms are more effective and mostly timesaving, they can make administrative powers less transparent and accountable for their decisions. Public administrations must warrant their use by knowing what data they use, what results

[4] https://acm.org/euacm.

[5] https://usacm.org.

are produced and what results they were expecting [89]. It is important to expose the design decisions and nature of algorithms in systems that consist of interconnected algorithms to identify accountability and liability. Multiple initiatives can help improve this:

1. Pilot-test the model to investigate bias and include stakeholders to have clear definition of what you are trying to achieve
2. Publish the model and the data to explain its provenance
3. Monitor outcomes for differential impacts (e.g., focus on minorities)
4. Right to challenge and redress (e.g., EU's General Data Protection Regulation)
5. Better governance to improve oversight
6. The private sector should adhere to standards of accountability and governance

Diakopoulos [81] discusses the importance of understanding the types of decisions an algorithm can make: prioritize, classify, associate and filter. Governments provides social goods and uses its power through moderated norms and regulations and is accountable for the citizens. On the other hand, private organizations do not have the same public accountability regulations. Robust policy and a transparency standard could solve this organizational gap. [81] proposes five categories to consider disclosing: (1) **Human involvement**: explain the goal, purpose and intent of the algorithm (2) **Data**: Share data accuracy, completeness, timeliness, uncertainties and other limitations (3) **The model**: Share the model and the modelling process (4) **Inferencing**: Benchmarking and testing to identify further limitations (5) **Algorithmic presence**: Inform when the algorithm is in use or not [81]. McGregor et al. [91] apply international human rights law (IHRL) as a framework for algorithmic accountability, and identify five factors for effective accountability: (1) A clear understanding and definition of "harm" (2) Full overview of the design, development and deployment cycle of an algorithm (3) Nodes of power [86] must have clear obligations and responsibilities (4) Clear guideline for emergency management of harm caused (5) Focus on accountability measures throughout the life cycle of an algorithm [91].

Algorithmic decisions are not objective but are designed for a set of actions [96]. Organizations want to conduct good business, but mistakes are unavoidable. Mistakes can come through bad inputs, bad reasoning and bad executions. In order to produce good decisions, organizations apply algorithms and autonomous systems to help this process. However, the algorithms also produce biased decisions and make mistakes. It is therefore important to identify mistakes in algorithmic decision making, and these fall into two classes (1) Category mistakes and (2) Process mistakes [96].

Category mistakes are algorithms that categorize individuals and are prone to two mistakes which are false positives (labelled as paying attention when they are not) and false negatives (not labelled as paying attention when they are). Process mistakes occur when an algorithm makes a fault in how a decision is made, disregarding the outcome.

As algorithms often "learn" factors that are important from current data, they may use unsuitable factors even when designed not to do so [96].

Designing accountability for mistakes produces better algorithmic decisions as they can identify responsibilities related to handling of mistakes [86, 94, 96, 97] study governance frameworks for algorithmic accountability and transparency. Algorithmic Impact Assessment (AIA) is a framework to support policymakers to understand an algorithmic system, where they are used, and allow the community to raise mitigation issues [94].

11.7 Algorithmic Accountability of Smart Technology in Education

In this section we consider the needs and possibilities for establishing algorithmic accountability for smart technology use in education. In Table 11.1 we have summarized all the affordances and issues regarding four of the five topics of the impact of AI on education that we investigated. The topic of AI and accountability will be discussed separately. We base our insights on algorithmic accountability based on these observations.

Figure 11.2 shows that AI technologies bring flexibility in the presentation of material, personalization, and increase motivation. We have listed issues that are more general regarding the use of AI in education. We did not find much research done on the negative influence of AI technologies on students' performance particularly. There can be several reasons for it. It is possible that it is complicated to get consent from the parents to be able to process and analyze the students' personal data. It also can be connected to the fact that using AI applications in schools is somehow new phenomena as well as can be expensive to have. In addition, the fact that AI is popular and used in various aspects of our lives make people focus on its positive aspects more, but we still need to understand that the negative effects and problems with AI should also be highlighted in detail.

Although the affordances for the various surveillance methods that were reviewed are noble, several concerning reactions are revealed by the students. Hence, it is to be argued that this prison-like state that rampant surveillance is presenting at schools, breaches trust for all parties. Teachers lose their trust for the student's ability to self-monitor, while the students lose their trust in their school's good faith as they are treated as suspects. We believe that the goal of schools should be to provide a

Table 11.1 Thematic Overview

Topic	References
Accountability	[83, 89, 95, 81, 84, 90, 82, 97, 94, 88, 85, 96, 87, 91, 98, 92, 99, 93, 80]
AI in education	[20, 2, 12, 9, 3, 8, 11, 18, 4, 13, 6, 7, 5, 16, 19, 15, 14, 21]
Wearables in school	[63, 76, 69, 68, 79, 67, 77, 71, 65, 70, 66, 74, 64, 78, 75, 73, 72, 62]
Surveillance in school	[32, 30, 41, 23, 43, 40, 37, 25, 36, 22, 39, 35, 33, 38, 42, 29, 24, 44, 34, 31, 27, 28, 61, 26]
Psychology of school surveillance	[50, 55, 52, 58, 46, 51, 49, 53, 54, 56, 47, 60, 86, 48, 57, 59]

	AI in education	Surveillance in schools
Affordances	- Personalized support - More flexible presentation material - Better respond to needs - Increasing performance and motivation - Virtual agents increase motivation - More training and practices - Increase of attention	- Prevention of crime - Prevention of vandalism - Prevention of bullying - Detection of suicidal behavior - Blocking piracy - Blocking pornography
Issues	- Privacy - Rapid revision of learning plan - Does not provide a clear pedagogical alternative - AI technologies provided by private sector	- Breach of privacy - Prison-like state - Alienation - Paranoia - Unintentional blocking - Prone to hacking - Decreased trust - Increased protective measures by students
	Wearables in education	**Psychological effect of surveillance**
Affordances	- Learn from learning - First person view - Simulation of situations - Helping children with disabilities - Health	- Wearable tech less obtrusive
Issues	- Safety of children - Distraction - Dependent - Surveillance	- Decreased Interest - Erosion of enjoyment - Undermine intrinsic motivation to learn - Self monitoring - Lack of autonomy

Fig. 11.2 Thematic overview

safe and encouraging environment for the students to learn and discover themselves, and the heavy use of surveillance clouds this goal by treating students as potential wrongdoers.

Schools are supposed to teach children how to become functional and contributing members of society as they become adults and prepare them to handle themselves independently. As the use of wearable technologies is emerging and there are no long-term studies done on this phenomenon. It leaves us to argue that it might be counterproductive to micromanage every single move that the students make to make sure that they fall in line without being able to evaluate themselves.

Wearables in education show great promise on the number of affordances, see Fig. 11.2. Ranging from helping children with disabilities to health benefits. There was a lot of researchers that utilized wearables as a data collection tool in the classroom, but not researching on the consequence of use over time.

The lack of research in this domain might be because of how new wearable technology is. There might be more of this research over time as wearables are getting cheaper and more accessible. If we look at the issues listed, one might say that the issues have larger consequences than the affordances, thus making the issue outweigh the affordances. The literature in psychology indicates that the use of wearables correlates with lower school performance in young children. However, none of the psychological studies we found used wearable technologies.

We found that the way the students were being told that they were under "surveillance" affected how they perceived this surveillance, and thus also their performance. This indicated that more work should be done with regards to how new technologies are introduced into a classroom setting, in order to reduce potential negative consequences.

We identify accountability as a process that includes multiple stakeholders and must thus be treated as such instead of as confined entities. The gap between government bodies and private organizations must be closed, and regulatory frameworks can prevent the renouncement of accountability in both sectors. By strictly defining accountability relationships, we think that focus should shift onto design frameworks and methods to create responsible and safe use of AI systems that can properly identify responsible agents. Through transparent design, development and deployment it will be easier to understand the use and implementation of wearables in school.

We consider that accountability must always be identified, and the technology itself must be explained and tested to prove its use and disprove bias and potential faulty decision-making. Further development or changes must be explained and accepted before they are implemented. Only then can the technology be fully transparent and successfully delegate accountability.

Sandall [98] writes "Wearable technology has the potential to impact school sin the same way as the computers and mobile devices of today". With this in mind, it is important to create boundaries and identify how smart technology should be implemented, as mentioned by [99]. We identify the need for a regulatory framework to govern algorithmic account-ability with wearables in school. Based on insights from our literature review, we propose the following framework to identify accountable parties:

1. The establishing of a regulatory institute.
2. Publication of proposed technology.
3. Publication of scope intended use and the technology's effect on the educational process.
4. Properly test and identify potential faults, bias and harm.
5. Properly identify and notify necessary stakeholders. Technology must be transparent and explainable to non-technical stakeholders.

The technology must be made publicly available along with its intended use, scope and effects on education (e.g., open source). Faults, biases and risk management must be identified and tested by professionals (e.g., engineers, artificial intelligence experts, technology designers, educators, psychologists). Open source would produce transparency, hence the need for a regulatory institute where experts can inspect the technology and make it explainable to the non-technical stakeholders. Further, stakeholders can issue complaints and accurately be provided with explainable action and identification of accountable parties.

For a technology to be adequate, there must be: (1) no risk of biased decision-making to impact a student's progress. (2) no faulty technology to physically endanger the user, provoke fatigue, affect concentration or be uncomfortable. (3) no possibility of the technology being hacked or misused. (4) considerations for privacy. (5) clear guidelines for; when to use it, how to use it, emergency management.

The information on the scope must be communicated through relevant venues, fora, and other platforms that include stakeholders (e.g., websites, email, conferences).

Inclusion of all stakeholders is essential to manage the accountability gap. Stakeholders include: (1) Creators of the technological idea (organization, government). (2) Creators of the technology (engineers, programmers, designers). (3) Users of the technology (schools, teachers, students). In the case of young students, guardianship or authorities must be included as they make decisions while the students are below legal age. The stakeholders must accept the usage of the proposed technology either through communication with the school or regulatory institute and should be made part of an obligatory assessment before a child enrolls into a school.

The regulatory institute will vary based on cultural differences (region, country, municipality) but must include the same core components: (1) Be an agent where the public (e.g., parents, teachers, school staff, students) can voice their concern. (2)Actively participate in the design, development and deployment phases of proposed technology. (3) Must approve the use of proposed technology. (4) The institute must include experts from multiple fields, such as: wearable technology, psychology, education, artificial intelligence, engineering and law. We consider the regulatory institute as a necessity for the development of smart technology because it closes the accountability gap by identifying accountable parties in the life cycle of smart technology. Further addenda on the framework can include research into law and the professional conduct of technology developers.

We describe some limitations to our research. Firstly, there are lack of studies dealing with psychological effects of new technologies in the classroom. Future work should examine how "being under surveillance" affects students, and how to present the fact that students are indeed under surveillance. Secondly, there is limited literature on educational surveillance that uses AI, which led to us researching general surveillance systems and drawing parallels as to how AI assisted systems may impact schools. Thirdly, the number of articles and research scope must also be considered as a limitation factor. As we did not have access to technical product details and their applications, we had to investigate general concepts.

11.8 Conclusions

The purpose of this review was to identify the state of the art in smart technology in the classroom for the purpose of gaining insights into how to establish algorithmic accountability for this technology. We consider smart technologies as a more general category of AI systems because it is not simple to identify which technology is AI. We have observed that accountability is not tackled, and that smart technology use is considered, apart from systems called AI, in relation with wearable devices and in relation with technology used for surveillance. The more interesting aspects of surveillance for algorithmic accountability can be found in the context of psychology studies, so we considered these as well. Table 11.1 (In the Appendix) lists the literature included in the review organized by sub-topic. It is difficult to draw direct conclusions on what kind of effect the increased use of smart technology has on students. The research indicates that the surveillance aspect of using wearables in school can have a negative effect on student performance. However, the extent of this impact is not entirely clear, and more research is needed, especially regarding surveillance supported by AI. This, we believe supports our conclusion that algorithmic accountability for smart technology must be considered and established before we proceed with this trend of digitizing education.

We have identified that in order to bring some understanding to how algorithmic accountability for smart technology can be established, research regarding different aspects of the use of AI at schools is needed: how can smart technology affect the performance of the students? What kind of data should be collected in order to present the best recommendation for a learning program for a particular student? How does the AI algorithm work? Can it fail at some point? These are questions we have hoped to answer by doing this systematic review but have not been able to. There are a lot of factors that must be considered on the road to algorithmic accountability of smart technology in the classroom and some of these would be dictated by the specific technology and specific role it is assigned in education.

11.9 Appendix

Table 11.1 lists the literature included in the review organised by sub-topic.

References

1. M. Ribble, Digital citizenship in schools: nine elements all students should know, in *International Society for Technology in Education*, 3rd edn. (2015)
2. R.S. Baker, P.S. Inventado, Educational data mining and learning analytics, *in Learning Analytics: From Research to Practice*, (Springer, New York, 2014), pp. 61–75. Doi:https://doi.org/10.1007/978-1-4614-3305-7_4

3. M. Chassignol, A. Khoroshavin, A. Klimova, A. Bilyatdinova, Artificial intelligence trends in education: a narrative overview, in *Procedia Computer Science*, vol. 136 (Elsevier B.V., 2018), pp. 16–24. doi:https://doi.org/10.1016/j.procs.2018.08.233
4. R. Luckin, W. Holmes, M. Griffiths, L.B.F. Pearson, Intelligence unleashed an argument for AI in education, in Tech. rep. (Pearson Education, London, 2016)
5. H.S. Nwana, Intelligent tutoring systems: an overview. Artif. Intell. Rev. **4**(4), 251–277 (1990)
6. T. Murray, An overview of intelligent tutoring system authoring tools: updated analysis of the state of the art, in *Authoring Tools for Advanced Technology Learning Environments* (Springer Netherlands, 2003), pp. 491–544. doi:https://doi.org/10.1007/978-94-017-0819-7_17
7. J.C. Nesbit, O.O. Adesope, Q. Liu, W. Ma, How effective are intelligent tutoring systems in computer science education?, in Proceedings–IEEE 14th International Conference on Advanced Learning Technologies, ICALT (Institute of Electrical and Electronics Engineers Inc., 2014), pp. 99–103. doi:https://doi.org/10.1109/ICALT.2014.38
8. C. Conati, K. Porayska-Pomsta, M. Mavrikis, Ai in education needs interpretable machine learning: lessons from open learner modelling. arXiv preprint arXiv:180700154 (2018)
9. J. Beck, M. Stern, E. Haugsjaa, Applications of AI in education. Crossroads **3**(1), 11–15 (1996). https://doi.org/10.1145/332148.332153
10. G. Paviotti, P.G. Rossi, D. Zarka, Intelligent tutoring systems: an overview. (Pensa Multimedia, 2012)
11. A.A. Gokhale, Collaborative learning enhances critical thinking. J. Technol. Educ. 7(1), (1995). doi:https://doi.org/10.21061/jte.v7i1.a.2
12. A.L. Baylor, Promoting motivation with virtual agents and avatars: role of visual presence and appearance. Philos. Trans. R. Soc. B Biol. Sci. **364**(1535), 3559–3565 (2009). https://doi.org/10.1098/rstb.2009.0148
13. M. Muehlenbrock, Formation of learning groups by using learner profiles and context information, in AIED (2005), pp. 507–514
14. M. Sattar, S. Palaniappan, A. Lokman, N. Shah, U. Khalid, R. Hasan, Motivating medical students using virtual reality based education. Int. J. Emerg. Technol. Learn. (iJET) **15**(2), 160–174 (2020). https://www.learntechlib.org/p/217172
15. J. Psotka, Immersive training systems: virtual reality and education and training. Instr. Sci. **23**(5–6), 405–431 (1995). https://doi.org/10.1007/BF00896880
16. V.S. Pantelidis, Virtual reality and engineering education. Comput. Appl. Eng. Educ. **5**(1), 3–12 (1997)
17. V.S. Pantelidis, Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. Themes Sci. Technol. Educ. **10**(2), 59–70 (2017)
18. M. Hussein, C. Nätterdal, The benefits of virtual reality in education-a comparison study. Bachelor's thesis, Chalmers University of Technology, (2015), https://core.ac.uk/download/pdf/43559881.pdf
19. F. Pedro, M. Subosa, A. Rivas, P. Valverde, Artificial intelligence in education: challenges and opportunities for sustainable development. (2019). https://unesdoc.unesco.org/ark:/48223/pf0000366994
20. J. Andriessen, J. Sandberg, Where is education heading and how about ai. Int. J. Artif. Intell. Educ. **10**(2), 130–150 (1999)
21. B.P. Woolf, H.C. Lane, V.K. Chaudhri, J.L. Kolodner, Ai grand challenges for education. AI Mag. **34**(4), 66 (2013)
22. A. Hope, Governmentality and the 'Selling' of school surveillance devices. Sociol. Rev. **63**(4), 840–857 (2015). https://doi.org/10.1111/1467-954X.12279
23. R. Casella, School security and its corporate offerings, in *The Palgrave International Handbook of School Discipline, Surveillance, and Social Control*, (Springer International Publishing, 2018), pp. 389–404. doi:https://doi.org/10.1007/978-3-319-71559-9_20
24. J.P. Nance, School surveillance and the fourth amendment. Wisconsin Law Rev. 2014
25. A. Hope, CCTV, school surveillance and social control. Br. Edu. Res. J. **35**(6), 891–907 (2009). https://doi.org/10.1080/01411920902834233

26. E. Taylor, et al., The rise of the surveillance school, in *Routledge handbook of surveillance studies* (2012) pp. 225–232
27. E. Taylor, I spy with my little eye: the use of CCTV in schools and the impact on privacy. Sociol. Rev. **58**(3), 381–405 (2010). https://doi.org/10.1111/j.1467-954X.2010.01930.x
28. E. Taylor, UK schools, CCTV and the data protection act 1998. J. Educ. Policy **26**(1), 1–15 (2011). https://doi.org/10.1080/02680939.2010.493226
29. M. McCahill, R. Finn, The social impact of surveillance in three UK schools: 'angels', 'devils' and 'teen mums'. Surv. Soc. **7**(3/4), (2010). doi:https://doi.org/10.24908/ss.v7i3/4.4156
30. M. Birnhack, L. Perry-Hazan, S. German Ben-Hayun, CCTV surveillance in primary schools: normalisation, resistance, and children's privacy consciousness. Oxf. Rev. Educ. **44**(2), 204–220 (2018). https://doi.org/10.1080/03054985.2017.1386546
31. V. Steeves, P. Regan, L.R. Shade, Digital surveillance in the networked classroom, in *The Palgrave International Handbook of School Discipline, Surveillance, and Social Control* (Springer International Publishing, 2018), pp. 445–466. doi:https://doi.org/10.1007/978-3-319-71559-9_23
32. D. Ahrens, Schools, cyberbullies, and the surveillance state. Am. Crim. Law Rev. 49 (2012)
33. A.D. Hope, School internet use: case studies in the sociology of risk. Ph.D. thesis, Durham University, 2002
34. L.R. Shade, R. Singh, "Honestly, we're not spying on kids": school surveillance of young people's social media. Soc. Media+Soc. **2**(4):205630511668000 (2016). doi:https://doi.org/10.1177/2056305116680005
35. A. Hope, Unsocial media: school surveillance of student internet use, in *The Palgrave International Handbook of School Discipline, Surveillance, and Social Control* (Springer International Publishing, 2018), pp. 425–444. doi:https://doi.org/10.1007/978-3-319-71559-9_22
36. A. Hope, The shackled school internet: Zemiological solutions to the problem of over-blocking. Learn. Media Technol. **38**(3), 270–283 (2013). https://doi.org/10.1080/17439884.2012.670646
37. A. Hope, Risk taking, boundary performance and intentional school internet "misuse". (2007). doi:https://doi.org/10.1080/01596300601073663
38. A.K. Jain, A. Ross, Introduction to biometrics. In: *Handbook of Biometrics* (Springer, US, 2007), pp. 1–22. doi:https://doi.org/10.1007/978-0-387-71041-9_1
39. A. Hope, Biopower and school surveillance technologies 2.0. Br. J. Sociol. Educ. **37**(7), 885–904 (2016). doi:https://doi.org/10.1080/01425692.2014.1001060
40. S.L. Gray, Biometrics in schools, in *The Palgrave International Handbook of School Discipline, Surveillance, and Social Control* (Springer International Publishing, 2018), pp. 405–424. doi:https://doi.org/10.1007/978-3-319-71559-9_21
41. T. Bryce, M. Nellis, A.J. Corrigan, H. Gallagher, P. Lee, H. Sercombe, Biometric surveillance in schools: cause for concern or case for curriculum? Scott. Educ. Rev. **42**(1), 3–22 (2010)
42. D. Maltoni, R. Cappelli, Fingerprint recognition, in *Handbook of biometrics*, (Springer, 2008), pp. 23–42
43. B. Gastic, Metal detectors and feeling safe at school. Educ. Urban Soc. **43**(4), 486–498 (2011). https://doi.org/10.1177/0013124510380717
44. C.J. Schreck, J.M. Miller, Sources of fear of crime at school: What is the relative contribution of disorder, individual characteristics, and school security? J. Sch. Violence **2**(4), 57–79 (2003). https://doi.org/10.1300/J202v02n04_04
45. E.L. Deci, R.M. Ryan, R. Koestner, A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. DOI (1999). https://doi.org/10.1037/0033-2909.125.6.627
46. M.E. Enzle, S.C. Anderson, Surveillant intentions and intrinsic motivation. J. Pers. Soc. Psychol. **64**(2), 257–266 (1993). https://doi.org/10.1037/0022-3514.64.2.257
47. M.R. Lepper, D. Greene, Turning play into work: effects of adult surveillance and extrinsic rewards on children's intrinsic motivation. J. Pers. Soc. Psychol. **31**(3), 479 (1975)
48. R.W. Plant, R.M. Ryan, Intrinsic motivation and the effects of self-consciousness, self-awareness, and ego-involvement: an investigation of internally controlling styles. J. Pers. **53**(3), 435–449 (1985). https://doi.org/10.1111/j.1467-6494.1985.tb00375.x

49. B.A. Hennessey, If I were secretary of education: Afocus on intrinsic motivation and creativity in the classroom. Psychol. Aesthet. Creat. Arts **9**(2), 187–192 (2015). doi:https://doi.org/10.1037/aca0000012
50. T.M. Amabile, Effects of external evaluation on artistic creativity. J. Pers. Soc. Psychol. **37**(2), 221–233 (1979). https://doi.org/10.1037/0022-3514.37.2.221
51. B.A. Hennessey, The social psychology of creativity. Scand. J. Educ. Res. **47**(3), 253–271 (2003). https://doi.org/10.1080/00313830308601
52. S. Dawson, The impact of institutional surveillance technologies on student behaviour. Faculty of Sci. Med. Health–Pap. Pt. A (2006)
53. A. Hope, Panopticism, play and the resistance of surveillance: case studies of the observation of student Internet use in UK schools. Br. J. Sociol. Educ. **26**(3), 359–373 (2005). https://doi.org/10.1080/01425690500128890
54. A.M. Jansen, E. Giebels, T.J. van Rompay, M. Junger, The influence of the presentation of camera surveillance on cheating and pro-social behavior. Front. Psychol. **9** (2018). doi:https://doi.org/10.3389/fpsyg.2018.01937
55. P. Bourrat, N. Baumard, R. McKay, Surveillance cues enhance moral condemnation. Evol. Psychol. **9**(2), 193–199 (2011). https://doi.org/10.1177/147470491100900206
56. D. Knox, A good horse runs at the shadow of the whip: surveillance and organizational trust in online learning environments. Can. J. Media Stud. 7 (2010)
57. T. Rooney, Trusting children: how do surveillance technologies alter a child's experience of trust, risk and responsibility? Surveill. Soc. **7**(3/4), 344–355 (2010). https://doi.org/10.24908/ss.v7i3/4.4160
58. E.L. Deci, R.M. Ryan, The support of autonomy and the control of behavior. J. Pers. Soc. Psychol. **53**(6), 1024 (1987)
59. B. Williamson, Decoding classdojo: psycho-policy, social-emotional learning and persuasive educational technologies. Learn. Media Technol. **42**(4), 440–453 (2017)
60. J. Manolev, A. Sullivan, R. Slee, Learning, media and technology the datafication of discipline: classdojo, surveillance and a performative classroom culture. Taylor Francis **44**(1), 36–51 (2018). https://doi.org/10.1080/17439884.2018.1558237
61. E. Taylor, Surveillance schools. Palgrave Macmillan UK (2013). https://doi.org/10.1057/9781137308863
62. S. Wilson, R.M. Laing, Wearable technology: present and future, in *91st World Conference of The Textile Institute* (2018)
63. C. Anderson, K. Anderson, Wearable technology: it has a place in schools-learning & technology library (LearnTechLib), in *Association for the Advancement of Computing in Education* (2017)
64. D. Holloway, L. Green, The Internet of toys. Commun. Res. Pract. **2**(4), 506–519 (2016). https://doi.org/10.1080/22041451.2016.1266124
65. V. Geršak, H.S. Vitulic, S. Prosen, G. Starc, I. Humar, G. Geršak, Use of wearable devices to study activity of children in classroom; case study—learning geometry using movement. Comput. Commun. **150**, 581–588 (2019). https://doi.org/10.1016/j.comcom.2019.12.019
66. F. Goh, A. Carroll, R.M. Gillies, A review of the use of portable technologies as observational aids in the classroom. Inform. Learn. Sci. **120**(3–4), 228–241 (2019). https://doi.org/10.1108/ILS-08-2018-0080
67. T. Coffman, M.B. Klinger, Google glass: using wearable technologies to enhance teaching and learning, in Association for the Advancement of Computing in Education (AACE) (2015)
68. M. Bower, D. Sturman, What are the educational affordances of wearable technologies? Comput. Educ. **88**, 343–353 (2015). https://doi.org/10.1016/j.compedu.2015.07.013
69. A.C. Borthwick, C.L. Anderson, E.S. Finsness, T.S. Foulger, Special article personal wearable technologies in education: value or villain? J. Dig. Learn. Teach. Educ. **31**(3), 85–92 (2015). https://doi.org/10.1080/21532974.2015.1021982
70. J.N. Gilmore, Securing the kids: geofencing and child wearables. Convergence (2019). https://doi.org/10.1177/1354856519882317

71. E. Freeman, G. Wilson, S. Brewster, G. Baud-Bovy, C. Magnusson, H. Caltenco, Audible beacons and wearables in schools: Helping young visually impaired children play and move independently, in *Conference on Human Factors in Computing Systems - Proceedings, Association for Computing Machinery*, vol. 2017 (New York, NY, USA, 2017), pp. 4146–4157. doi:https://doi.org/10.1145/3025453.3025518
72. A.M. Ortiz, S.J. Tueller, S.L. Cook, R.D. Furberg, ActiviTeen: a protocol for deployment of a consumer wearable device in an academic setting. JMIR Res. Protoc. **5**(3), e153 (2016). https://doi.org/10.2196/resprot.5934
73. J. Müller, A.M. Hoch, V. Zoller, R. Oberhoffer, Feasibility of physical activity assessment with wearable devices in children aged 4–10 years-a pilot study. Front. Pediatr. **6** (2018). doi:https://doi.org/10.3389/fped.2018.00005
74. V.A. Goodyear, C. Kerner, M. Quennerstedt, Young people's uses of wearable healthy lifestyle technologies; surveillance, self-surveillance and resistance. Sport Educ. Soc. **24**(3), 212–225 (2019). https://doi.org/10.1080/13573322.2017.1375907
75. A.J. Mills, R.T. Watson, L. Pitt, J. Kietzmann, Wearing safe: physical and informational security in the age of the wearable device. Bus. Horiz. **59**(6), 615–622 (2016). https://doi.org/10.1016/j.bushor.2016.08.003
76. B. Attallah, Z. Ilagure, Wearable technology: facilitating or complexing education? Int. J. Inform. Educ. Technol. **8**(6), 433–436 (2018). https://doi.org/10.18178/ijiet.2018.8.6.1077
77. F. De Arriba-Pérez, M. Caeiro-Rodríguez, J.M. Santos-Gago, Towards the use of commercial wrist wearables in education, in Proceedings of 2017 4th Experiment at International Conference: Online Experimentation, exp.at 2017 (Institute of Electrical and Electronics Engineers Inc., 2017). pp. 323–328. doi:https://doi.org/10.1109/EXPAT.2017.7984354
78. K.A. Mackintosh, S.E. Chappel, J. Salmon, A. Timperio, K. Ball, H. Brown, S. Macfarlane, N.D. Ridgers, Parental perspectives of a wearable activity tracker for children younger than 13 years: acceptability and usability study. JMIR mHealth and uHealth **7**(11) (2019). doi:https://doi.org/10.2196/13858
79. K.W. Ching, M.M. Singh, Wearable technology devices security and privacy vulnerability analysis. Int. J. Netw. Sec. Appl. **8**(3), 19–30 (2016). https://doi.org/10.5121/.nsa.2016.8302
80. M. Wieringa, What to account for when accounting for algorithms: a systematic literature review on algorithmic accountability, in *FAT* 2020—Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency, Association for Computing Machinery, Inc*, (New York, NY, USA, 2020), pp. 1–18. doi:https://doi.org/10.1145/3351095.3372833
81. N. Diakopoulos, Accountability in algorithmic decision making. Commun. ACM **59**(2), 56–62 (2016). https://doi.org/10.1145/2844110
82. A. Goffey, Algorithm, in *Software Studies: A Lexicon*, ed. by M. Fuller. (MIT Press, 2008)
83. M. Bovens, Analysing and assessing accountability: a conceptual framework. Eur. Law J. **13**(4), 447–468 (2007). doi:https://doi.org/10.1111/j.1468-0386.2007.00378.x
84. V. Dignum, *Responsible artificial intelligence: designing AI for human values* (Springer, 2017)
85. J.A. Kroll, J. Huey, S. Barocas, E.W. Felten, J.R. Reidenberg, D.G. Robinson, H. Yu, Accountable algorithms. Univ. Pa. Law Rev. **165**(3), 633–705 (2017)
86. W. Orr, J.L. Davis, Attributions of ethical responsibility by artificial intelligence practitioners. Inform. Commun. Soc. 1–17 (2020). doi:https://doi.org/10.1080/1369118X.2020.1713842
87. K. Martin, Ethical implications and accountability of algorithms. J. Bus. Ethics **160**(4), 835–850 (2019). https://doi.org/10.1007/s10551-018-3921-3
88. F. Kraemer, K. van Overveld, M. Peterson, Is there an ethics of algorithms? Ethics Inf. Technol. **13**(3), 251–260 (2011). https://doi.org/10.1007/s10676-010-9233-7
89. I. Cerrillo, A. Martínez, (2019) How can we open the black box of public administration? Transparency and accountability in the use of algorithms. Rev Catalana Dret Public **58**, 13–28 (2019). https://doi.org/10.2436/rcdp.i58.2019.3277
90. S. Garfinkel, J. Matthews, S.S. Shapiro, J.M. Smith, Toward algorithmic transparency and accountability. Commun. ACM **60**(9), 5 (2017). https://doi.org/10.1145/3125780
91. L. McGregor, D. Murray, V. Ng, International human rights law as a framework for algorithmic accountability. Int. Comp. Law Q. **68**(2), 309–343 (2019). https://doi.org/10.1017/S0020589319000046

92. H. Shah, Algorithmic accountability. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. **376**(2128), 20170362 (2018). https://doi.org/10.1098/rsta.2017.0362
93. J. Torresen, A review of future and ethical perspectives of robotics and AI. Front. Robot. AI **4**, 75 (2018). https://doi.org/10.3389/frobt.2017.00075
94. A. Koene, C. Clifton, Y. Hatada, H. Webb, R. Richardson, A governance framework for algorithmic accountability and transparency. (2019). https://doi.org/10.2861/59990
95. K. Crawford, J. Schultz, AI systems as state actors. Columbia Law Rev. **119**, 1941–1972 (2019)
96. K. Martin, Designing ethical algorithms. MIS Q. Executive **18**(2) (2019a)
97. Y. Kanellopoulos, A model for evaluating algorithmic systems accountability. arXiv preprint arXiv:180706083 (2018)
98. B.K. Sandall, Wearable technology and schools: where are we and where do we go from here? J. Curr. Teach. Learn. Leadership Educ. **1**(1) (2016)
99. H. Strandell, Mobile phones in children's after-school centres: stretching of place and control. Mobilities **9**(2), 256–274 (2014). https://doi.org/10.1080/17450101.2013.802488

Chapter 12
Objective Tests in Automated Grading of Computer Science Courses: An Overview

Marin Lujak, Marija Slavkovik, Alexis Lebis, Mathieu Vermeulen, and Arnaud Doniec

Abstract In this chapter, we analyze and mutually compare the most used objective tests in computer science courses in Learning Management Systems (e.g., Moodle) and MOOCs. We outline their advantages, technical limitations, and ethical challenges. We also consider test feedback mechanisms that facilitate continuous learning for students as well as the identification and recognition of possible evaluation mistakes of the system of AI-supported methods for automating objective tests in programming. These tests come with a range of technical challenges to promote students' empowerment and support their autonomy in the learning process. There are also ethical challenges that arise when a human evaluator is replaced by software. We discuss and analyze these tests and focus on identifying and mitigating the context-specific ethical challenges. A clearly defined form of evaluation also checks and promotes students' integrity and genuineness in summative evaluations. Contrarily, in formative evaluations, automated objective tests should help to motivate students to commit to the learning process. We emphasize the essential characteristics for these tests to correctly provide these two types of evaluations in courses.

M. Lujak (✉)
CETINIA, University Rey Juan Carlos, Madrid, Spain
e-mail: marin.lujak@urjc.es

M. Slavkovik
Department of Information Science and Media Studies, University of Bergen, Bergen, Norway
e-mail: marija.slavkovik@uib.no

A. Lebis · M. Vermeulen · A. Doniec
IMT Nord Europe, CERI Numerique, University of Lille, Lille, France
e-mail: alexis.lebis@imt-nord-europe.fr

M. Vermeulen
e-mail: mathieu.vermeulen@imt-nord-europe.fr

A. Doniec
e-mail: arnaud.doniec@imt-nord-europe.fr

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_12

12.1 Introduction

The demand for professionals with programming skills and most recently AI skills is constantly growing. We observe an ever-increasing number of students in both face-to-face and online engineering and programming courses. Yet, the number of lecturers and teaching assistants does not keep pace with the student demand. As a result, the number of students per course increases, leading to massification issues most evident in the Massive Open Online Courses (MOOCs). One of the issues is related to student dropout and disengagement, mostly due to the lack of motivation (see, e.g., [80]).

Interlaced with this problem is the issue related to the effective and continuous assessment of the students' progress in time. In order to determine students' competency in achieving curriculum expectations, summative tests assess what has already been learned and is often done at the end of the unit, period, or course. Ultimately, the goal is to assure the assessment is meaningful to support well-designed lesson planning. The assessment should be both consistent and valid as well as fair to all students. By fair, we mean impartial and just without favoritism or any kind of discrimination.

Technology can assist us in providing authentic cross-curricular assessment through the use of online education platforms as an aid to the teaching in the classroom as well as a support of the courses held completely online through, e.g., Learning Management Systems (e.g., Moodle[1]) or MOOCS. In such platforms, objective tests are the most common way of student evaluation. They are automatically evaluated providing interpretive reports. The strengths of automated tests, among others, include objectivity, consistency, speed, and 24 h availability [4]. Other ICT technologies in assessment that are out of the scope of this chapter include AI-based robotic process automation, machine learning, pattern matching, and natural language processing; all of these giving new perspectives to the Technologies Enhanced Learning (TEL), especially for exam and progress evaluation (see, e.g., [39]).

In this chapter, we analyze and mutually compare the most used objective tests in computer science (CS) courses taught online. We outline their advantages, technical limitations, and ethical challenges. We also consider test feedback mechanisms that facilitate continuous learning for students. These tests and their feedback mechanisms come with a range of technical challenges to promote students' empowerment and support their autonomy in the learning process.

There are also ethical challenges that arise when a human evaluator is replaced by software (fairness, transparency, bias, explainability, etc.). Numerous ethical guidelines and some laws (e.g., GDPR in the EU) are being proposed to ensure that the use of personal data and automation of human tasks are done ethically. Of particular concern is the possibility for an automated process to introduce or reinforce bias in society, or operate unjustly, cutting stakeholders and users from the ability to correct introduced mistakes. Although some general principles can be outlined for all TEL

[1] Moodle; http://www.moodle.org. Accessed 1 July 2021.

solutions, there remains the need to discuss and analyze them in a specific context and focus on identifying and mitigating the context-specific ethical challenges.

Nonetheless, objective tests serve more roles than just establishing whether the student has given a correct answer to a problem. A clearly defined form of evaluation also checks and promotes the integrity and genuineness of a student (e.g., prevent a student gaming the system) in a summative evaluations context. On the other hand, in a formative evaluations context, objective tests should help motivate students to commit to the learning process. We emphasize the essential characteristics for these tests to correctly provide these two types of evaluations in computer science courses.

Our methodological approach to this overview is drawn from three main concerns from the point of view of the students and the teachers using objective tests in automated grading of computer science courses: their advantages, limitations, and ethical challenges. As such, this chapter is not intended as a review of the current state of research in objective tests but is rather an overview capturing key aspects of objective tests in automated grading of computer science courses. It is intended both as introductory material for the researchers in the field as well as for the teachers using objective tests in automated grading of their computer science courses. The methodology encompasses objective test development and design activities, a description of challenges to sustain their efficient and effective use, and applicability criteria outlining the kind of learning outcomes and tasks that can benefit from them. This chapter is organized as follows. In Sect. 12.2, we give an overview of learning assessment and online objective tests in automated grading of computer science courses. We discuss the differences between assessment and testing, and subjective versus objective assessment. We give five principles of testing and assessment that will be used as key performance indicators in the evaluation of objective tests. In Sect. 12.3, we categorize objective tests, while in Sect. 12.4, we discuss bias, ethical issues and explainability in objective tests in automated grading of computer science courses. Finally, in Sect. 12.6, we consider open challenges and discuss the requirements for future proactive automated grading systems.

12.2 Background

Student learning outcomes are the knowledge, skills, attitudes, and values that students obtain in a course. These outcomes identify the obtained student's abilities and aptitude related with the learned material at the end of the course as well as the value of the learning process. Based on the hierarchy of cognitive-learning levels of Bloom's taxonomy [6, 16], cognitive domain can be divided in: (i) knowledge of specific facts and conventions that is the lowest-level of learning shown through remembering of previously learned material, (ii) comprehension or understanding, (iii) application or the ability to use the learned material in a new and concrete situation, (iv) analysis or the ability to break down the learned material into its components to analyze their relationships and to recognize underlying organizational principles, (v) synthesis or the ability to resolve contradictions and to create a new whole by mutually assembling the parts, and (vi) evaluation or the ability to judge the value of compiled material for a given purpose.

The necessary cognitive skill required in higher-education computer science courses is to understand basic programming concepts, principles, and paradigms, i.e., the main constructive elements for writing program code. However, understanding the concepts and principles does not assure the capacity to write computer programs, which requires extensive practical experience and skills. To acquire them, a student should develop a higher-level knowledge by applying the guiding concepts, principles, and paradigms on simple programming tasks, analyze the code for debugging tasks, and synthesize the code in advanced programming assignments.

12.2.1 Differences Between Assessment and Testing

Testing serves to determine final grades or to make promotion decisions, to identify the areas that need improvement or stronger emphasis or where the curriculum is weak, to motivate students to study and to communicate to students what material is important (see, e.g., [58].

Conventional classroom tests are performed in a given limited time in a written or oral form to measure the learning process at a specific point in time. Assessment is a broader concept of testing where a teacher uses a range of continuous-learning procedures to evaluate the learning process and includes both formal and informal observable measures for judgement (see, e.g., [15, 61]. It is a continuous process in which measurable and clear student learning outcomes determine how well student learning matches expectations (see, e.g., [19, 89]).

We can distinguish formative (used during the teaching process), summative (measuring long term academic goals, mostly used for grading, e.g., midterms and final unit tests and projects), and diagnostic assessments (used to get prior knowledge on students and to plan future instruction, e.g., a test before a course).

Formal assessments are strict and specific testing procedures and rules, e.g., a standardized test such as the SAT), while informal assessments lack supporting data and use normal classroom testing procedures. Performance-based assessments assess student's ability to complete work in an academic task, e.g., the design of an application for a computer programming class.

From the point of view of administering the assessment, it can be an individual or group assessment. Norm-referenced assessments are based on a comparison of students against similar demographics.

12.2.2 Objective Versus Subjective Tests

Generally, we can divide test questions into objective and subjective ones. In an objective question, a student should select the correct response from several alternatives or provide a short answer or complete a statement. Subjective questions, on the other hand, allow for an extended original answer to a question in terms of an essay, a problem solving or performance answer. Choosing between objective or subjective tests depends on the learning objective that we want to measure.

Automated assessment requires questions that can be marked objectively. There is no objective assessment in the absolute meaning of that word. Each assessment performed by a human is made with inherent bias built into decisions about relevant subject matter and content. If a teacher is not cross-culturally sensitive, further bias related with socioeconomic status, age, disability, cultural background, ethnicity, religion, gender, and sexual orientation may occur (see, e.g., [53, 72]).

However, in addition to these biases, subjective assessment is further limited by individual evaluators that can rate the same exam differently over time. The lack of anonymity as well as handwriting and grammar can affect the grading process (see, e.g., [71]).

The presence of marking bias requires either the use of multiple assessors for each student, or standardization of marks between assessors, to minimize the problem. This problem is related to intra- and inter-rater reliability.

For a teacher, subjective questions are generally easier and faster to construct than most objective questions. Students with good writing skills will generally perform better in subjective tests. Moreover, due to the extent of time required to respond to a subjective question, the number of the questions in a subjective test is generally much lower than the same in an objective test. In the case of lack of penalties, objective tests can be correctly answered through blind guessing, while subjective tests can be partially responded through well-written bluffing.

For some learning purposes, objective or subjective tests may prove more efficient and appropriate but both can measure similar content and learning objectives. Students respond almost identically to both tests covering the same content (see, e.g., [42]).

12.2.3 Five Principles of Testing for Assessment

The five commonly recognized principles of testing and assessment are: validity, reliability, authenticity, practicality, and washback.

Validity

There are multiple definitions of validity in the literature that seem to be evolving (see, e.g., [64]). One of them is that validity considers the extent to which inferences made from the scores on a test are appropriate, meaningful, and useful for the purpose of the test [55]. Airasian [2] defines validity as the degree to which assessment information permits correct interpretations of the desired kind. In general, validity concerns accurate measuring of what we aim to measure through test results; it is a measure of fitness for the decisions that will be based on those scores.

Reliability

Reliability is related to the degree of consistency of test scores or the degree to which they are free from various types of chance effects and errors of measurement (see, e.g., [24]). Reliability considers the likelihood that a student's score would change if that student repeated the same test or took another version of the test.

Reliability can be classified into *student reliability* (factors that affect a student's state of mind in the testing process resulting in an inaccurate test score), *intra-rater reliability*, i.e., how consistently the teacher scores individual tests in the class due to, e.g., fatigue, imprecise marking criteria, or student bias, *inter-rater reliability*, i.e., how criteria change from one teacher to another evaluating the same class tests, and *test reliability*, or how much, if a test is to be taken more than once, two or more equivalent forms of the same test mimic one another while being sufficiently different to avoid for the student to look up the answer.

Test reliability can be improved by clear task instructions. If the instructions are clear, the marks will be more consistent because the task makers know what to expect. Clear assessment criteria and scales are another way of increasing reliability because if the raters know what they need to focus on in marking, they will have high levels of agreement. The reliability is also increased by training teachers/examiners to deliver tests and score tests in a consistent way.

Clear assessment criteria and scales are supported by an analytic scale that breaks down the holistic scale based on certain criteria, and it facilitates reliability as the teachers can follow the scale in marking a test taker.

Authenticity

Authenticity relates to how closely tested material matches authentic challenges and conditions of real-world applications that students will encounter outside the classroom, i.e., authentic tasks in authentic contexts closely related to work done in the real world that students may engage in once they leave the class. Authentic tests involve engaging problems or questions of importance, error-free representation of the real-world context or field of study, and challenging tasks, among others (see, e.g., [97]).

As an example, problem-based learning (PBL) develops higher-order thinking skills by providing students with authentic and complex tasks that take place in real-world settings. However, multiple choice questions are not a particularly authentic testing method in checking the programming knowledge nor are they appropriate as predictors of real-world training criteria.

Practicality

Practicality relates to test logistics such as development time, scoring time, budget, resources, feedback delivery and administration issues including the means of test evaluation. A test is practical if it respects budgetary limits, it can be performed entirely within the given test writing time, requiring not more than available human and material resources for both design, test monitoring, and scoring (see, e.g., [20]).

Washback

Test impact or washback relates to the direct effect of the test on learning and is the feedback given to students following a test or assessment. The best way to improve the impact is to test those abilities whose development you would like to encourage and not necessarily what is easiest to test. The challenge here is transmitting the results in a positive way that does not overwhelm the student in the most adequate form.

Formative feedback is aimed at helping students to improve their skills. Keuning et al. [63] give a systematic literature review of automated feedback generation for programming exercises in 101 tools to find out what kind of feedback is provided, which techniques are used to generate the feedback, how adaptable the feedback is, and how these tools are evaluated. They argue that feedback mostly focuses on identifying mistakes and less on fixing problems and taking a next step while the tools are not easily adaptable by teachers to their own needs.

To conclude, an effective and efficient test should test what it sets out to test (validity) while producing scores that can be trusted (reliability) and supporting learning (positive impact). However, it should be practical to develop and deliver.

The gender and background of the learner as well as personality traits could affect the way they perform (see, e.g., [85]).

12.2.4 Online Educational Assessment

Both examiners and students usually prefer online testing because of the convenience of the online platforms.

The ever-increasing number of online courses and MOOCs requires the use of techniques and methods to assess online learners. Although the use of computers brings many benefits for teaching [14], the very context of online education makes online assessments problematic and difficult for teachers. Indeed, learners are increasingly more numerous (often several thousand in the case of MOOCs), and they are in a distance learning context, both distant from other learners and teachers. Therefore, it becomes difficult to assess some elements which were first rather easily observable, like learner's participation or effectiveness regarding a specific task (e.g. is it really the learner who performed the task?). Furthermore, the formalism induced by learning systems hinders the evaluation of learners' competencies. Common questions we face when setting up such online courses are for example how could several dozens of a learner's open text responses be evaluated or how could soft skills be assessed in online training as well?

These issues are emphasized by the fact that classical assessments have been carried over online courses. Notable among those is the evaluation by tests that reports the result of a reasoning process (answer to a problem, closed question, etc.).

They are poorly suited to the assessment of skills and give little to no information about the reasoning behind the given result. However, online grading is fast during the actual grading phase, but some of this benefit is offset by the additional overhead prior to online grading [23].

There is also online homework, which is a more complete approach than a simple test since it requires learners to produce an authentic document. However, due to the context of online courses, they are difficult and time-consuming to set up for mass training courses, and this raises important questions regarding learner's honesty.

Consequently, several new modalities have emerged these last years to tackle these issues, mostly shifting the focus of examination towards the students. It is the case of ePortoflio assessments for example, which propose an increased range of evidence such as video, text or even audio, to facilitate assessment and bring meaningful information for learners [99]. Nonetheless, widely used modalities are peer evaluations (e.g., [60, 92, 100]), where learners contribute to the grading of other learners, thus increasing their engagement and mobilizing their skills, particularly in MOOCs [74], and self-assessment were the learners grade their own assignments. Additionally, these two modalities bring strong formative feedback [93] and are already in use, for example, in Coursera and EdX.

Moreover, researchers in Learning Analytics (LA) and Educational Data Mining (EDM) explore the new possibilities offered by the online educational environment by gathering and analyzing learner data in order to answer assessment issues. Through this data, it is possible to gain knowledge regarding learners' knowledge and behavior, as well as bringing new feedback both to learners and teachers [47, 95] and even grade them based on their activities [50]. While EDM relies heavily on the machine to perform analyzes (e.g. clustering), LA is a more involving process per se, and attempts to include at least teachers in the analysis and thus, presumably, better encompasses pedagogical expectations [45]. Either way, EDM and LA are useful for proposing indicators [34] and/or dashboards [29] to teachers and/or learners, which are profitable to understand a learning situation. These approaches are particularly interesting because many learners' activities can be observed, particularly those that are spread out over time (e.g. mobilization of soft skills in group work) and they have a high prospect regarding the sharing and the re-usability of analyzes across online courses and online systems [67, 78].

Finally, it has to be noted that the context of the COVID health crisis has highlighted once again the limitations of conventional assessments modalities in dematerialized environments [79]. The most notable limitations teachers face are an important amount of plagiarism and cheating from their students, thus preventing teachers from assessing students' skills, and the difficulty to adapt their tests and evaluation for online teaching is mostly due to the lack of guidelines. Nonetheless, the use of automatic processes to provide automatic correction or feedback in online teaching is steadily becoming more important [9], and maybe a part of the solution.

12.3 Automated Objective Tests

An objective test is a test consisting of factual questions requiring usually short answers that are either correct or incorrect. These answers can be quickly and unambiguously scored by anyone with total reliability with an answer key, thus minimizing subjective judgments by both the person taking the test and the person scoring it.

Objective tests are most suitable for use at lower-order cognitive levels such as memory, basic comprehension and application of numerical procedures but it is also possible to design these tests to test higher-cognitive levels.

Objective assessment is a generic term referring to tests that can be marked with complete reliability as there are clear right and wrong answers. Objective assessments can be summative, where marks are used to calculate a final grade for the student, or formative, where student efforts are met with feedback on their performance that does not directly contribute to final grades.

Objective tests can be set to test a wide topic area at any required level of difficulty, where large numbers of questions may be answered in a relatively short time covering widely course content and focusing on specific knowledge and skills although sometimes superficially. They are especially useful with large student groups where the test can be reused.

For large classes, it represents an efficient way of testing a large number of students rapidly and within short time frames, particularly when computers are employed to assist marking. As with all forms of assessment it is necessary to align assessment with the desired learning outcomes for the course.

The strength of objective tests is fairness, impartiality of evaluation, and no scoring variation due to the evaluator's fatigue or lack of student anonymity. Also, the strength is fast reporting of scores. Impartiality assumes equal treatment of all students and implies that the evaluation is based on objective criteria, and not on the basis of bias, prejudice or any other method that would benefit one student over another for improper reasons.

However, there are three major weaknesses of objective testing: if a bank of questions is missing, initially, it is very difficult and lengthy to construct it; test questions require to be tested before they are used in order to check their validity; and there are also known issues with gender differences in student performance of objective tests since, on average, women have a higher aversion to risk-taking in attempting to answer a question when a student is not certain of the result (see, e.g., [5, 25].

12.3.1 Types of Studied Objective Test Questions

It is important to note that there is no type of test that is intrinsically good or bad; each one has its advantages and weaknesses that should be evaluated in considering the fitness for the purpose of the test. However, concentrating on computer science

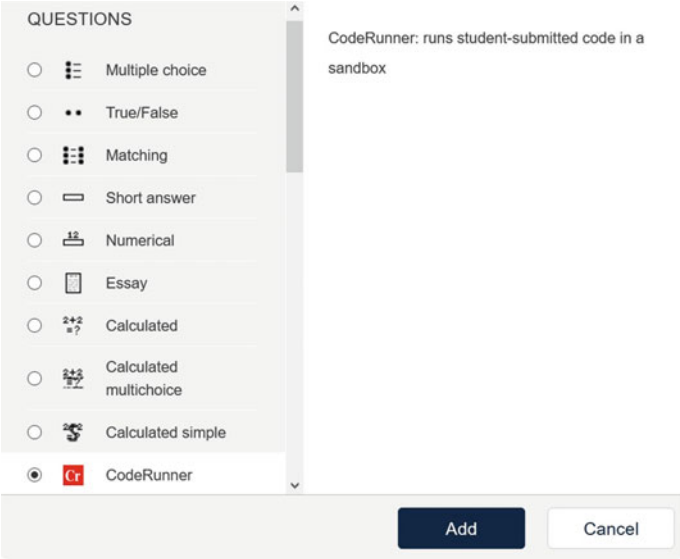


Fig. 12.1 Some question types in Moodle

courses, we study in this paper the following objective factual tests available in Moodle: multiple choice, true/false, matching, extended matching, and short response tests as well as automatic grading systems for programming (CodeRunner among others), Fig. 12.1.

We briefly present in the following each one of them and give their main characteristics. Their more detailed description can be found in, e.g., Gordon et al. [54].

12.3.1.1 Multiple Choice Questions (MCQ)

This most widely used type of objective tests allows the selection of a single or multiple responses from a predefined list. The test taker is usually given a short question (the stem) with usually four to five optional answers of which one or more are correct (the key) and others wrong (the distractors). A test taker must choose the right one(s) (see, e.g., [57]).

One of the advantages of multiple-choice tests is that questions with different levels of cognitive processing including higher-order thinking can be created. For example, we can measure reasoning, comprehension, application, analysis, and other complex thinking processes. Tasks are fairly easy to mark automatically online. The weakness of this test method is that there is a high chance of getting the correct answer through guessing [32]. It assumes that the world is fixed,there is a fixed number of answers and only certain ones are correct. The differences between the answers may be so small that a high proficiency of the context may be required, the context that is not usually strictly related to what is being tested.

Answering a multiple-choice question is not necessarily authentic since, in real life, the test taker will not choose a multiple-choice option. Additionally, the set of answers may be incomplete or misunderstood by the test maker based on the cultural background or the proficiency in the language the test is written in. Regarding bias, this kind of test may favor male students since they are statistically more likely to be risk takers (see, e.g., [13]). Therefore, this kind of test should be balanced with other test types. For an overview of multiple-choice tests (see, e.g., [7, 94]). McCoubrie [73] present the guidelines for the construction of multiple choice questions tests while [3] give a review of the literature treating the topic of improving the fairness of multiple-choice questions.

12.3.1.2 True/False Questions

A true/false test is a simple form of multiple-choice question with two choices: true and false. It can be divided into the tests where an examinee must select all options that are true and a single best answer.

Selecting all options that are true requires additional judgement and guessing in case the options are either not completely true or not completely false. This is why options must be absolutely true or false without doubt.

Even though the true–false tests are often considered as superficial tests that lack the pedagogical efficacy of more substantive tests, Brabec et al. [18] found that especially when carefully constructed, true–false tests can elicit beneficial retrieval processes that resemble those of other types of tests. Such benefits, however, might not be as consistent or powerful as those elicited by other tests [83].

12.3.1.3 Matching Questions (MQ)

This is a variation of a multiple-choice test where the answer to each of a number of sub-questions must be selected from a list of possibilities. Each item consists of two lists of statements, words, symbols, or numbers which have to be matched one with another. In general, the two lists contain different numbers of entries, those entries in the longer list that do not correspond to entries in the shorter list serving the function of distractors.

12.3.1.4 Extended Matching Questions (EMQ)

Extended matching tests are similar to multiple-choice tests. Given are at least two different scenarios and an answer option list where the options may be used once, more than once, or not at all.

This kind of test allows for an in-depth test of knowledge by providing scenarios similar in structure and content related to the question theme with one'best' answer from the plethora of answer options given (see, e.g., [98]). There is a greater chance of answering incorrectly if an examinee cannot synthesize and apply their knowledge.

12.3.1.5 Short Response Questions (SRQ)

Short response or short answer tests require a direct answer made of one or a few words rather than simply chosen from a number of options provided. A short response test may consist of incomplete statements where the examinee must supply the missing pieces of information, e.g., a word. phrase or a number.

It is graded by comparing against various model answers, which may contain wildcard characters.[2] The problem with the use of the wild card character is that the number of answers considered correct is potentially infinite.

Short response tests can be used for both formative and summative assessment. Generally, they have high reliability, focusing on specific knowledge or skills and are relatively quick and easy to mark. Also, in the case of unique answer questions, the examinee has to provide an answer to a question in terms of a word or a number.

12.3.1.6 Automatic Grading Systems for Programming

Among the program features that can be automatically assessed, there are: (i) functionality (checking that the program functions according to the given requirements by running the program against several test data sets), (ii) efficiency, e.g., measuring running time of the program during the execution and comparing it to an existing model solution, and (iii) student's skills of designing test cases and testing thoroughly before submitting the program, (iv) programming style and design, just to mention a few. However, since all programming skills cannot be assessed automatically, manual inspection of some skills is still necessary (see, e.g., [4]). In this case, some tools can help to save time especially when teaching many students. In [28], for example, the authors propose to identify equivalences between algorithms submitted by students and then to cluster similar answers requiring similar feedbacks.

Over the past few years, many MOOCs in programming were created offering learners an integrated environment to do all the exercises directly in a browser. This type of MOOC has two main advantages: from the learner's point of view, it avoids tedious installation and configuration of non-user-friendly software (compilers, code editor, versioning system, etc.), which is often the first obstacle for beginners in programming; and from the teacher's point of view, it allows to implement an automatic grading framework.

Such an automatic grading framework must meet several objectives: allow the teacher to detect errors and deduce a grade, avoid cheating, allow the learner to get continuously quick and readable feedback, guide the student in solving algorithmic

[2] A Wildcard Character is a Kind of a Placeholder Represented by a Single Character, E.G., Asterisk (*), Interpreted as a Set of Literal Characters or an Empty String.

problems and writing code. Most experiments using automatic grading in programming MOOCs have used a well-known practice in software engineering: test-driven development (TDD) [10]. TDD consists of writing unit tests describing the functionality to implement before any attempt of coding. A unit test is a piece of code that checks the correct operation of a source code supposed to do something. Most programming languages provide frameworks for the implementation of unit tests, e.g., JUnit for Java, CUnit for C, and PyUnit for Python.

Transposed to teaching with MOOC, this principle requires the teacher to describe the expectations for each exercise in the form of unit tests. Depending on the programming language (and the associated unit test library), these unit tests allow us to evaluate the validity of the solution produced by the learner's code and in some cases the quality of the code.

Works presented in Canou et al. [22] show it is possible to create an automatic grader with the same assessment refinement as a real teacher. The authors succeed in evaluating the coding style of a learner checking for example the use of nested loops when necessary. They were also able to evaluate the algorithmic complexity of a code. Since using a running time limit cannot always be reliable (depending on the machine load), they use a tuned execution environment able to count the number of performed operations.

From a technical perspective, implementing automated grading is challenging. Two approaches are possible. The first one consists of running automated grading on a server; this means that the code written in the learners' browsers is sent to the server to be run over unit tests. This execution must be done in an isolated environment to prevent any malicious intent from a malicious user, e.g., memory exhaustion or extra CPU time consumption. The second one consists of executing automated grading directly in learners' browsers. This solution allows distributing the computation cost over all the learners and to avoid the possible attacks mentioned previously.

Romli et al.[82] give a review of approaches that were implemented in various studies regarding automatic programming assessment, test data generation and integration of both of them up till 2010.

Caiza and Del Alamo [21] reviews tools for automatic grading of programming assignments. The review includes the definition and description of key features e.g. supported languages, used technology, infrastructure, etc. emphasizing improvements on security, support of different languages, plagiarism detection, etc. emphasizing the lack of a grading model for assignments in the reviewed tools. However, there is no common grading being applied. Thus, further research is required to propose an automatic assessment that grades the student achievement based on learning taxonomy such as Bloom Cognitive Competency model [66].

In the following, we mention some state-of-the-art systems for automated testing of code. The aim is not to give an exhaustive list of the software but to give a short overview based on the main characteristics of the frequently used software.

Web-CAT[3] is a free, open-source automated grading system that grades students on how well they test their own code [43]. It is highly customizable and extensible, and

[3] https://web-cat.github.io/projects/Web-CAT/. Accessed 8 January 2021.

supports virtually any model of program grading, assessment, and feedback generation. It supports student-written tests, measurement of test coverage, and grading on test thoroughness. It also supports static analysis tools to assess documentation and coding style. In the static analysis, the student's code is compared with the model programs given by a teacher: the closer the student code is to the model programs, the higher is the mark. It also supports manual grading with direct on-line markup of assignments.

CodeRunner[4] [38, 69] available in Moodle is another free open-source question-type plug-in tool that allows submitting code as a solution to an assigned question and assesses computer programming skills by compiling and executing student-submitted code in a sandbox in different possible programming languages. CodeRunner has also been used in computer science and engineering for automatic test grading when multiple correct answers are possible.

The output is compared to the solution provided by the teacher. A student receives his/her test-case results and feedback immediately and is given the opportunity to modify the solution and resubmit, typically with a small penalty. This encourages students to learn through an iterative process until they achieve the correct solution. Such a system lifts the workload from evaluators and provides uniformity and equality in the final grade (see, e.g., [38, 69]).

Codingbat[5] generates a fixed set of tests for Java and Python and shows the student the result of (some of) these tests. Codingbat also keeps track of the student's history with a problem by producing a time-based graph showing each time the student tried to run the program and the percentage of unit tests that were successful.

CLoudCoder[6] [76] is still another open source web-based integrated development environment (IDE) for creating, assigning, and sharing short programming exercises for C/C++, Java, Python and Ruby. It is a property of Microsoft Research inspired by CodingBat. Similarly to CodingBat, CloudCoder uses unit tests in a web-based game to give players an opportunity to exercise their inductive skills. Players are given the results of a set of unit tests (calculated result versus expected result) and are asked to write code that will pass all the unit tests without knowing the problem description.

Code Hunt[7] is another system made by Microsoft Research [91]. An exercise requires the student to write a small amount of code as an answer to a given problem. The student is presented a series of puzzles that he/she has to explore through clues that are presented as test cases. The student must find a solution to the problem, introducing changes in the code that he/she writes until it matches the functional behavior of some secret solutions.

The correctness of the student's code is judged automatically by running the code against a set of tests. If all of the tests pass, the student's code is judged to be correct. Since this tool is web-based and the assessment is automatic, students can work

[4] http://coderunner.org.nz. Accessed 8 January 2021.

[5] http://codingbat.com. Accessed 8 January 2021.

[6] https://cloudcoder.org/. Accessed 8 January 2021.

[7] http://codehunt.com. Accessed 8 January 2021.

wherever and whenever is convenient for them, and receive immediate feedback (see, e.g., [87]).

Spinoza[8] [30] is Python IDE to enable classroom orchestration in introductory programming classes. It supports active learning [11] in introductory Java programming courses.

Active learning is any activity that is course-related and that all students in a class session are called upon to do other than simply watching, listening, and taking notes [46]. It is learner-centered, not teacher-centered; the active participation of a student is a necessary aspect in active learning. Students must be doing things and simultaneously think about the work done and the purpose behind it so that they can enhance their higher order thinking capabilities. The motivation behind this approach is that undergraduate students in classes with traditional stand-and-deliver lectures are 1.5 times more likely to fail than students in classes that use more stimulating active learning methods [49].

Spinoza includes the features of Codingbat, CloudCoder and Code Hunt. Spinoza differs from other similar systems in providing the instructor with detailed feedback in real time about the progress of the students during in-class coding sessions, both at the level of the individual student and the class as a whole. From the students' view, Spinoza provides authenticated access to a collection of named programming problems and a web-based IDE which allows students to code, run, unit test, and debug those problems. From the instructor's view, Spinoza provides interfaces for creating a variety of programming challenges and also provides multiple views of students' progress in solving the coding problems [31].

Spinoza can be used to generate this type of challenge but it does not provide the game-like interface of Code Hunt. Code Hunt, in turn, lacks the dashboard view of Spinoza.

Table 12.1 gives a qualitative evaluation of the studied objective tests in terms of (high, medium or low) ease of gaming the system by the student, the time for preparation of the test by the teacher, complexity of elaboration, depth of the tested knowledge, the field specificity, test efficiency, authenticity of the test, accessibility of the test, and the dependency on the statements' accuracy. Besides, a great overview of automatic assessment systems for programming until 2005 can be found in Douce et al. [36].

12.3.2 Assembly of Automated Objective Tests

The previously presented objective tests can be both grouped in a question (item) bank or a subpool in a Learning Management System (e.g., Moodle) and can be delivered online. The questions in a test may be selected manually or automatically (randomly) (e.g., one question per subpool), statically offline. There is a perception among students that randomly selected questions from item banks are unfair [35].

[8] https://github.com/abudeebf/Spinoza-2.0. Accessed 8 January 2021.

Table 12.1 Qualitative comparison of objective tests in terms of their characteristics

	Method					
Characteristic	MCQ	True/false	MQ	EMQ	SRQ	CTS
Gaming the system	High	High	Medium	Low	Low	Low
Time consuming for user	Low	Low	High	High	Medium	High
Complexity of elaboration	Low	Low	Medium	High	High	High
Depth of the tested knowledge	Low	Low	Low	High	Medium	High
Field specific	Low	Low	Low	High	Low	High
Test efficiency	Medium	Low	Low	High	High	High
Authenticity of the test	Low	Low	Low	High	Medium	High
Accessibility of the test	Medium	Medium	High	Low	High	Low
Dependent of the statements' accuracy	Low	Low	Low	High	High	Medium

The questions can be selected also dynamically as the examinee performs during the administration of the test (adaptive tests). Questions here are selected dynamically at testing time and depend on the prior performance of the examinee. (see, e.g., [68]).

Social networks as well as fast and simple group messaging and calling applications provide for easy communication among examinees, and therefore, facilitate academically dishonest behavior and cheating. Various high-security solutions exists to minimize and eliminate cheating during the exam (e.g. lockdown features in the OS, Safe Exam Browser, Windows Take a test) but it can be also decreased by conducting continuous background checks, logging and reporting of suspected cheating to the teacher (see, e.g., [37, 48, 52, 88]).

Student Learning Experience

Learning is enhanced through active involvement in personally meaningful experiences accompanied by processing for meaning and future use [70]. However, tests generally are an intimidating experience that should be neutralized by explaining to the students the purpose for the test and stress the positive effects it will have. Many may have very negative feelings left over from previous bad experiences.

Detailed planning and development of e-assessment can contribute to generalizing and increasing the quality of student learning experience, increasing the confidence in test levels of engagement and cooperation (see, e.g., [35]).

12.4 Bias in Objective Tests, Ethical Issues, Explainability

Artificial intelligence is sometimes defined as the discipline concerned with automating tasks that require intelligence [12]. Automation, in turn, is the process of enabling machines and software to operate without direct control or supervision of people. When the outcome of automation has a direct impact on the well-being of people, we are rightly concerned with ensuring our capacity to adeptly monitor and analyze the automated activity. This concern has recently given rise to the field of AI ethics which includes, but is not limited to, the problems of accountability, transparency, fairness, and ethics.

Accountability

Accountability is defined in the Oxford dictionary as "the fact of being responsible for your decisions or actions and expected to explain them when you are asked" [1]. In Test-based accountability, tests are used to determine student status with respect to specific content standards. Every participant of the learning process is considered accountable for student test scores based on which the educational system has assigned criteria for rewards and sanctions for students, teachers, and/or schools. The educational system is responsible for communicating their functioning to educators and the public [59].

Test-based accountability can make teachers cover more material in the course and adopt better curricula or more effective teaching methods. However, test-based accountability can also make teachers teach only tested aspects incidental to the domain the test is intended to represent at the expense of untested aspects of the standards.

Intensified test-based accountability can also facilitate cheating on tests while decreasing equity, well-being, and justice (see, e.g., [81, 84]).

Another definition of accountability by Bovens [17] is:

> a relationship between an actor and a forum, in which the actor has an obligation to explain and to justify his or her conduct, the forum can pose questions and pass judgment, and the actor may face consequences.

In the context of AI and algorithms, we define algorithmic accountability as the accountability relationship in which the subject of the account is an algorithm [96].

When we are talking about the accountability of a system that is deployed, we are asking how we can empower a forum to attain accountability from the system. In contrast, when we are talking about a system in the design phase, then we are concerned with identifying who should have the power to change the behavior of the system being developed. When the new system is to replace human activity with an algorithm, we need to be concerned with the impact this change will have on powers that the user has. A human user can always freely and directly communicate with a human exam evaluator. However, this power is necessarily taken away when an automated evaluator is used. While we may not want to give students the power to change the behavior of an automated evaluator, we need to ensure a clear feedback communication path. This means that a student can react to perceived malfunction and should be given a timely response to the concern.

Transparency

Transparency is defined as the quantity and quality of information made available to the forum [33]. Test transparency is related with the clarity of information given to the students regarding how they will be assessed and based on what criteria, e.g., how to answer the tests, available test time, the assessment procedure, and the formula for calculating the final grade. Test transparency also includes accessibility to sample questions and clarifying the evaluation criteria by making available to the students their detailed evaluation results.

The transparency of an algorithm is measured as the extent to which the available information about the algorithm that is subject to accountability allows the forum to monitor the workings or performance of that algorithm. In the context of automated evaluation, transparency can mean how much is the student aware of the workings of the evaluation system. This can be as trivial as the student does (not) know the evaluation is automated. It can also be that students are given details of the principles of the algorithm used; for example, whether a rule-based system is used, or a machine learning system, on which data is the system trained etc.

Explainability

Explainability, also called explainable AI (XAI), is explicitly concerned with the account, the possibility of generating it by human or automatic means [56]. When a decision or an evaluation is made about a person, particularly an undesirable one, explainability plays a crucial role to empower that person to improve their standing by mitigating the circumstances that led to the undesirable outcome. Beyond that explanation plays a role in enabling the designers of an algorithm to analyze its behavior particularly in specific contexts.

In the evaluator-student accountability relationship, explainability is a very important property of an automated system as it can make a difference to the learning experience. There are two aspects to be explained here. The first is shared with human evaluates: why is a particular answer marked as wrong? Explainability of AI and algorithms in general refers to its ability to identify how the input affects the output. In other words, an algorithm is explainable if it can provide information on how the outcome can be changed. There are three basic ways to attain explainability, but not all the three ways are possible for all types of algorithms.

The first is *explainability by design*. Some algorithms can be transparent to the user who can directly inspect them. For instance, informing a student they have obtained 125 points and that the threshold for a B is 130 points explains why they got a C. In the case of a multiple-choice exam, together with the solution key, this is sufficient explanation because the student learns how to improve their grade.

The second approach is "*backtracking*". Explainability can be accomplished by an algorithm that "backtracks" its own work to extract justifications or reasons for each decision it takes. This approach is particularly suited for rule-based systems. But tracking back the rules that have yielded the final evaluation, and which conditions were satisfied that made the rule applicable, one can understand why a particular evaluation was made. Knowing which rules the system can follow and changing some of the conditions, will result in an improved evaluation.

Lastly, there is the approach of *interpretation*. Explainability can also be accomplished by a second algorithm that creates interpretations of the decisions made by the algorithm that is subject of the account. This approach is explored for some machine learning algorithms [56] where none of the other two approaches can be applied. In automated evaluation that uses machine learning, one has to be clear that the rule "learned" by training is not an inference but a correlation that heavily depends on the data used in training. The use of historic data in assigning grades comes with serious possible consequences[9] and if machine learning cannot be avoided, then it is very important to couple such an algorithm with strong accountability to the students and their guardians.

Fairness

When the output of an algorithm is different for different people, a major concern is whether that algorithm is *fair*, namely whether it works equally well for all persons. Fairness studies are motivated by the use of machine learning in the context of decision-making [77], however concerns for fairness extend to all algorithms that are part of systems that ethically impact individuals and society.

As an example of algorithmic bias in education, consider the case of a "virtual teaching assistant for a Georgia Tech course on artificial intelligence" which responded more successfully to concerns of male than those of female students [44]. The use of historical data can reinforce existing bias by transforming past correlations between socio-demographic properties and grades into present rules of inference.

The *unfairness* of an algorithm can be introduced at two points: by using input that has some kind of bias, or by having unfairness built in its operation and use. The ethical impact of an unfair algorithm is in an output that has an impact on equity, namely unevenly distributing resources among groups or individuals, but also by supporting or exalting existing undesirable phenomena in society. These points of introducing unfairness are not clearly separated and often bump into each other. *Algorithmic bias* refers to the second type of introduced unfairness: "Algorithmic bias is added by the algorithm itself and not present in the input data" [8]. Real-world examples of the occurrences of data bias are listed in, for example [62, 75].

Two general notions of fairness are considered, both of interest for decision-making and evaluation algorithms used in education: *group fairness* and *individual fairness*. In group fairness [75], we are concerned with statistical notions of fairness where a small number of protected demographic groups are identified. We are concerned with ensuring that (approximate) parity of some statistical measure across all these groups is maintained.

Individual fairness, on the other hand, is a metric that compares the similarity of evaluations for similar answers. In individual fairness [41], we are concerned that similar individuals should be treated similarly. A particular challenge for individual similarity is the identification of a metric for comparing the likeness of individuals. In group fairness we are concerned with the ability to identify many different metrics which may be mutually unaligned.

Fairness in machine learning is challenging to achieve for a variety of reasons [65]. Regardless of the problem, there sometimes does not exist a solution which is universally fair, equitable and just. The additional requirement of fairness can

[9] https://www.nytimes.com/2020/08/20/world/europe/uk-england-grading-algorithm.html.

come at a cost of efficiency—an algorithm can only be made fairer if it is made less correct. It has been shown that certain fairness types cannot be simultaneously achieved in machine learning [26]. In such situations, a trade-off would be necessary, meaning that we need to have a way to resolve such conflicts fairly. Both the data bias and algorithmic fairness measures evaluate a particular machine learning problem. However, local decisions, particularly when repeated over time, can lead to emerging global effects. Namely, by allowing a particular data bias to go undetected or by invisibly but consistently preferring one type of users over another, we may change our society. The risk of emerging effects from automated decision-making is difficult to localize, measure and mitigate.

The highest concern when we consider the fairness of algorithms that automate grading is that, as Chouldechova and Roth argue, "statistical definitions of fairness do not on their own give meaningful guarantees to individuals or structured subgroups of the protected demographic groups. Instead, they give guarantees to 'average' members of the protected groups" [27].

When the new system is to replace human activity with an algorithm, we need to be concerned with the impact this change will have on the service provider-service recipient relationship. In this relationship, both parties have both rights and obligations. One must be vigilant as to how this relationship changes when the evaluator role is supplemented with an algorithm. A somewhat neglected aspect of fairness is the disruption of this power balance: more obligations are transferred from the human evaluator to the human student. For example, in non-multiple-choice tests, a human evaluator will directly comment on the answer and how it can be improved. The student gets this comment when receiving the evaluation. When that same evaluation is automated, the answer can be marked as incorrect, but a human evaluator needs to supply the explanation. Now, the student would have to explicitly ask for the explanation, thus introducing an added obligation on the student that was not there before: figure out how to ask for the explanation and from whom. This too can be considered unfair behavior: students that have a strong technical understanding of the system will be at an advantage.

Privacy

Lastly, the much-discussed property of algorithms today is that of *privacy*. As discussed in Garshi et al. [51], new technology offers to blur the line between supervision and surveillance and change the learning experience altogether. Privacy in the context of performance evaluation is not a concern that is unique to new technologies. There is no one definition of what privacy or breach of privacy is but as per Solove [86], privacy can be breached by three main information-related activities: information collection, processing, and dissemination.

In the context of automated evaluation, this means a student's privacy can be violated when data from the student is collected, when the evaluation is done and when the results of the evaluation are disseminated. We would add that the world of machine learning algorithms offers a fourth possibility—including information from the evaluation process in a data set further used in training algorithms or made available to third parties. The topic of the "classic" three privacy vulnerable points is, as far as we are aware, not explored in the context of automated grading and evaluation.

The problem of student data use is a pertinent one that is to a certain extent tackled by ensuring that any data collected satisfies differential privacy conditions [40]. This means that data points that would make it possible for a student to be identified in a data collection are removed. While ensuring differential privacy is the first step in guaranteeing the privacy of students whose data is collected, it is not a magic bullet. The problem of specifying what constitutes a violation of privacy in automated grading and evaluation and how to prevent those violations is still an open challenge.

12.5 Comparison of Factual Tests and Code Testing Systems

This section discusses the selection of an appropriate type of test for each type of knowledge: understanding of programming concepts and principles that do not include writing program code, application—simple programming tasks, analysis—debugging tasks, and synthesis—advanced programming assignments. We compare the five principles of testing as well as ethical issues and explainability of the previously presented factual tests including multiple choice questions, true/false questions, matching questions, extended matching questions, and short response questions as well as code testing systems including Web-Cat, CodeRunner, Codingbat, Cloud-Coder, Code Hunt, and Spinoza.

The performance indicators we consider are learning experience, transparency, explainability, authenticity, reliability, practicality, and positive washback, Table 12.2.

The rating system of the studied performance indicators is represented by a 3-point rating scale that measures whether a goal was accomplished. A 3 ranking implies that a goal was met, a 2 ranking is given to partially met goals, and a 1 ranking is assigned to an unfinished goal where most or all dimensions were not achieved. Note that the indicated rating is given for the optimized questions designed to respond at best to the type of the question.

A pleasant experience with an online test does not stress the student unnecessarily and it facilitates and stimulates learning. Learning experience in factual tests is generally much lower than in code testing systems whose user interface (UI) plays a major role that is generally useful, with an intuitive interface and the structure and presentation of content and multimedia, easy to navigate, with a good graphic design for a high-quality learning experience.

In the case of ambiguity of a factual test, the lack of space prohibits the students to explain their answer and the interpretation of the question, which can result in a negative experience. Moreover, code testing systems run in iterations. Spinoza is apt for active learning, but it does not provide the game-like interface of CodeHunt.

Table 12.2 Comparison of factual tests and code testing systems considering learning experience, transparency, explainability, reliability, practicality, and positive washback

Group →	Factual tests						Code testing systems				
	Method										
Category	MCQ	True/false	MQ	EMQ	SRQ	Web-Cat	CodeRunner	Codingbat	CloudCoder	CodeHunt	Spimoza
Learn. experience?	2	1	2	1	2	3	3	3	3	3	3
Transparent?	3	3	3	3	3	2	2	2	2	2	1
Explaninable?	3	3	3	3	3	3	3	3	3	3	3
Authentic?	2	1	1	1	1	3	3	3	3	3	3
Reliable?	3	3	3	3	3	2	2	2	2	2	2
Pratical?	3	3	3	3	3	2	2	2	2	2	2
Pos. washback?	3	3	3	3	2	2	2	2	2	2	2

The transparency of factual texts in general is higher than the transparency of code testing systems since the rules of evaluation are very simple and given in advance. In the studied code testing systems, in static analysis, the students' code is compared with the model programs given by a teacher: the closer the student code is to the model programs, the higher is the mark. Here it is more difficult to give a clear-cut explanation on the grade as there are more sources of error that may be syntactic and structural. Optionally, manual grading by the teacher with direct on-line markup of code is possible, which is a type of subjective grading prone to bias and to other errors discussed previously.

All the studied factual tests and code testing systems are explainable since we can interpret the marks given while being able to clearly traverse back, from the grades to the student answers, on the rule-based path the test took to arrive at the marks.

The authenticity of factual tests in evaluating computer programming knowledge and skills is generally much lower than the authenticity of code testing systems.

Reliability in Table 12.2 refers to test reliability that can be improved by clear task instructions, clear assessment criteria, and scales. However, creating an analytic scale for marking a test is more difficult in the case of code testing systems than in factual tests.

In general, practicality in factual tests is also higher than in code testing systems since the time and effort that the development of models and feedback delivery require in code testing systems is much higher than in factual tests. Moreover, both in factual tests as in code testing systems, it is difficult to give a personalized positive washback that helps students to improve their skills. While feedback in code testing systems mostly focuses on identifying errors, factual tests let the teacher adapt washback for each type of answer. However, detecting errors in code-testing helps the student to fix them and thus evolve in an iterative code development, even though not in the most constructive environment.

Since validity depends on the type of knowledge tested, we compare the latter in previously mentioned tests for testing basic concepts and paradigms, simple programming, debugging, and advanced programming. Additionally, we give the rating of the matching of the four learning objective categories in computer science courses with the discussed factual tests and code testing systems aiming at providing a higher degree of test validity in Table 12.3. The 3-point rating scale that measures whether a goal was accomplished here is the same as in Table 12.2.

The validity of factual tests in testing basic computer science concepts and paradigms is high, contrary to code testing systems since here we speak about understanding the basic constructive concepts, definitions, and their relations in computer science. However, even though we may design multiple-choice questions for testing simple programming skills, factual tests are, in general, not apt for testing the knowledge and skills in simple programming, debugging, and advanced programming. Additionally, the studied code-testing systems are apt for testing introductory programming knowledge and skills but are not suitable for advanced programming evaluation for which code testing systems are still waiting to be developed.

Table 12.3 Validity comparison of factual tests and code testing systems

Group →	Factual tests						Code testing systems				
	Method										
Category	MCQ	True/false	MQ	EMQ	SRQ	Web-Cat	CodeRunner	Codingbat	CloudCoder	CodeHunt	Spimoza
Basic concepts	3	3	3	3	3	1	1	1	1	1	1
Simple programming	2	2	2	2	2	2	3	3	3	3	3
Debugging	1	1	1	1	1	3	3	3	3	3	3
Adv. programming	1	1	1	1	1	2	2	2	2	2	2

12.6 Conclusions and Future Challenges

To achieve creative and critical thinking in our students and to facilitate their collaboration and lifelong learning given the constant evolution of technology and the related high probability of changing career paths, we need to provide for a fast development of new skills and the change in the assessment going beyond conventional reactive rule-based automated grading systems.

Contrary to traditional lecturing mostly used in the classroom, active learning through online learning technologies (e.g., Spinoza) is a preferable learning approach that specifically presupposes students' activity. It benefits on average all students while offering increased benefits for students from underrepresented groups. Widespread implementation of high-quality active learning can help reduce learning gaps in computer science courses and promote student equity (see, e.g., [90]).

In Table 12.4, we give a three-level qualitative grading scale comparison (more, equal, and less) of software based objective tests versus subjective tests performed by human evaluators in terms of the following characteristics: fairness, bias, transparency, explainability, and reliability. If designed well, in general, objective tests may be more fair, less biased, more transparent, explainable, and more reliable compared to subjective tests performed by human evaluators. This summative and coarse comparison should be taken with reserve due to significant variations in terms of subdiscipline and other relevant parameters that influence the choice of the test. Since the discipline of learning assessment develops rapidly, it is likely that this qualitative comparison will change in the future.

Yet another issue with advanced programming assessment tools in online tests is that they still depend on human teacher evaluation capacity that cannot yet be easily automatized. Thus, the scalability of these tools depends on the availability of skilled teaching staff and on the level of preparedness and the homogeneity of the academic background of the students in the class.

To bridge the gap between the active learning requirements for automated grading of computer science courses online and the state-of-the-art online grading methods, automated grading should consider learning preferences and constraints of each student. Instead of reactive rule-based objective tests, a proactive automated grading system of the future should be able to function as a learning assistant adaptable to the learning pace, characteristics, preferences, and abilities of each student whether they are at introductory, intermediate, or advanced programming level. Such a system should also serve for connecting compatible students in creating study groups in large MOOCs and thus facilitate students' empowerment and learning autonomy, where seamless meeting of new peers and establishing study networks among students

Table 12.4 Qualitative comparison of automated (software based) objective tests versus subjective (human evaluated) tests

Fairness	Bias	Transparency	Explainability	Reliability
More	Less	More	More	More

is still an open challenge. From our perspective, software agent technology seems to be a promising line of research for active learning and efficient and effective application of code testing systems in advanced programming based on the learning pace, requirements and needs of each student.

References

1. Accountability, Oxford learner's dictionaries (2021), https://www.oxfordlearnersdictionaries.com/definition/english/accountability. Accessed 9 Jan 2021
2. P.W. Airasian, *Classroom Assessment: Concepts and Applications* (ERIC, 2001)
3. M.O. Al-Rukban, Guidelines for the construction of multiple choice questions tests. J. Family Commun. Med. **13**(3), 125 (2006)
4. K.M. Ala-Mutka, A survey of automated assessment approaches for programming assignments. Comput. Sci. Educ. **15**(2), 83–102 (2005)
5. J. Anderson, Sex-related differences on objective tests among undergraduates. Educ. Stud. Math. **20**(2), 165–177 (1989)
6. L.W. Anderson, B.S. Bloom et al., *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives* (Longman, 2001)
7. J.M.M.L. Azevedo, A.P. Lopes, M.D.L. Babo, C. Torres, Multiple-choice tests: a tool in assessing knowledge. ICERI (2010)
8. R. Baeza-Yates, Bias on the web. Commun. ACM **61**(6), 54–61 (2018). https://doi.org/10.1145/3209581
9. S.P. Balfour, Assessing writing in moocs: Automated essay scoring and calibrated peer review™. Res. Pract. Assess. **8**, 40–48 (2013)
10. K. Beck, *Test-Driven Development: By Example* (Addison-Wesley Professional, 2003)
11. B.S. Bell, S.W. Kozlowski, Active learning: effects of core training design elements on self-regulatory processes, learning, and adaptability. J. Appl. Psychol. **93**(2), 296 (2008)
12. R.E. Bellman, *An Introduction to Artificial Intelligence: Can Computers Think?* (Boyd & Fraser Publishing Company, 1978)
13. G. Ben-Shakhar, Y. Sinai, Gender differences in multiple-choice tests: the role of differential guessing tendencies. J. Educ. Measur. **28**(1), 23–35 (1991)
14. R. Bennett, M. Goodman, J. Hessinger, H. Kahn, J. Ligget, G. Marshall, J. Zack, Using multimedia in large-scale computer-based testing programs. Comput. Hum. Behav. **15**(3–4), 283–294 (1999)
15. R.E. Bennett, The changing nature of educational assessment. Rev. Res. Educ. **39**(1), 370–407 (2015)
16. B.S. Bloom, M.D. Engelhart, E.J. Furst, W.H. Hill, D.R. Krathwohl, Taxonomy of educational objectives: the classification of educational goals. *Handbook I Cognitive Domain* (David McKay Company Inc, New York, 1956)
17. M. Bovens, Analysing and assessing accountability: a conceptual framework1. Eur. Law J. **13**(4), 447–468 (2007). https://doi.org/10.1111/j.1468-0386.2007.00378.x
18. J.A. Brabec, S.C. Pan, E.L. Bjork, R.A. Bjork, True-false testing on trial: guilty as charged or falsely accused? Educ. Psychol. Rev. 1–26 (2020)
19. G.A. Brown, J. Bull, M. Pendlebury, *Assessing Student Learning in Higher Education* (Routledge, 2013)
20. H.D. Brown, P. Abeywickrama, *Language Assessment: Principles and Classroom Practices*, vol. 10 (Pearson Education White Plains, NY, 2010)
21. J.C. Caiza, J.M. Del Alamo, Programming assignments automatic grading: review of tools and implementations, in *7th International Technology, Education and Development Conference (INTED2013)* (2013), p. 5691

22. B. Canou, R.D. Cosmo, G. Henry, Scaling up functional programming education: under the hood of the Ocaml MOOC. Proc. ACM Program. Lang. **1**(ICFP):4:1–4:25 (2017). https://doi.org/10.1145/3110248
23. Y. Cao, L. Porter, S.N. Liao, R. Ord, Paper or online? A comparison of exam grading techniques, in *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education* (2019), pp. 99–104
24. E.G. Carmines, R.A. Zeller, *Reliability and Validity Assessment* (Sage Publica tions, 1979)
25. G. Charness, U. Gneezy, Strong evidence for gender differences in risk taking. J. Econ. Behav. Organ. **83**(1), 50–58 (2012)
26. A. Chouldechova, Fair prediction with disparate impact: a study of bias in recidivism prediction instruments. Big Data **5**(2), 153–163 (2017). https://doi.org/10.1089/big.2016.0047,doi:10.1089/big.2016.0047
27. A. Chouldechova, A. Roth, A snapshot of the frontiers of fairness in machine learning. Commun. ACM **63**(5), 82–89 (2020). https://doi.org/10.1145/3376898
28. J. Clune, V. Ramamurthy, R. Martins, U.A. Acar, Program equivalence for assisted grading of functional programs, vol. 4 (OOPSLA, 2020). https://doi.org/10.1145/3428239
29. I. Dabbebi, S. Iksal, J.M. Gilliot, M. May, S. Garlatti, Towards adaptive dashboards for learning analytic: an approach for conceptual design and implementation, in *9th International Conference on Computer Supported Education (CSEDU 2017)*, Porto, Portugal (2017), pp. 120–131. https://doi.org/10.5220/0006325601200131
30. F.A. Deeb, T. Hickey, Spinoza: the code tutor, in *Proceedings of the International Conference on Computer and Information Science and Technology*, Ottawa, Canada (2015)
31. F.A. Deeb, T. Hickey, Flipping introductory programming classes using spinoza and agile pedagogy, in *2017 IEEE Frontiers in Education Conference (FIE)* (IEEE, 2017), pp. 1–9
32. P. Denny, S. Manoharan, U. Speidel, G. Russello, A. Chang, On the fairness of multiple-variant multiple-choice examinations, in *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (2019), pp. 462–468
33. N. Diakopoulos, Transparency, in *The Oxford Handbook of Ethics of AI*, ed. M.D. Dubber, F. Pasquale, S. Das (Oxford University Press, 2020). https://doi.org/10.1093/oxfordhb/9780190067397.013.11
34. A. Dimitrakopoulou, State of the art on interaction and collaboration analysis. (D26.1.1) EU Sixth Framework programme priority 2, Information society technology, Network of Excellence Kaleidoscope, (contract NoE IST-507838), project ICALTS: Interaction & Collaboration Analysis (2004)
35. G. Domino, M.L. Domino, *Psychological Testing: An Introduction* (Cambridge University Press, 2006)
36. C. Douce, D. Livingstone, J. Orwell, Automatic test-based assessment of programming: a review. J. Educ. Resourc. Comput. (JERIC) **5**(3), 4–es (2005)
37. F. Drasgow, *Technology and Testing: Improving Educational and Psychological Measurement* (Routledge, 2015)
38. W. Du, *Code Runner: Solution for Recognition and Execution of Handwritten Code* (Standford University, 2012), pp. 1–5
39. E. Duval, M. Sharples, R. Sutherland, *Technology Enhanced Learning* (Springer, 2017)
40. C. Dwork,F. McSherry, K. Nissim, A. Smith, Calibrating noise to sensitivity in private data analysis, in *Theory of Cryptography*, ed. S. Halevi, T. Rabin (Springer Berlin Heidelberg, Berlin, Heidelberg, 2006), pp. 265–284
41. C. Dwork, M. Hardt, T. Pitassi, O. Reingold, R.S. Zemel, Fairness through awareness (2011), http://arxiv.org/abs/1104.3913
42. R.L. Ebel, D.A. Frisbie, *Essentials of Educational Measurement* (Prentice-Hall Englewood Cliffs, NJ, 1972)
43. S.H. Edwards, M.A. Perez-Quinones, Web-cat: automatically grading programming assignments, in *Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education* (2008), pp. 328–328

44. B. Eicher, L. Polepeddi, A. Goel, Jill Watson doesn't care if you're pregnant: grounding AI ethics in empirical studies, in: *Proceedings of the 2018 AAAI/ACM Conference on AI, Ethics, and Society, Association for Computing Machinery*, New York, NY, USA, AIES '18 (2018), pp. 88–94. https://doi.org/10.1145/3278721.3278760
45. Elias T (2011) Learning analytics. Learning 1–22
46. R.M. Felder, R. Brent, Active learning: an introduction. ASQ High. Educ. Brief **2**(4), 1–5 (2009)
47. R. Ferguson, Learning analytics: drivers, developments and challenges. Int. J. Technol. Enhanc. Learn. **4**(5–6), 304–317 (2012)
48. M. Finkelman, M.L. Nering, L.A. Roussos, A conditional exposure control method for multidimensional adaptive testing. J. Educ. Measur. **46**(1), 84–103 (2009)
49. S. Freeman, S.L. Eddy, M. McDonough et al., Active learning increases student performance in science, engineering, and mathematics. Proc. Natl. Acad. Sci. **111**(23), 8410–8415 (2014)
50. S. García-Molina, C. Alario-Hoyos, P.M. Moreno-Marcos, P.J. Muñoz-Merino, I. Estévez-Ayres, C. Delgado Kloos, An algorithm and a tool for the automatic grading of MOOC learners from their contributions in the discussion forum. Appl. Sci. **11**(1) (2021). https://doi.org/10.3390/app11010095, https://www.mdpi.com/2076-3417/11/1/95
51. A. Garshi, M.W. Jakobsen, J. Nyborg-Christensen, D. Ostnes, M. Ovchinnikova, M. Slavkovik, Smart technology in the classroom: systematic review and prospects for algorithmic accountability, in *Handbook of Intelligent Techniques in Educational Process* (Springer, in this book, 2021)
52. E. Georgiadou, E. Triantafillou, A.A. Economides, A review of item exposure control strategies for computerized adaptive testing developed from 1983 to 2005. J. Technol. Learn. Assess. **5**(8), n8 (2007)
53. A. Gopal, Internationalization of higher education: preparing faculty to teach cross-culturally. Int. J. Teach. Learn. High. Educ. **23**(3), 373–381 (2011)
54. C. Gordon, J. Hughes, C. McKenna, Assessment toolkit ii: Time-constrained examinations (2017), https://london.ac.uk/sites/default/files/cde/assessment-toolkit-II-2017.pdf. Accessed 9 Jan 2021
55. N.E. Gronlund, *Assessment of Student Achievement* (ERIC, 1998)
56. D. Gunning, D. Aha, Darpa's explainable artificial intelligence (XAI) program. AI Mag. **40**(2), 44–58 (2019)
57. T.M. Haladyna, *Developing and Validating Multiple-Choice Test Items* (Rout ledge, 2004)
58. R.K. Hambleton, H. Swaminathan, *Item Response Theory: Principles and Appli cations* (Springer Science & Business Media, 2013)
59. L.S. Hamilton, B.M. Stecher, S.P. Klein, *Making Sense of Test-Based Accountability in Education* (Rand Corporation, 2002)
60. Y. Han, W. Wu, Y. Yan, L. Zhang, Human-machine hybrid peer grading in spocs. IEEE Access **8**, 220922–220934 (2020). https://doi.org/10.1109/ACCESS.2020.3043291
61. R.M. Harden, Learning outcomes and instructional objectives: is there a difference? Med. Teach. **24**(2), 151–155 (2002)
62. M. Kearns, A. Roth, *The Ethical Algorithm: The Science of Socially Aware Algorithm Design* (Oxford University Press, 2019)
63. H. Keuning, J. Jeuring, B. Heeren, A systematic literature review of automated feedback generation for programming exercises. ACM Trans. Comput. Educ. (TOCE) **19**(1), 1–43 (2018)
64. R. Killen, Validity in outcomes-based assessment. Perspect. Educ. **21**(1), 1–14 (2003)
65. M.J. Kusner, J.R. Loftus, The long road to fairer algorithms. Nature 34–36 (2020). https://doi.org/10.1038/d41586-020-00274-3
66. A. Lajis, S.A. Baharudin, D. Ab Kadir, N.M. Ralim, H.M. Nasir, N.A. Aziz, A review of techniques in automatic programming assessment for practical skill test. J. Telecommun. Electron. Comput. Eng. (JTEC) **10**(2–5), 109–113 (2018)

67. A. Lebis, M. Lefevre, V. Luengo, N. Guin, Capitalisation of analysis processes: enabling reproducibility, openess and adaptability thanks to narration, in *LAK '18—8th International Conference on Learning Analytics and Knowledge* (ACM, Sydney, Australia, 2018), pp. 245–254. https://doi.org/10.1145/3170358.3170408, https://hal.archives-ouvertes.fr/hal-01714184
68. W.J. van der Linden, C.A. Glas, *Elements of adaptive testing* (Springer, 2010)
69. R. Lobb, J. Harlow, Coderunner: a tool for assessing computer programming skills. ACM Inroads **7**(1), 47–51 (2016)
70. Luckner JL, Nadler RS (1997) Processing the experience: Strategies to enhance and generalize learning. ERIC
71. J.M. Malouff, E.B. Thorsteinsson, Bias in grading: a meta-analysis of experimental research findings. Aust. J. Educ. **60**(3), 245–256 (2016)
72. H.W. Marsh, Students' evaluations of university teaching: dimensionality, reliability, validity, potential biases and usefulness, in *The Scholarship of Teaching and Learning in Higher Education: An Evidence-Based Perspective* (Springer, 2007), pp. 319–383
73. P. McCoubrie, Improving the fairness of multiple-choice questions: a literature review. Med. Teach. **26**(8), 709–712 (2004)
74. S.E. Meek, L. Blakemore, L. Marks, Is peer review an appropriate form of assessment in a MOOC? Student participation and performance in formative peer review. Assess. Eval. High. Educ. **42**(6), 1000–1013 (2017)
75. N. Mehrabi, F. Morstatter, N. Saxena, K. Lerman, A. Galstyan, A survey on bias and fairness in machine learning (2019). CoRR http://arxiv.org/abs/1908.09635
76. A. Papancea, J. Spacco, D. Hovemeyer, An open platform for managing short programming exercises, in *Proceedings of the Ninth Annual International ACM Conference on International Computing Education Research* (2013), pp. 47–52
77. D. Pessach, E. Shmueli, Algorithmic fairness. 2001.09784 (2020)
78. J. Pivarski, C. Bennett, R.L. Grossman, Deploying analytics with the portable format for analytics (PFA), in *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining* (ACM, 2016), pp. 579–588
79. Y. Reyneke, C.C. Shuttleworth, R.G. Visagie, Pivot to online in a post-covid-19 world: critically applying BSCS 5E to enhance plagiarism awareness of accounting students. Account. Educ. 1–21 (2020)
80. E.G. Rizkallah, V. Seitz, Understanding student motivation: a key to retention in higher education. Sci. Ann. Econ. Bus. **64**(1), 45–57 (2017)
81. J. Ro, Learning to teach in the era of test-based accountability: a review of research. Prof. Dev. Educ. **45**(1), 87–101 (2019)
82. R. Romli, S. Sulaiman, K.Z. Zamli, Automatic programming assessment and test data generation a review on its approaches, in *2010 International Symposium on Information Technology*, vol 3 (IEEE, 2010), pp. 1186–1192
83. C.A. Rowland, The effect of testing versus restudy on retention: a meta-analytic review of the testing effect. Psychol. Bull. **140**(6), 1432 (2014)
84. D. Santori, Test-based accountability in England, in *Oxford Research Ency clopedia of Education* (2020)
85. N. Siddiquei, R. Khalid, The relationship between personality traits, learning styles and academic performance of e-learners. Open Praxis **10**(3), 249–263 (2018)
86. D.J. Solove, A taxonomy of privacy. Univ. Pennsylvania Law Rev. **154**(3), 477–564 (2006), http://www.jstor.org/stable/40041279
87. J. Spacco, P. Denny, B. Richards, D. Babcock, D. Hovemeyer, J. Moscola, R. Duvall, Analyzing student work patterns using programming exercise data, in *Proceedings of the 46th ACM Technical Symposium on Computer Science Education* (2015), pp. 18–23
88. M.L. Stocking, C. Lewis, Methods of controlling the exposure of items in cat, in *Computerized Adaptive Testing: Theory and Practice* (Springer, 2000), pp. 163–182
89. L. Suskie, *Assessing Student Learning: A Common Sense Guide* (Wiley, 2018)
90. E.J. Theobald, M.J. Hill, E. Tran, et al., Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. Proc. Natl. Acad. Sci. **117**(12), 6476–6483 (2020)

91. N. Tillmann, J. De Halleux, T. Xie, J. Bishop, Code hunt: gamifying teaching and learning of computer science at scale, in *Proceedings of the First ACM Conference on Learning@ Scale Conference* (2014), pp. 221–222
92. K.J. Topping, Peer assessment. Theory Pract. **48**(1), 20–27 (2009)
93. O.M. Ventista, Self-assessment in massive open online courses. E-Learn. Digit. Media **15**(4), 165–175 (2018)
94. E. Ventouras, D. Triantis, P. Tsiakas, C. Stergiopoulos, Comparison of examination methods based on multiple-choice questions and constructed-response questions using personal computers. Comput. Educ. **54**(2), 455–461 (2010)
95. K. Verbert, N. Manouselis, H. Drachsler, E. Duval, Dataset-driven research to support learning and knowledge analytics. J. Educ. Technol. Soc. **15**(3), 133–148 (2012)
96. M. Wieringa, What to account for when accounting for algorithms: a systematic literature review on algorithmic accountability, in *Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency, Association for Computing Machinery*, New York, NY, USA, FAT*'20 (2020), pp. 1–18. https://doi.org/10.1145/3351095.3372833
97. G. Wiggins, Assessment: authenticity, context, and validity. Phi delta kappan **75**(3), 200–213 (1993)
98. E. Wood, What are extended matching sets questions? Biosci. Educ. **1**(1), 1–8 (2003)
99. C. Wyatt-Smith, J. Cumming, *Educational assessment in the 21st century* (Springer, 2009)
100. J. Xu, Q. Li, J. Liu, P. Lv, G. Yu, Leveraging cognitive diagnosis to improve peer assessment in MOOCS. IEEE Access **9**, 50466–50484 (2021). https://doi.org/10.1109/ACCESS.2021.3069055

Chapter 13
Correlating Universal Design of Learning and the Performance in Science at Elementary School Level

Munazza A. Mirza, Khawar Khurshid, Asma Hasan, Zawar Shah, and Faryal Shah

Abstract Recently, we have been relying greatly on technology and scientific advancements in every filed of life, therefore, a science class must include scientific literacy regardless of gender, social circumstances, interests, learning styles or learning difficulties without any barriers. A barrier to learning is anything that hinders the way of a child being able to learn effectively. A learner may experience one or more barriers to learning throughout his or her education. A teacher needs to have a number of options for methods s/he can use to deliver the lesson to the pupils. If a single method is used to deliver the content to diverse learners it might create barriers and all pupils may not grasp the concept thoroughly. When teachers preplan their lessons with respect to three principles of Universal Design of Learning (UDL) framework, its guidelines, and network of brain associated with each principle using blended learning approach, it helps eradicate the barriers and provide inclusive learning environment to improve learner's academic performance. Science teachers need to preplan their lesson using multiple means of representation, assessment and engagement for inclusive educational environment. Therefore, the present study aims to investigate the impact on learner's academic performance when a teacher uses Universal Design of learning framework for planning Science lesson. The unit of food and health from the national curriculum for General Science of

M. A. Mirza · K. Khurshid (✉)
School of Electrical Engineering and Computer Science, National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
e-mail: khawar.khurshid@seecs.edu.pk

M. A. Mirza
e-mail: mmirza.msite17seecs@seecs.edu.pk

A. Hasan
Royal Melbourne Institute of Technology, Melbourne, Australia

Z. Shah
Sydney International School of Technology and Commerce, Sydney, Australia
e-mail: zawar.s@sistc.nsw.edu.au

F. Shah
Australian Institute of Higher Education, Sydney, Australia
e-mail: f.shah@aih.nsw.edu.au

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_13

Pakistan was selected for experiment for the elementary grade pupils. UDL, a framework based on the constructivist theory, built on cognitive neuroscience emphasizes on engaging multiple brain networks by providing guidelines organized into three essential principles. This framework condemns the teacher-centered methodology where teacher's lesson plan does not cater the needs of all pupils and advocates the learner-centered approach, where pupils are provided with various ways to understand learning content, express what they have learnt and stay engaged during the learning process. To evaluate the effectiveness of the UDL based lesson implementation in science, a quasi-experimental pre-test post-test design was used in the study. The UDL compliant lesson plan was also mapped with UDL principles, guidelines or checkpoints. Participants of the study were fourth grade pupils (N = 60) of private school in capital of Pakistan with age ranges between 8 and 11 years. Through experimental study, it was found that elementary grade pupils perform better in science when taught using universal design of learning approach in contrast to those who have taught using traditional teaching method. The finding also discovered that there are similar check points within the UDL framework, therefore, during the mapping of pedagogical strategies (method, materials and assessments) with checkpoints, overlaps were observed.

Keywords Universal design of learning · Framework · Principles · Pre-test · Post-test · Elementary grade · Curriculum integrated

13.1 Introduction

A barrier to learning is anything that stands in the way of a child being able to learn effectively. A learner may experience one or more barriers to learning throughout his or her education. These barrier impact negatively on learners' interest in their studies and may lead to increase in dropout rate. Providing an engaging learning environment by cognizing and eradicating learning barriers is challenging for educators. When teacher defines goal and decide a single path to achieve the goal then it will not be possible to incorporate all kinds of learners with different needs. To achieve a defined goal, the teacher selects certain materials which will be used to deliver the content of lesson. The teacher needs to have several different flexible media in order to effectively deliver the lesson to the pupils. If a number of options are not provided in terms of materials all pupils might not grasp the concept thoroughly. Then it might create learning barriers and adversely influence learners' interests and academic performance. The teacher needs to have several different flexible media in order to effectively deliver the lesson to the pupils. All pupils have different needs, interest and different ways of expressing themselves so it's important for a teacher to have multiple ways for engaging and assessing the pupils.

Universal design for learning is an approach towards learning with the aim to design lessons, which are inclusive and effective for all. UDL is a framework based on the constructivist theory, built on cognitive neuroscience which emphasize on engaging multiple brain networks by providing guidelines organized into three essential principles i.e., Multiple means of representation, engagement and assessment [2]. These principles advise the design of inclusive curriculum [23].

Most of the pupils in a classroom have gaps in their previous knowledge. When the concepts are built on a prior knowledge, it is more likely to be assimilated. Scaffolding like pre teaching the vocabulary [5], use videos or illustrations and explaining difficult concepts in small easy part can help pupils learn easily. For the proactive preparation of engaging, accessible instructions in a classroom with diverse learners, Universal Design of Learning (UDL) is a valued tool [48]. UDL principles help us to know an individual's strength rather than their learning difficulties by providing multiple means of representation, engagement and assessment. Inclusive practices in science classroom make pupils with learning difficulties more confident so that they can feel comfortable in sharing their ideas with peers and teachers and keeps them engaged in the class activities. Developing countries today are incorporating technology in their classrooms for better understanding of concepts through videos and internet resources which are used by pupils and teachers both [38]. Moreover, it provides more options to include all kinds of learners in a single classroom which is the basic goal of UDL. Learning barriers can also be identified with respect to three principles of UDL and network of brain associated with each principle i.e. (a) recognition network, (b) strategic network and (c) affective network.

13.1.1 Recognition Network

Recognition network is associated with principle of representation. This principle states that you have to provide multiple means of representation so that all the pupils with diverse backgrounds and needs can grasp the concept well. The representation of a particular content in the class in one particular way cannot deliver the content meaningfully or in an effective way. Pupils with diverse needs and backgrounds may face barriers which can make understanding of concepts difficult and result in poor learning outcomes.

Today we rely so much on technology and scientific advancements so a science class must include all the pupils to develop scientific literacy regardless of their gender, cultural background, social circumstances, learning styles or learning difficulties [4]. It is widely suggested that online technologies can help address issues of educational equity and social exclusion [22]. When teachers use UDL framework, they mostly incorporate technological assistance for multiple means of media and tools. For example, teachers can show video before reading and then use graphic organizers to categorize the new information. In this way though UDL principle of representation teacher provide various ways to explain and present new knowledge. This provides learners opportunity to interact with content in various ways, which help cater diverse learners in classroom.

13.1.2 Strategic Network

Strategic network is related to how the pupils will express what they have learned. If they are not provided with enough means of expression, it is quite possible that they end up failing to express the knowledge they have gained. While few learners are able to express and answer question successfully when traditional assessments techniques are used i.e., text book question or paper pencil assessment approach, but several learners answer haphazardly. Therefore, educators target needs to have learners express the understanding of main ideas identified in the learning objectives [48]. It is therefore extremely important for a teacher to provide the pupils with multiple means of action and expression. To express the knowledge, pupil can be given choices such as make a presentation using PowerPoint, write a poem, short story, slogans, make poster or painting, use tape recorder to record oral responses, essay or orally give answer themselves etc. this way learners will be able to express their knowledge successfully and participate despite their learning challenges [43]. This let learners to demonstrate the knowledge with respect to their learning preferences. Providing choices is not just about providing varieties of activity and differentiation, but most vital is that learner's metacognition evolved by focusing on their own learning assets [48]. The above-mentioned ideas for assessment can be used and adapted with respect to the content and rubric must be provided for communicating the expectations of teacher from learners. When learners are able to select form broad choices of authentic formats, they are able to express with respect to their strengths and feel more comfortable with assessment. Teachers also need to be prepared and have familiarity of the differentiated techniques required implement the framework effectively [13].

13.1.3 Affective Network

It is extremely important for a teacher to develop the interest of pupils in what they need to learn. If they will not be interested in the content of a lesson they will not be motivated to learn. This might result in poor concentration and learning outcomes. To avoid such kind of barriers a teacher needs to provide pupils with multiple means of engagement. These barriers are associated with affective network of brain. This is about how learners feel about the content they learn. One way that this principle suggest is to reduce threat that learners feel or may feel during work such as answering in front of peers, reading aloud, work in noisy or crowded environment when concentration is required for the work. To decrease these threats, teachers can allow them to take small breaks and allow learners to 'say no' to reading aloud or answering in front of class fellows, instead provide them chance to answer in a written form or to teacher during break time. Additionally, allowing learners choices such as to work alone, in pair or group of their own choice when feasible also motivate them and keep them comfortable. Furthermore, grading in detail such as grading for expression of content knowledge and rewarding remarks for effort helps enhance engagement and motivation. In general education classroom for pupils with special needs, effective tool for successful inclusion is to grade for process and product distinctly [47].

The present work considers learning through UDL framework as a remedy to learning barriers that limits the provision of inclusive educational experience for learning science. The UDL compliant lesson plan was conducted with aim of investigating the research question of whether the UDL compliant Science lesson is more effective to have better learning gain in contrast to traditional Science learning. For this purpose, quantitative method, pretest posttest quasi experimental technique was used. The learning gain refers to the increase in academic performance of learners after experiencing UDL based educational environment as compared to conventional teacher-based methods of book and worksheets.

13.1.4 Research Question

The study was designed to focus on following research question:

RQ: Is there a positive impact of instructions strategy based on framework: Universal Design of Learning on pupil's academic achievement?

13.2 Literature Review

To enhance the accessibility, interests and engagement for science in classroom, it is critical that teacher recognize and address barriers that excludes learners from accessing the quality education. At elementary level, having a personal association to science is essential for both teacher and learners as they have fewer science exposure in daily life and also a dislike for it Roychoudhury [44]. Literature reviewed showed that there can be barriers related to goal setting in a science class i.e., pupils do not know why they are learning and what the role of science in their daily lives is Williams et al. [53]. This leads to rote memorization of the textbook where teacher comes to the class, reads book but this method of teaching is not effective especially in science class [24]. Williams, Papierno, Makel and Ceci, described that there must be a link between pupil's lives and the content they are studying so that they can think scientifically about their environment and this will keep them engaged [53].

A basic purpose of science is to construct representations that have analytical and investigative power, where such goals are supporting in daily knowledge growth. Roychoudhury advised that the science is required to be grounded in everyday experiences, so pupils develop the sense from their experience of learning science (2012). When pupils' needs are responded it helps to address learning barriers [14]. Therefore, teachers require professional training that promotes thinking, talking and doing science in classroom [29, 44]. Thinking in science advocates using commonly accepted concepts which may be solved through collaborative group learning in which pupils will brainstorm ideas and discuss it with teacher. Pupils are often not being able to express scientific ideas. This can be overcome through collaborative talks and use of multiple media and tools to express ideas of science as promoted in idea of talking in science. Not being able to carry out experiments is the biggest concern of learning science and doing science. Provide pupils with multiple options of performance is the solution [29].

Another serious difficulty, which pupils might face in science is misconceptions that needs to be treated very seriously. Misconceptions are those early perceptions based on personal experiences, that are not in line with the scientific theories [8]. Pupil's naïve theories may interfere with their capability to understand Science concepts adequately [37] and if clarification is not provided it stays in pupil's minds. There are diverse pupils in science class with different preconceptions and a teacher must consider those pupils who have misconceptions about the lesson and without clearing them, pupils cannot build new knowledge on those misconceptions [19]. Wahyuningsih, Rusilowati and Hindarto, mentioned that teachers are often unable to identify that pupil's academic performance in science is adversely impacted because of pupil's misconception or misunderstanding [52]. According to Pine, Messer and Jhon teachers rated one third of science topics as abstract and difficult, also identified more than hundred misconceptions that pupils have in primary Science curriculum (2010). Teaching approaches that provide well scaffolded instructions and constant formative assessment takes account of learner's prior knowledge and misconceptions [14]. While representation of knowledge, teacher needs to identify misconception and address them timely through query-based technique, discussion or preassessment in classroom [52]. Franke, Scharfenberg and Bogner, suggests that constructivist pedagogical approach can help change the pupil's misconceptions in favor of scientific conception [19].

Lemke states that leaners are not taught how to talk in science, which is required to discuss, explore, investigate or express science in writing [29]. Pupil have difficulties to describe or use the scientific terms when explaining scientific concepts, thus poor Science vocabulary is another barrier mentioned in literature [6, 19, 31, 41]. Learning science means learning complex vocabulary meaning some words are unfamiliar to pupils and some are used specifically in science, which can be a barrier for many pupils [41] because thinking and talking in science is very important and thinking requires language [53]. Franke, Scharfenberg and Bogner found that 52.8% pupils failed to deliver appropriate concept for the scientific term e.g., enzymes [19]. Pupils are often not being able to express scientific ideas. Moreover, Science vocabulary is challenging for both native English speakers and English language learners because several terminologies are uncommon [21]. This can be overcome through collaborative talks and use of multiple media and tools to express ideas of science using scientific vocabulary [1]. Lemke advised that to learn Science language, one needs to speak it with those who mastered it and use it during learning process [29]. Therefore, they advised that teachers need to use suitable strategy by introducing and describing the scientific terms clearly with emphasis so pupil use them appropriately [19]. For example, text book reading sessions [21], discussion-based approach with emphasis on science terms [1], use of collaborative work with scaffolding i.e., visual aids, flash cards, graphic organizers [21]. However, it is not merely using the vocabulary but to learn how to associate the meanings of diverse terminologies with respect to accepted ways of talking science [29]. Brown and Concannon advised the literacy strategies to support Science learning including learner's perceptions of vocabulary knowledge and associate it with significant content achievement [6].

To eradicate all the barriers to learning, teacher tries its best to make the course accessible for varying needs and strengths. Universal Design for Learning is an effective framework and provide distinct set of guidelines that support teachers to plan lessons that is accessible for all pupils in the classroom [10]. Literature suggests that when teacher plans the lessons using the framework, it helps to eradicate the persisting barriers in curriculum and allow learners to access and engage in curriculum [16, 24]. UDL popularity in recent years as pedagogical approach to fulfil the learning need of all the pupils with diverse abilities is substantial [25]. UDL is a framework based on the constructivist theory and built on cognitive neuroscience which emphasize on engaging multiple brain networks [2]. UDL framework is based on three main principles to eradicate learning barriers i.e. (1) Multiple means of representation, (2) Multiple means of action and expression and (3) Multiple means of engagement [35]. Science is all about concepts and constructing new knowledge over prior knowledge with experiences or experiments. According to Singh and Yaduvanshi, learners actively construct knowledge in the science classroom by actively participating in the classroom, brainstorming, group discussions and experiments, [46]. Clearly stating the purpose of the undertaking Science problem is vital [53] which is one of the basic guidelines of recognition network. UDL principles help us to know an individual's strength rather than their learning difficulties by providing multiple means of representation and assessment [4].

Schreffler, Vasquez, Chini and James synthesizes the UDL based literature for STEM education of postsecondary pupils and suggested that UDL based lesson planning is very beneficial in term of accessibility, self-regulation and enhancing attention in classroom [45]. According to McPherson, learner takes responsibility of their work and develop sufficient self-reliance when flexibility in learning processes is offered with respect to the framework [31]. Baurhoo and Asghar, stated that pupils with a learning disability or any physical disability in primary and secondary grades are not performing well in their science class as compared to their peers and 56% of the teacher accepted that they use the term "Disability" as a reason of the failure of these pupils [4]. Moore, Holterman, Simone and Huggett recommended that team-based learning applied with UDL guidelines can be very advantageous for pupils and it does not have any disadvantages such as noise because 90% pupils find these sessions more successful to improve learning in classroom [32]. McPherson found the evident positive influence of instructional planning in learner's performance when based on neurological networks for Pre-K-4 Science education [31]. Narkon and Wells designed instructions with evidence-based story mapping technique using

UDL guidelines to improve comprehension for reading primary grade pupils and found it very effective [35]. When a case study and participatory action research as methodology was used to evaluate the process of redesigning the Science curriculum for high school learners with and without disabilities using UDL framework, most positive outcome was observed in term of teamwork, empathy development and academic performance [16].

It is challenging to evaluate the UDL impact on learning because of its design, flexibility and iterative nature [3]. Murphy states that, effectiveness of UDL frame work is yet to be proven before applying the framework in educational institutes [33]. The application of UDL framework for improvement of learner's performance is not reported much, however, variability of learners and lesson planning are addressed [40].

13.3 Methodology

To evaluate the effectiveness of the UDL based lesson implementation in science, a quasi-experimental pre-test post-test design was used in the study.

13.3.1 Participants

The study was conducted in a private school situated in the city of Islamabad, the capital of Pakistan. The school was selected on the basis of convenient sampling, because technological equipment was required for the intervention, which was easily accessible in the selected school.

Research participants were fourth grade pupils (N = 60) with age ranges of 8 to 11 years. Participants were divided in two comparison groups named as control group (N = 30) and experimented group (N = 30). For comparative analysis, control group was taught in traditional instruction (teacher-centered lecture based with very little involvement of pupils) conversely, experimental group received UDL compliant instructions (pupil-centered with technological incorporation, where teacher acts a facilitator). The structure of classes was kept intact, as the school administration wanted to keep the class structure intact and did not allow to create partitions within the class. However, the school had two sections for grade four, thus, the groups were assigned between two sections of grade four. It was also ensured that the previous academic records of the two groups did not contain any inherent bias that may affect the study. Both groups were assigned the same instructor for any particular subject, and each group demonstrated similar grades and learning achievements, prior to this study.

13.3.2 Intervention: Time, Resources and Space

Learner profiles were created using the Felder Silverman's tool to diagnose learner's preferences and learner interest and technological accessibility and preference was also identified through questionnaire. After understanding learner's interests, technological and learning preferences, lesson was planned using the learner's information with respect to UDL guidelines and checkpoints. Afterwards, pre-test was conducted for both the control and the experimented group. The intervention was then continued for three weeks, based on the span of 12 sessions of 30 min each. The intervention span of three weeks was suitable for the experiment as it has been practiced by Khan et al. [27]. Experimented group received instructions in the computer lab because technological tools required for interventions were not available in the classroom, however, the control group received traditional teaching (lecture-based teacher centered approach) in their own classroom.

13.3.3 Instructional Objective

The typical curriculum is usually based on written material and devised for uniform group of pupils, ignoring the needs of diverse learner needs. Thus, traditional curriculum puts a burden on educators to create modified materials that will support various learner needs [39]. As indicated before, blended learning approach are more viable to attain the required instructional objectives when UDL framework is linked to curriculum. Heterogenous group of pupils in a classroom can engage in appropriately challenging learning environment when curriculum objectives are attained using multiple means of expression, assessment and engagement [39]. Thus, the UDL framework implementation is based on the following learning goals as proposed in the Pakistan National Curriculum of Science for Grade four.

- To identify the sources of common food
- To explain the properties of major food groups
- To classify different food into their basic groups
- To differentiate between balanced and unbalanced diet
- To suggest the balanced meal from given list of foods and to explain why each food was chosen
- Explain the effects of unbalanced diet on health
- Explain hygiene and its basic principles.

After understanding the learning goals and expected learning outcome from the unit's curriculum, commonly used lecture based and teacher centered-traditional approach was used for control group. However, the UDL based lesson plan was developed to teach the experimental group. Both the pedagogical approaches are discussed and compared below.

13.3.4 Traditional Instructional Design for Control Group

According to traditionally planned lesson provided to teacher by the school for teaching the unit food and health did not require any technological resource. Thus, the control group received the instructions in their own classroom. After greeting the class, the teacher prepared the whiteboard, and there she mentioned the unit title and number form the text book i.e., Unit 4: Food and Health. Then she asked the pupils to open their books and look at the pictures of different foods and asked about their favorite food items from the picture. Next, she started to explain why food is important for human body and then linked it to the first topic i.e., food group and sources. She opened the book and showed the pupils pictures of different food items and explained the groups they belonged. Afterwards she asked the pupils to read the explained topic form the book. If the pupils faced any difficulty reading any word, the teacher read it for them and asked them to read again. Teacher used only the English language as mode of instruction in class. After the reading session, pupils were asked to take out their science note books while the teacher wrote True and False statements based on the discussed topic on the white board and asked pupils to copy the work on their notebooks. Answers were not provided and the pupils were only asked to copy the statements first. Once all the pupils copied the statements, teacher gave them fifteen minutes to use the book and write whether each statement is true or false. After fifteen minutes, the teacher wrote the answers on the bord and asked the pupils to copy them or make necessary corrections. Additionally, the activity in the book was given as homework. Afterwards, the teacher checked their notebooks to make sure that all the pupils copied the work correctly from the white board.

To teach the topic: balanced diet, its importance and food pyramid, the teacher pasted a chart showing a food pyramid and connected the previously taught topic by explaining importance of each group for the human body. She pointed at each group of food shown in the pyramid and explained how the amounts of different food groups make a balanced diet. Teacher read the topic and then explained again. After that the teacher wrote 20 statements with blanks for the pupils to solve. Pupils were given 20 min to copy and write the answers. When given time was over, the teacher wrote the answers and checked the notebooks to ensure all the pupils completed the written task correctly.

In the next session, the teacher pointed at the mounted chart and revised the importance of a balanced diet. She asked the pupils to raise their hands to answer questions such as, how can they make sure they eat balance diet? What does food pyramid show? Why vitamins and minerals are important? What does fat provide us? If the pupils did not provide expected answer, the teacher provided the answer and asked them to repeat after her so that they may learn it by heart. Then she linked it with topic: unbalanced diet and its harms. After explanation of topic, the teacher wrote short questions on white board from the text book and left some space for answers between each question. Pupils were given 25 min to copy the work and answer the questions. Later, the teacher wrote the answers on board and made rounds to ensure each pupil completed his or her written task in given time. Multiple choice questions provided in the text book exercise were given as homework.

To teach the last topic of the unit, the teacher read the topic and explained the meaning and significance of personal hygiene. Then she asked all the pupils to open their books and one by one each pupil was asked to read the topic at their turn. After the reading session, the teacher asked the pupils to copy the exercise of match-the-columns from the white board and gave them ten minutes to do the work on their own. When the ten minutes passed, the teacher mentioned the answers and checked whether all the pupils completed the work or not. A quiz from the work done on the notebook was assigned for the next session.

13.3.5 Instructional Design Based on UDL Framework for Experimental Group

A unit, Food and Health, from national curriculum for general science of Pakistan was selected for experiment. After understanding the learning goal and expected learning outcome from the unit's curriculum, the UDL based lesson plan was developed. Barriers in material, method and assessment was cognized and it was ensured that these barriers are removed. Technology was incorporated for representation and assessment of content through power point slides, videos with audio and subtitle, PDF files of exercises question with images and games. The non-technological pedagogical approaches for representation and assessment were also incorporated in the lesson, such as, inquiry-based class discussions, class activities, outdoor games, role playing and group project. Three topics of selected unit (i.e., food group and sources, balanced diet and its importance, unbalanced diet and its harms) were taught in two weeks and two topics (i.e., food pyramid, and personal hygiene) were taught in one-week period.

Teacher used both English and Urdu language as medium of instruction. Mostly English language was used, but since Urdu is the first language of the pupils, therefore, the teacher also explained in Urdu but used the specific vocabulary of Science in English. Science vocabulary required for the unit topic discussion was provided on paper with pictorial representation and it was pasted on the board. Also, the second chart was displayed which presented the nutritional value of several food items along with the pictures. The vocabulary of the taught content is vital and needs to be presented to comprehend the text and it is one of the fundamental checkpoints provided to implement UDL framework [5]. Learning science vocabulary from someone who masters it and then use it appropriately in class discussions, arguments and during analyzing or writing, is essential for science education [29].

It is vital to support and work on authentic scientific thinking of learners that can help them to make better decisions to improve daily life [53]. Thus, the goal of the unit was not only to teach the textbook-based content but also help the learners internalize the habit required for leading healthy life so they can practice the learnt concept of science in daily life. Therefore, first lesson started with a short video which showed the impact of eating habits on a person's health. The goals of the topic were discussed by posing questions from the video, such as, what was the difference in eating habit of boy and girl shown in the video, why the boy got tiered and felt unwell. Using technological medium like the video can provide alternative input for learners who require it King-Sears [28].

To enhance engagement, learners' own eating habits were discussed in the classroom by posing several questions, such as, what is your favorite food? When you go to market? Do your parents allow to pick food items of your own choice? Which food would you prefer in the given list and why? What kind of food is available in school cafeteria? Do you buy from school cafeteria? What kind of food do you prefer to buy form your pocket money? What kind of food your parents persist to consume in daily life? Afterwards, the pupils were asked to write down the list of their favorite food items and mention which of them are healthy. Then the misconceptions were cleared and new knowledge was presented by relating it to prior knowledge in a discussion session.

Subsequently**, food group and sources, balanced diet and its importance, unbalanced diet** and its harms were demonstrated using video composed of images related to the text given in the book with background audio and subtitles as suggested by Spencer [48]. Facilitator paused the video several times and asked questions from the video to keep the learners engaged. Next, the facilitator read the mentioned topics from e-book shown through multimedia projector, and learners looked at the chapter in their books. The colorful images of the food groups and its sources are provided in the textbook. Worksheet based on questions related to the topics discussed through video and explained in reading session was provided to the pupils, which comprised the book exercise. Pupils worked in pairs to do the exercise provided in the book. Pupils were more motivated and engaged to participate in pairs or groups of their choice [48]. Facilitator also provided the option of working alone, but all the pupils preferred to work in pairs. After discussing the worksheet with each other, one pupil was required to write the answers and one was required to share the answer with class. As an option, the pupils were allowed to use the audacity software in computer using their headsets to record their responses in case they did not wish to present in the class themselves. This was opted only by a single group. For support during formative assessment, the video was provided to the pupils on their computer systems, if pupils required, they could watch the video again on their pace using earphones or use the text book for support. Additionally, pupils were given a choice to use their text book to look for answer as well. Facilitator provided feedback and support continuously during class activities and group work.

Afterwards, the pupils were asked to make groups of their own choice and through power point presentation labelled images were shown to the class to connect the acquired knowledge of **balanced diet and its impact on our health**. For this purpose, images were displayed on multimedia comprising different meals which included balanced or unbalanced diet. Facilitator asked the pupils to choose the 3 meals for themselves and prepare their healthy diet plan for one day. Pupils were also required to discuss the effect of their chosen meal on their health and describe if it is based on balanced diet or not. Groups were allowed to express their work either by writing their answer, drawing pictures, explaining verbally or preparing a short presentation.

An activity was performed to internalize the concept of learnt topics. In the group activity, each group was provided two baskets and bag of food. Each group was required to add food in the basket for a healthy and balanced diet meal and also write the name of food group on the sticker and paste it on the food item or explain verbally to demonstrate the group of the food item. Pupil were also provided with the nutritional value chart to make the meal balanced for support.

For homework, pupils were asked to record what they eat daily and categorize the foods into groups in order to monitor whether a balanced diet is being taken or not. For support, worksheet was given to them but the pupils were provided choices to represent their work in different ways such as, use audio recording, a small video, a presentation, drawing, a short essay or a chart.

The topics i.e., **Food Pyramid and Personal Hygiene** needed to be connected to the previous lessons, therefore, facilitator showed a short-curated video to pupils which connected the new topics to the previously taught topic and asked few questions at the end of the video as advised in literature [28, 48]. Then a worksheet based on textbook was given to the pupils and it was also displayed through multimedia projector. Facilitator asked the pupils to fill at least three food items for each group of food and then afterwards the teacher explained what is food pyramid and how can we make a balanced meal using guidelines from the food pyramid. Afterwards, teacher displayed the concept map chart on the soft board and explained in which described the topic food pyramid and then a small video was shown how to develop a concept map. Pupils were asked to develop a concept map in a group activity and facilitator provided the support when required. Pupils were also provided with the video on their computer to revisit the idea of how to develop concept map on their own. Facilitator read the topic form the book aloud for recognition of science vocabulary. Next, the pupils were asked to read the topic form text book. Pupils were also provided the e-book, the text to speech feature of e-book helped them to read the difficult words. Important vocabulary items were emphasized as advised by Lemke [29].

After the reading session, pupils were provided with a worksheet comprising two types of fun questions. To do this formative assessment, pupils were given a choice between match the column exercise or play the cross-word puzzle in groups of three. This helped them to combine science terminologies and meanings and supported in understanding and comprehension.

Literature suggests that video games are an effective way to offer pupils multiple means of representation and expression [17, 30]. The group who completed their work in given time and showed discipline in their work were recognized by a reward. Then the pupils played the digital game: healthy eating kids food game where they prepared the meal for the character i.e., a Panda. The pupils prepared the meal for the panda and then facilitator asked questions regarding the choice of food items for the meal with respect to the food pyramid. Khan, Ahmad and Malik recommended game-based learning for science in comparison to conventional science lesson for significant impact on learner's engagement [26].

Science homework was a small project from the text book that was given to the pupils where they were required to make a booklet of the different food items used by their family during breakfast, lunch and dinner and then describe whether the meals were balanced with respect to the food pyramid guidelines or not. For providing multiple ways of expression, learners were allowed to write, paste or draw pictures for the booklet. Rubric for the project was provided in the form of a printed copy and attached in pupils' notebooks to clearly communicate the expectations of the work.

Next, the unit topic i.e., **personal hygiene** was also demonstrated using video composed of images related to the text given in the book with background audio and subtitles as advised by King-Sears [28]. Teacher asked questions afterwards to explore learner's understanding related the topic as suggested by Darling-Hammond, that when instructions are thoughtfully interwoven with inquiry, it helps understand learner's engagement, and provide timely feedback [14]. Teacher then explained the topic showing the images provided in the book through multimedia projector. For formative assessment, pupils worked on the class activity based on role playing to show how to take care of their personal hygiene in a group of their choice. Pupils had a choice to present in the class or record a video of their role play. Only two groups opted the option of video recording. Rubric was provided to each group in form of a hard copy. When all learners presented their work, similarity and differences in the role play was discussed. Also, the most compelling reasons for prioritizing personal hygiene in daily lives mentioned by the groups in their role play were highlighted in the discussion.

Reinforcement-based-homework was given where learners were required to build projects from the given choices such as taboo card game based on Unit topics, a short story book on Unit: Food and health, a puppet show for the unit topic, poems for each topic in the unit. Rubric for each kind of representation was provided to pupils so that they have clarity of expected performance. Pupil picked projects of their choices and in next class presented their work and shared the learnt knowledge with their classmates. All of the above-mentioned assessment techniques used in classwork and homework were considered as formative assessment. After the completion of the unit, a post-test was conducted.

13.3.6 Instructional Design with Respect to UDL Checkpoints

The following Tables 13.1, 13.2, and 13.3 provide the details of the pedagogical strategies of UDL compliant lesson mapped with the standard recognition, strategic, and affective network checkpoints, respectively.

In Table 13.1, the check points related to the recognition network are described. The recognition network deals with the 'what' of learning. The table includes all the check points belonging to the categories of perception, language and symbol, and the comprehension. Each of these categories are further divided in to several check points as shown in the table. For each of the checkpoints, the corresponding pedagogical methods, supplementary material, and the modes of assessments are

Table 13.1 Pedagogical strategies of UDL compliant lesson mapped with recognition network's checkpoints

UDL network	Recognition network The 'WHAT' of learning			
UDL principle	Provide multiple means of representation			
Check point no	Guideline for check points	Methods	Materials	Assessment
1	Perception			
1.1	Suggest modes to customize the presentation of information	– Teacher explains video and plays it twice – Large font and images used on Chart and – E-book provided to pupils – Discussion through questions	– Video – Chart paper – E-book – Verbal questions – Paper pencil – Multi-media projector	– Verbal questions – Worksheet – List down asked information
1.2	Suggest substitutes for audio information	– Chart for vocabulary – Use of underline and bold feature in E-book – Video of text book content with large images and subtitles with clear and large fonts	– E-book – Video with images form text book and background audio	NA
1.3	Suggest substitutes for ocular information	– Text to speech feature provided in the book	– E-book	NA
2	Language & Symbol			
2.1	Clarify terminology and symbols	– Pre-teach science vocabulary – Highlight complex terms	– Chart paper with pictorial representation on soft board – E. book – Multi-media projector	– Questions related to science vocabulary during reading session – Underline the words and write down description
2.2	Clarify composition and assembly	– Link between ideas and concepts	– Verbal explanation	Underline the words and write down description
2.3	Help interpreting text, mathematical representations	– Access to e-book on their computer system	– E-book's text to speech feature	NA

(continued)

Table 13.1 (continued)

UDL network	Recognition network The 'WHAT' of learning			
UDL principle	Provide multiple means of representation			
Check point no	Guideline for check points	Methods	Materials	Assessment
2.4	Support understanding across languages	– Explained book content in and video on both English and Urdu language	– Verbal explanation	– Questions during reading sessions
2.5	Illustrate through multiple media	– Explained concepts and made links between information	– Chart paper with pictorial representation on soft board – Video – Text book – E book – Multi-media projector	– Questions
3	Comprehension			
3.1	Stimulate background knowledge	– Pre-teach critical prerequisites—explains video and play it twice – Chart explained – Connection between information through discussion and questions	– Video – Chart paper – Verbal questions – Paper pencil	– Verbal questions – Worksheet – List down asked information
3.2	Emphasize patterns, critical features, big viewpoints and associations	Use of cues and prompts to draw attention to critical features	– Video – Verbal questions	– Verbal questions – Worksheet – List down asked information
3.3	Guide information processing and visualization	Introduce gradual scaffolds to support information processing – Chunk information into smaller elements – Progressing release of information	– Verbal feedback – Chart paper – Video – Verbal questions	
3.4	Increase transfer and generality	– Revisit the idea and opportunity to revisit ideas – Questions based on learner's real-life experience and practices – Provide template to create concept maps	– Chart on softboard – Video	– List down asked information – Create concept map

Table 13.2 Pedagogical strategies of UDL compliant lesson mapped with strategic network's checkpoints

UDL network	Strategic network The 'HOW' of learning			
UDL principle	Provide multiple means of action and expression			
Check point no	Guideline for checkpoints	Methods	Materials	Assessment
4	Physical Action			
4.1	Adapt the ways for answer and navigation	Provided alternatives for physical responses, technologies, range of motor action required to interact with content	– Audio recording, a small video, power point presentation, drawing, write a short essay or make a chart – Paste picture, write or drawn with paper pencil – Present or record video of role play – Make card game, paper pencil to write story or poem. Puppet show	– Worksheet was given to categorize food items – Worksheet comprised of fun question with choice – Project: make a booklet – Role play – Project
4.2	Optimize provision of instruments and assistive technologies	Teacher provided technological assistance for the class work	– Head phones—Computer – Text to speech feature	For reading and worksheets
5	Expression and Communication			
5.1	Use several methods for interaction	– Allowed to use several media for responses – Answer questions using a variety of strategies	– Audio recording, a small video, power point presentation, drawing, write a short essay or make a chart – Past picture, write or drawn with paper pencil – Present or record video of role play – Make card game, paper pencil to write story or poem. Puppet show	– Worksheet was given to categorize food items – Worksheet comprised of fun question with choice – Project: make a booklet – Role play – Project

(continued)

Table 13.2 (continued)

UDL network	Strategic network The 'HOW' of learning			
UDL principle	Provide multiple means of action and expression			
Check point no	Guideline for checkpoints	Methods	Materials	Assessment
5.2	Use several tools for creation and arrangement	Provided and allowed to use the several tools for answering questions	– Text to speech feature of e-book – Voice recorder, -Audacity software – Headphone set and mic A chart paper with Science vocabulary and related images	Answer the worksheet
5.3	Build fluencies with progressed levels of help for exercise and implementation	– Read topic using text book with support of e-book – Provide differentiated feed – Started with worksheets and then projects were given	Text to speech feature of e-book – Verbal support by facilitator	Varied types of assessment methods were used
6	Executive Functions			
6.1	Guide appropriate goal-setting	– Objectives were discussed in the beginning – Provision of rubric – Time of tasks were provided	– Printed hard copy – Classroom wall clock	NA
6.2	Support planning and strategy development	– Provision of rubric with time to submit the project and checklist that shows expectations – Provision of support to achieve the goal	– Printed hard copy – Video links	Project: make a booklet – Role play – Project on all topics
6.3	Facilitate managing information and resources	Guided pupils for note-taking	– Note book – Worksheet	Assessment given in text book
6.4	Enhance capacity for monitoring progress	Provision of scoring rubrics Concept map example	– Printed hard copy – Video links	Rubrics were provided for assessments

Table 13.3 Pedagogical strategies of UDL compliant lesson mapped with affective network's checkpoints

UDL network	Affective network The 'WHY' of learning			
UDL principle	Provide multiple means of engagement			
Check point no	Guideline for checkpoints	Methods	Materials	Assessment
7	Recruiting Interest			
7.1	Optimizing individual choice and autonomy	– Choice between reward was given – Choices were provided to express their work	– Smiley sticker or start sticker – Audio recording, a small video, power point presentation, drawing, write a short essay or make a chart – Past picture, write or drawn with paper pencil – Present or record video of role play – Make card game, paper pencil to write story or poem. Puppet show	– Work sheets and Projects
7.2	Optimize relevance, value and authenticity	Activities were age appropriate and examples were taken from real life context – Activities that allow to practice the content – Activities included to promote the use of creativity	– Make card game, drawing, write a short essay or make a chart paper pencil to write story or poem. Puppet show	Project and experiment based on content knowledge
7.3	Minimizing Threats and distractions	– Continuous reminder to complete task in time – Allow extra time to complete the task – Use of equipment that help control noise in environment – Provided choices to perform the tasks	Class room wall clock – Headphones – Recording, a small video, power point presentation, drawing, write a short essay or make a chart – Paste picture, write or drawn with paper pencil – Present or record video of role play – Make card game, paper pencil to write story or poem. Puppet show	– Work-sheet, experiment and project

(continued)

Table 13.3 (continued)

UDL network	Affective network The 'WHY' of learning			
UDL principle	Provide multiple means of engagement			
Check point no	Guideline for checkpoints	Methods	Materials	Assessment
8	Sustaining Effort and Persistence			
8.1	Heighten salience of goals and objectives	– Teacher demonstrated how to use given application on computer – Discuss the content using real life example from pupil's life	– Audacity software – E book – power point – Verbal discussion	– Work-sheet and experiment
8.2	Vary demands and resources to optimize challenge	– To perform the given tasks, choices were provided with differentiated degree of difficulty	– Audio recording, a small video, power point presentation, drawing, write a short essay or make a chart – Past picture, write or drawn with paper pencil – Present or record video of role play – Make card game, paper pencil to write story or poem. Puppet show	– Work-sheet, experiment and project
8.3	Foster collaboration and community	Promoted group work in class with division of assignment of roles and responsibilities – Asked pupils to take help form facilitator in specific activities – Expectations for the work was communicated – Learners were also allowed to choose to work in group, pair or alone	– Worksheet – Multimedia projector – Computers – Printed rubric – Basket and food items	– Work sheets – Class activity – Experiment

(continued)

Table 13.3 (continued)

UDL network	Affective network The 'WHY' of learning			
UDL principle	Provide multiple means of engagement			
Check point no	Guideline for checkpoints	Methods	Materials	Assessment
8.4	Increase mastery-oriented feedback	– Timely feedback was provided after each activity and assessment – Mistakes and misconceptions were discussed without specifying any pupil	NA	For all kind of assessment techniques mentioned in lesson plan
9	Self-Regulation			
9.1	Promote expectations and beliefs that optimize motivation	– Teacher modelled and explained the process – Provided reminders to complete task in time and rubrics with guidelines so that pupils complete the tasks themselves	– Basket and food items – Multimedia Projectors – Computer	– Experiment – Concept map activity
9.2	Facilitate personal coping skills and strategies	– Teacher provided support to the pupils in a group's activity and individual tasks were also given in group so peers can also help each other when required – For homework, ample practice was done during formative assessments and rubrics were also given	– Computers – Paper – Card board – Pencils	– Game – Worksheet – Home assignments
9.3	Develop self-assessment and reflection	– Provided support for self-assessment through rubric – Feedback was provided	– Paper – Verbal feedback	For all kind of formative assessments

mentioned. Similarly, Table 13.2 describe the strategic network which is related to the 'how' of learning. All the checkpoints and the associated pedagogical methods, materials and the assessments are listed in this table. Lastly, Table 13.3 contains the checkpoints related to the affective network which deals with the 'why' of learning. Against each individual checkpoint, the associated methods, supplementary materials and assessments are mentioned.

13.4 Results

13.4.1 Pre-test and Post-test Design

The content of the pre-test and post-test was formulated carefully from selected units of science from the text book exercise. The pre and post-test consisted of ten multiple choice questions, which were used to check the understanding of the concept in contrast to memorization.

The content validity of the pre-test and post-test were ensured by obtaining the approval of several teachers through moderation, as practiced by Khan et al. [27] and suggested by Gay et al. [20]. Pupils were familiar and comfortable with paper worksheet method; thus, tests were conducted on paper worksheets. This specifically helped to keep the conductance method same [27]. The concepts, time period, level of difficulty and conductance method, for pre-test and post-test were kept same as advised by Creswell [12]. The test took 10 to 25 min depending on learner's pace. The knowledge in the assessment was covered in the lesson delivered during twelve sessions (each of 30 min span). Teacher remained in the classroom for providing support to the pupils during the tests. The support included helping pupil understand question and reading the question statements if required. Post-test was conducted in the fourth week. After marking all the tests, the scores were recorded using Statistical Package for Social Sciences (SPSS).

13.4.2 Data Analysis

The data of independent variables were evaluated by conducting descriptive analysis with certain assumptions i.e., normal distribution, because the parametric tests were based on normal distribution [18]. Shapiro–Wilk test was employed to test the normality of data because the sample was less than 100. A non-significant result i.e., $p > 0.05$, shows normality. In Table 13.4, the results of Shapiro–Wilk tests are provided which show that for both pre-test and post-test we get $p > 0.05$, which suggests that the assumption for normality is satisfied and therefore the inferential statistics t-test can be employed.

Table 13.4 Test for normality

	Shapiro–Wilk		
	Statistics	DF	P
Pre-test	0.96	60	0.075
Post-test	0.968	60	0.119

Table 13.5 Similarity of groups based on pre-test data

Group		Descriptive statistics		Independent sample t-test		
	N	M	SD	T	DF	P
Control	30	12.8	3.51	0.269	58	0.7
Experimental	30	12.5	5.00			

Similarity of groups based on pre-intervention data

The equal variance independent sample t-test was conducted, by setting a confidence interval of 95% to compare the means of experimental and control groups before applying intervention. The purpose was to check whether the learners of the two groups were at similar learning level in terms of their pre-test score before the intervention. As shown in Table 13.5, both the groups i.e., control and experimental, consisted of 30 learners. The mean (M) and standard deviation (SD) of the pre-test scores for both the groups came out to be similar. The subsequent inferential statistics results i.e., T (60) = 0.269, p = 0.7, show that both the control and the treatment group were at similar level of learning as presented in Table 13.5.

Evaluation of learning outcomes between the groups

To analyze the impact of UDL based lesson intervention, comparison of post-test scores of learners between experimental and control group was done. For this purpose, independent sample t-test was employed after testing the data for certain assumption i.e., data for the parametric tests is normally distributed which was calculated using Shapiro–Wilk test resulted in $p > 0.05$ to be exact $p = 0.119$ as shown in Table 13.4. The mean score for the experimental group was significantly higher 14.8 ± 4.34 as compared to the control group 12.8 ± 3.97. The learning outcomes calculated through independent sample t-test shows the statistically significant difference between experimental and control group in favor of experimental group (Table 13.6).

Table 13.6 Difference in learning outcome after intervention (post-test)

Group		Descriptive statistics		Independent sample t-test		
	N	M	SD	T	DF	P
Control	30	12.8	3.97	1.996	58	0.03
Experimental	30	14.8	4.34			

This indicates that when science lessons were taught using the UDL approach, the academic performance of learners improved significantly.

Evaluation of learner's pre-test and post-test within the group

The pair sample t-test was employed to evaluate the mean ranks of pre-test and post-test scores with in the experimental groups. The quantitative analysis showed that there was a statistical difference in the scores of pre-tests and post-test. For pre-tests ($M = 12.5$, $SD = 5.005$) to post-test ($M = 14.766$, $SD = 4.344$), $t (30) = 4.365$, $p = 0.000$, which is $p < 0.05$ (two-tailed), and $d = 29$. This test shows that the learners performed significantly better on post-test (after receiving UDL compliant instructions) as compared to their performance on the pre-test (after receiving UDL compliant instructions) in experimental group with a 95% confidence interval. The guidelines proposed the effect size larger that 0.014 as large [9], therefore eta squared statistics (0.39) indicated a large effect size.

13.5 Discussion

According to Supple and Abgenyenga, UDL is extremely beneficial to accommodate for diversity in learner where learners do not need to adapt with respect to the curriculum rather constraint of the curriculum are eliminated by teacher, [49]. Ok, Rao, Bryant and McDougall also agree that UDL based lesson plans has the potential to enhance improves academic performance, engagement and access to curriculum for pupils with special abilities, [36]. But through systematic review of thirteen studies, significant inconsistency was found in UDL based research when recording connection between UDL guidelines and its intervention in classroom [36]. Stolz states the critique that it is noticed in the literature of UDL that there is inconsistency in the research specifically lack of empirical evidence [50]. The present work investigated the extent to which he UDL based lesson implementation improved the learner's academic performance of Primary grade pupils in science classroom in Pakistan. The UDL based lesson planning had positive impact on learning outcome of science pupils of primary grade.

In response to the research question: "Does the proposed method based on UDL lesson planning improve the learning of science learners? the independent sample t-test shows the significant difference among the experiment and control group, indicating the learning of pupils were improved and learning benefits were attained via UDL based lesson plan. The difference in learning outcome between the groups in favor of experimental group in the present study can be associated to the several reasons. The way a teacher pre-plans the lesson and implements in the classroom has great impact on learning outcome of learners. Teachers are required to be prepared in accordance with the strategies of teaching for reaching diverse learners. When lesson is planned efficiently using UDL guidelines, it allows educators to more successfully meet their learners' needs [11]. In traditional classrooms usually a teacher is involved in catering many pupils at a time and single medium of communication is encouraged and this hinders learning because of pupils' passive role. Use of technology to support the lesson plan not only enhances the engagement in learning of science, but also plays an important role in the improvement of learning outcome. To make specific UDL strategies that are essential to deliver complete accessibility and success in meeting the lesson objectives, a thorough analysis of pupil's needs is fundamental [35].

Murphy, criticizes the evidence provided that supports the effectiveness of UDL framework and mentioned that only providing the sample lesson plans is not sufficient because it is impossible to investigate the specific impact of UDL [33]. Therefore, the present study provided the complete lesson plan and additionally mapped the lesson plan to the checkpoints of UDL framework given in the official website (https://udlguidelines.cast.org) of the CAST. These checkpoints or guidelines are the tools and specific suggestions that educators, researchers, curriculum developers even parents can use to apply the framework. Table 13.1, 13.2, and 13.3 showed the methods, material and assessment with respect to the UDL guidelines. However, Table 13.1 represents the lesson plan mapping on check-points for recognition network (i.e., multiple means representation), Table-2 for strategic network (i.e., multiple means of action and expression) and Table-3 for affective network (i.e., multiple means of engagement). The numbering of the checkpoints is kept same as provided in the CAST website (https://udlguidelines.cast.org).

All the guidelines have been followed to develop and implement the lesson plan in a way that learners could be able to comprehend the content, able to set goals, to achieve their goals and monitor their progress and able to self-regulate and engage in activities with intrinsic motivation. For this purpose, variety of pedagogical strategies were incorporated stepwise so they can achieve these goals. The teacher started with eradicating the misconceptions while activating prior knowledge, connecting the new knowledge to learner's own life experiences through discussion. Then gradually, with incorporation of technological resources teachers used several kinds of knowledge representation and formative assessment techniques so that the learners would be intrinsically motivated to take command as much as possible. In the lesson plan, it can be seen that at the start scaffoldings and support was very high but gradually there was release of support and learners were provided with rubrics to assess themselves and provided the tasks that they were able to perform alone on their own. At the beginning pair or group work helped learners to work with each other and get support with peers or facilitator but by the end of the lesson, learners were able to work alone on the class activities and project. Moreover, range of choices were also provided with assessments so learners could learn and perform with respect to their learning styles. Thus, the positive impact of the intervention is noticeable through the quasi-experimental pre-test and post-test design.

The similarity in the level of knowledge was determined by independent sample t-test of pretest results and it is observed that both control and experimental group were at same learning level as mentioned in Table 13.5. In the lesson plan, it is seen that there is overlap of planned strategies and UDL checkpoints. Boxtel and Sugita's finding also mentioned that there are similar check points within the UDL framework [51], thus overlapping of pedagogical strategies can be observed in the Tables 13.1, 13.2 and 13.3. For example, nine different check points, such as, 1.3, 3.3, 3.4, 6.1, 6.2, 6.4, 8.1, 8.3, and 9.1 suggest to signal/cue pupils to apply strategy [51].

When the statistical differences between groups were examined using independent sample t-test, the finding indicated a positive impact of UDL intervention on learner's academic performance in favor of experimental group. These findings are in line with UDL based research [41]. When the pair sample t-test was used to examine the mean ranks, statistical difference among pretest and post-test between experimental group was noticeable. The improvement in the academic performance of experimental group in contrast to control group can be related to number of factors. In order to eliminate most of these factors, it was ensured that there is not inherent difference in the learning abilities of the two groups. This was also validated through the t-test during the pre-assessment. The timing of the lectures was also consistent and both groups were taught during similar time of the day. The same teacher was assigned to both the groups so that there is no difference in the communication and inter-personal skills. With all these checks in place, the difference in the learning achievement among the control and experimental group is correlated with confidence to the traditional and the UDL based teaching approach.

The universally designed pre-planned lesson that addresses the diverse learners in classroom plays a vital role to heighten the motivation and increase the academic performance [24]. It is crucial to plan lesson using UDL principles, guidelines and checkpoints to eradicate the impediments that are essential for successful UDL implementation [23]. Therefore, to understand learner's, information was gathered through questionnaires and learner profiles was gathered at early stage before lesson planning. According to Dykes and Green, to facilitate the diverse group of learners in a classroom, it is fundamental to have knowledge of who these learners are and what are their preferences and interests [15]. This information included learner's preferences and learner interest and technological accessibility and preference. Thus, lesson plan included all kind of learner identified by the learner profile and it was made sure that diverse learning styles can be addressed for representation and assessment. Learning styles or preferences play important role in lesson planning of teachers who taught primary graders [34]. Chik and Abdullah also suggested identification of learning styles and incorporation of learning strategies that addresses diverse learner's preferences motivate and impact academic performance positively [7]. Keeping the interest of learners in mind while lesson planning, enhances the engagement and boost motivation and academic achievement [42]. Therefore, several options were provided to express knowledge with respect to learner's interests such as poetry, drawing, role playing etc.

The use of different technological methods also plays an effective role to enhance learner's engagement and performance. Rappolt-Schlichtmann et al. also agreed that

UDL is a method that attempts to influence the science learning in the user-experience design of educational environment [41]. When digital reading environment uses the assistive technology features such as text to speech, highlighting and hardware such as headphones at independent station, teacher is able to modify the level of support required by pupils as suggested by UDL check point 4.2 [51].

Limitations and implication for future research and practice

Some limitations were noticed in the design and implementation of the present study. Detailed demographics of representation sample is provided but variability with respect to ethnicity was not available in the sample. The study does not employ full curriculum of a course subject but the experiment was conducted on only one unit. Therefore, future study can by conducted using more units of science courses. The study is limited for the primary grade pupil for only science subject. It can also be employed for the secondary grade pupils and the effectiveness of UDL checkpoints applied to the instructions can be investigated. To have internal and external validity, experimental research with random selection and assignment to condition from population was not achieved because of the time and resources constraints. This work can be extended over a long period of time, with random grouping of the total population for each individual topic. This will eliminate any bias that could arise from mis-matched groups based on their learning abilities. Lastly, the present study is based on the quantitative method only, qualitative aspect of the intervention can be examined in further studies.

13.6 Conclusion

The goal of this study was to investigate the impact of UDL compliant Science lesson plan on learning outcome of elementary grade pupils. This study also explained that how UDL based preplanned lesson help engage pupils and boost their motivation and impact learner's academic performance. The data analysis revealed that when Science lesson is taught using UDL principles (i.e., multiple means of representation, multiple means of action and expression and multiple means of engagements), it had positive influence on learner's learning experience in comparison to those who are taught with traditional teaching approaches. Additionally, the UDL compliant lesson plan was also mapped with UDL principles (Tables 13.1, 13.2 and 13.3), guidelines or checkpoints, which reveals that there are similar check points within the UDL framework thus overlapping of pedagogical strategies (method, materials and assessments) can be observed.

References

1. A.N. Applebee, J.A. Langer, M. Nystrand, A. Gamoran, Discussion-based approaches to developing understanding: classroom instruction and student performance in middle and high school English. Am. Educ. Res. J. **40**(3), 685–730 (2003)
2. J.Y. Balta, B. Supple, G.W. O'Keeffe, The universal design for learning framework in anatomical sciences education. Anat. Sci. Educ. **14**(1), 71–78 (2020)
3. J.D. Basham, J.E. Gardner, S.J. Smith, Measuring the implementation of UDL in classrooms and schools: initial field test results. Remedial Spec Educ **41**(4), 231–243 (2020)
4. N. Baurhoo, A. Asghar, Using universal design for learning to construct inclusive science classrooms for diverse learners. Learn Landsc **7**(2), 59–81 (2014)
5. T. Baumann, I. Melle, Evaluation of a digital UDL-based learning environment in inclusive chemistry education. Chem. Teach. Int. **1**(2) (2019)
6. P.L. Brown, J.P. Concannon, Students' perceptions of vocabulary knowledge and learning in a middle school science classroom. Int. J. Sci. Educ. **38**(3), 391–408 (2016)
7. Z. Chik, A.H. Abdullah, Effect of motivation, learning style and discipline learn about academic achievement additional mathematics. Int. J. Acad. Res. Bus. Soc. Sci. **8**(4), 772–787 (2018)
8. J. Clement, D.E. Brown, A. Zietsman, Not all preconceptions are misconceptions: finding 'anchoring conceptions' for grounding instruction on students' intuitions. Int. J. Sci. Educ. **11**(5), 554–565 (1989)
9. Cohen, J. (1988). Statistical power analysis for the behavioral sciences, 2nd edition.
10. S.C. Cook, K. Rao, Systematically applying UDL to effective practices for students with learning disabilities. Learn. Disabil. Q. **41**(3), 179–191 (2018)
11. S.J. Courey, P. Tappe, J. Siker, P. LePage, Improved lesson planning with universal design for learning (UDL). Teach. Educ. Spec. Educ. **36**(1), 7–27 (2013)
12. J.W. Creswell, *Educational Research: Planning, Conducting, and Evaluating Quantitative* (Prentice Hall, Upper Saddle River, NJ, 2002), pp. 146–166
13. H. Dack, Structuring teacher candidate learning about differentiated instruction through coursework. Teach. Teach. Educ. Int. J. Res. Stud. **69**(1), 62–74 (2018)
14. L. Darling-Hammond, L. Flook, C. Cook-Harvey, B. Barron, D. Osher, Implications for educational practice of the science of learning and development. Appl. Dev. Sci. **24**(2), 97–140 (2020)
15. G. Dykes, S. Green, Learning profiles of social work students: who are you and how should this influence my teaching? Soc. Work **51**(4), 577–598 (2015)
16. S.K. Dymond, A. Renzaglia, A. Rosenstein, E.J. Chun, R.A. Banks, V. Niswander, C.L. Gilson, Using a participatory action research approach to create a universally designed inclusive high school science course: a case study. Res. Pract. Pers. Severe Disabil. **31**(4), 293–308 (2006)
17. N. El Mawas, M. Bratu, D. Caraman, C.H. Muntean, Investigating the learning impact of game-based learning when teaching science to children with special learning needs, in Society for Information Technology & Teacher Education International Conference. Association for the Advancement of Computing in Education (AACE) (2019, March), pp. 2371–2377
18. A. Field, Discovering Statistics Using IBM SPSS Statistics. Sage (2013)
19. G. Franke, F.J. Scharfenberg, F.X. Bogner, Investigation of students' alternative conceptions of terms and processes of gene technology. ISRN Education (2013)
20. L.R. Gay, G.E. Mills, P.W. Airasian, Educational Research: Competencies for Analysis and Applications. Student Value Edition (Merrill, Pearson, NJ, 2012)
21. F.H. Groves, A longitudinal study of middle and secondary level science textbook vocabulary loads. Sch. Sci. Math. **116**(6), 320–325 (2016)
22. S. Gulati, Technology-enhanced learning in developing nations: a review. Int. Rev. Res. Open Distrib. Learn. **9**(1) (2008)
23. T.E. Hall, A. Meyer, D.H. Rose (Eds.), Universal Design for Learning in the Classroom: Practical Applications (Guilford Press, 2012)

24. R. Javaid, T.A. Lashari, I. Haider, E. Afzal, U. Farooq, S. Javed, N. Gerard, The effect of curriculum integrated technology-based universal design of learning approach on academic achievement of elementary school students, in International Conference on Applied Human Factors and Ergonomics (Springer, Cham, 2020, July), pp. 343–349
25. P.D. Keough, D. Pacis, Best practices implementing special education curriculum and common core state standards using UDL, in Accessibility and Diversity in Education: Breakthroughs in Research and Practice (IGI Global, 2020), pp. 179–196
26. A. Khan, F.H. Ahmad, M.M. Malik, Use of digital game-based learning and gamification in secondary school science: the effect on student engagement, learning and gender difference. Educ. Inf. Technol. **22**(6), 2767–2804 (2017)
27. S. Khan, G.J. Hwang, M. Azeem Abbas, A. Rehman, Mitigating the urban–rural educational gap in developing countries through mobile technology-supported learning. Br. J. Edu. Technol. **50**(2), 735–749 (2019)
28. M.E. King-Sears, Three steps for gaining access to the general education curriculum for learners with disabilities. Interv. Sch. Clin. **37**(2), 67–76 (2001)
29. J.L. Lemke, Talking Science: Language, Learning, and Values. Ablex Publishing Corporation, 355 Chestnut Street, Norwood, NJ 07648 (1990). (Hardback: ISBN-0-89391-565-3; paperback: ISBN-0-89391-566-1)
30. M.T. Marino, C.M. Gotch, M. Israel, E. Vasquez III., J.D. Basham, K. Becht, UDL in the middle school science classroom: can video games and alternative text heighten engagement and learning for students with learning disabilities? Learn. Disabil. Q. **37**(2), 87–99 (2014)
31. S. McPherson, A dance with the butterflies: a metamorphosis of teaching and learning through technology. Early Childhood Educ. J. **37**(3), 229 (2009)
32. J. Moore, S. Searles, L.A. Holterman, C. Simone, K. Huggett, Universal design for TBL®: promoting inclusion and access for all learners. Med. Sci. Educ. **30**(1), 595–596 (2020)
33. M.P. Murphy, Belief without evidence? A policy research note on Universal Design for Learning. Policy Futures Educ., 1478210320940206 (2020)
34. S.E. Nancekivell, P. Shah, S.A. Gelman, Maybe they're born with it, or maybe it's experience: toward a deeper understanding of the learning style myth. J. Educ. Psychol. **112**(2), 221 (2020)
35. D.E. Narkon, J.C. Wells, Improving reading comprehension for elementary students with learning disabilities: UDL enhanced story mapping. Prev. Sch. Fail. Altern. Educ. Child. Youth **57**(4), 231–239 (2013)
36. M.W. Ok, K. Rao, B.R. Bryant, D. McDougall, Universal design for learning in pre-k to grade 12 classrooms: a systematic review of research. Exceptionality **25**(2), 116–138 (2017)
37. K. Pine, D. Messer, K. St. John, Children's misconceptions in primary science: a survey of teachers' views. Res. Sci. Technol. Educ. **19**(1), 79–96 (2001)
38. W.W. Porter, C.R. Graham, K.A. Spring, K.R. Welch, Blended learning in higher education: Institutional adoption and implementation. Comput. Educ. **75**, 185–195 (2014)
39. P.K. Ralabate, Universal design for learning: meeting the needs of all students. The ASHA Leader **16**(10), 14–17 (2011)
40. K. Rao, M.W. Ok, S.J. Smith, A.S. Evmenova, D. Edyburn, Validation of the UDL reporting criteria with extant UDL research. Remedial Spec. Educ. **41**(4), 219–230 (2020)
41. G. Rappolt-Schlichtmann, S.G. Daley, S. Lim, S. Lapinski, K.H. Robinson, M. Johnson, Universal Design for Learning and elementary school science: exploring the efficacy, use, and perceptions of a web-based science notebook. J. Educ. Psychol. **105**(4), 1210 (2013)
42. K.A. Renninger, S. Hidi, *The Power of Interest for Motivation and Engagement* (Routledge, 2015)
43. D.H. Rose, A. Meyer, Teaching every student in the digital age: universal design for learning. Association for Supervision and Curriculum Development, 1703 N. Beauregard St., Alexandria, VA 22311-1714 (Product no. 101042: $22.95 ASCD members; $26.95 nonmembers) (2002)
44. A. Roychoudhury, Connecting science to everyday experiences in preschool settings. Cult. Sci. Edu. **9**(2), 305–315 (2014)
45. J. Schreffler, E. Vasquez III., J. Chini, W. James, Universal design for learning in postsecondary STEM education for students with disabilities: a systematic literature review. Int. J. STEM Educ. **6**(1), 8 (2019)

46. S. Singh, S. Yaduvanshi, Constructivism in science classroom: why and how. Int. J. Sci. Res. Publ. **5**(3), 1–5 (2015)
47. Silva, M., Munk, D. D., & Bursuck, W. D. (2005). Grading adaptations for students with disabilities. Intervention in School and Clinic, 41(2), 87–98. Retrieved from http://isc.sagepub.com.
48. S.A. Spencer, Universal design for learning: assistance for teachers in today's inclusive classrooms. Interdiscip. J. Teach. Learn. **1**(1), 10–22 (2011)
49. B. Supple, J. Abgenyega, Developing the understanding and practice of inclusion in higher education for international students with disabilities/additional needs: a whole schooling approach. Int. J. Whole Sch. **7**(2), 92–108 (2011)
50. S. Stolz, Universal design for learning: changing the way we interact with diversity, in Oxford Research Encyclopedia of Education (2020)
51. J.M. Van Boxtel, T. Sugita, Exploring the implementation of lesson-level UDL principles through an observation protocol. Int. J. Incl. Educ., 1–17 (2019)
52. S. Wahyuningsih, A. Rusilowati, N. Hindarto, Analysis of misconception to science literacy using three tier multiple choice test in the materials of characteristic of light. Unnes Sci. Educ. J. **6**(3) (2017)
53. W.M. Williams, P.B. Papierno, M.C. Makel, S.J. Ceci, Thinking like a scientist about real-world problems: the Cornell institute for research on children science education program. J. Appl. Dev. Psychol. **25**(1), 107–126 (2004)

Chapter 14
Facilitating Collaborative Learning with Virtual Reality Simulations, Gaming and Pair Programming

Piia Näykki, Janne Fagerlund, Minna Silvennoinen, Mari Manu, Tuula Nousiainen, Merja Juntunen, and Mikko Vesisenaho

Abstract The chapter presents socio-interactional functions that support collaborative learning through three case examples. The examples stem from our long line of empirical research in which we have explored the possibilities of using various types of emerging digital technologies for enhancing collaborative learning and interaction. We present case examples from technology-enhanced simulation-based learning environments, Vive/Minecraft applying XR/VR and pair programming in a creative media project design with Scratch, which are all regarded as powerful experiential learning contexts that can provide engaging opportunities for collaborative learning.

Keywords Collaborative learning · Teacher-student interaction Simulation-based learning environments · Gaming · Pair programming · Virtual reality · XR/VR · Vive/Minecraft · Scratch

14.1 Introduction

Technological innovations are broadening learning and interaction opportunities by augmenting, enriching, and adaptively guiding learning and interaction. New research is especially keen on the potential of virtual (VR) and mixed reality (XR) [1–5], game-based learning platforms [6, 7] and creative programming [8–10] to offer immersive and engaging learning contexts. For several decades, interest has particularly been in developing technologies for social learning interaction in a framework of collaborative learning [11]. In general, collaborative learning is a powerful context for enhancing individuals' learning and is effective for developing group working skills [12]. Collaborative learning is built through interaction processes of sharing, questioning and justifying ideas and understanding in social interaction [13, 14]. Digital learning environments afford new types of opportunities for learners to engage and

P. Näykki (✉) · J. Fagerlund · M. Silvennoinen · M. Manu · T. Nousiainen · M. Juntunen · M. Vesisenaho
Faculty of Education and Psychology, University of Jyväskylä, Jyväskylä, Finland
e-mail: piia.t.naykki@jyu.fi

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_14

participate in collaborative learning activities [15, 16]. In particular, immersive environments add the aspect of human-technology interaction to the learning situation [3, 4]. Technology is changing both ways of learning and ways of teaching or facilitating learning and interaction. To further guide the implementation of technology in education in pedagogically meaningful ways, we need more evidence of how technology is affecting collaborative learning, teaching, and interaction processes [4, 17–20].

In general, the role of a teacher is changing, and a collaborative learning approach means a shift away from a teacher-centred approach to an approach that extends the teacher's role from information transmission to a designer of the learning experience [21, 22]. The aim is to empower students to take an active role in planning and conducting their learning activities in groups, and the teachers' role is, thus, to foster beneficial student interaction or design optimal conditions for collaboration, while giving direct support when needed to the students with cognitive, metacognitive, emotional and motivational activities [21]. The current questions are: How are new and emerging digital technology providing engaging and creative collaborative learning environments, and what kinds of interactive functions do they support to afford to establish meaningful interactions with and among users?

This book chapter seeks answers to these questions by elaborating socio-interactional functions that support collaborative learning through three case examples. The examples stem from our empirical research in which we have explored the possibilities of using various types of emerging digital technologies for enhancing collaborative learning and interaction. We present case examples from technology-enhanced simulation-based learning environments, Vive/Minecraft applying XR/VR and pair programming in a creative media project design with Scratch, which are all regarded as powerful experiential learning contexts that can provide engaging opportunities for collaborative learning. These three examples were chosen because of their likely impact on learning and instruction in current and future educational designs [23].

14.2 Group Engagement as a Central Part of Collaborative Learning

Collaborative learning is a specific type of learning and interaction process in which learners in a group share their overall learning process by negotiating their goals for learning and coordinating their mutual learning processes together [24]. As the process of collaborative learning consists of discussions, negotiations, and reflections on the task at hand, it has the potential to lead to deeper information processing than individuals would achieve alone [14]. The premise for successful collaborative learning is that group members are actively engaged in building, monitoring, and maintaining their shared learning processes on cognitive and socioemotional levels [25–27]. This suggests that interpreting and understanding how your actions and emotions affect others is essential to obtaining successful collaborative learning [28, 29].

We ground our studies in the increasing empirical understanding of the multi-faceted interaction processes involved in collaborative learning, integrating cognitive and socioemotional components as the core of collaboration [30–34]. Thus, collaborative learning requires group members to be aware of and to coordinate their cognitive, metacognitive, motivational, and emotional resources and efforts [35] by sharing their thinking and understanding, as well as showing verbally and behaviourally their commitment and engagement to the task and to the group. In addition to group activities, teacher-student interaction is essential in guiding students' engagement in learning. This means that how the teacher provides feedback and encouragement to students individually and as a group can have an effect on students' learning engagement [21, 36].

In general, researchers agree that engagement is a central part of collaborative learning and have defined it as a meta-construct encompassing at least three dimensions: behavioural, emotional, and cognitive [37, 38]. Behavioural engagement refers to positive conduct and active involvement in learning and participation in task activities. Emotional engagement is characterized through affective reactions of students during learning processes, how learners feel and manifest their feelings in the learning situation, and how socio-emotionally engaged are group members to the group's task. Cognitive engagement is highlighted as cognitive investments and the use of deep learning strategies when learning collaboratively as a group. The theoretical ideas behind cognitive investments in collaborative learning follow Roschelle's [12] notion of cognitive convergence: group members construct shared knowledge by monitoring the degree to which they understand each other's thinking, extend other people's ideas, acknowledge divergent interpretations, and resolve inconsistencies between the ideas that have been proposed. The premise underlying such learning relates to a process of explicating one's own ideas and engaging cognitively in the ideas of others [39].

However, students' engagement in collaborative learning situations requires skills that are different from and often more challenging than the skills required for individual learning [40]. To develop collaborative learning skills and afford learners possibilities to function as cognitively and socio-emotionally engaged group members, learners need their own experiences of collaboration-based instructional approaches with authentic and complex problems [41]. Technology is a natural part of this type of authentic learning.

14.3 Emerging Technologies as Support for Engagement in Collaborative Learning

We present and explore three case studies involving simulations using a virtual reality environment for learning, games for learning, and programming where emergent and contemporary technologies are used to support collaborative learning in open problem spaces, especially focusing on collaborative learning interactions and interaction processes between the student and the teacher. These emergent digital tools, with their respective socio-technical designs, were selected because they each represent different opportunities for learning. VR and XR technologies and simulations provide an immersive technology-enhanced context for experiential learning and a reflective discussion between the student and the teacher, while games and programming are contexts for creative learning. These technologies have often been present in informal contexts as associated with the social lives of the users, which may thus explain one of the reasons why they are able to access learners' engagement in powerful ways. These technologies hold the potential for learning in formal education as well, as a part of learning activities organized by educational institutions [42, 43].

14.4 Forestry VR Simulations in Vocational Education

Lately, there has been great interest in virtual reality simulations because of their potential to provide engaging, experiential, and immersive situations and contexts for learning [4, 44]. A recent analysis from 145 empirical studies of higher education contexts showed that simulation-based learning (SBL) is effective in facilitating the learning of complex skills across domains [45]. For example, in SBL, one can use or practice approaches that cannot be reached easily, safely or practiced at all in real life [46]. The SBL method is widely used, especially in safety-focused contexts such as aviation, healthcare, and the nuclear industry, where it provides possibilities for a repetitive practice of skills without major risks. Simulation is not a technology as such, even though technology often has a significant role in SBL [46]. In simulations, the learner typically has scenario-based problems or real-world problems to solve or skills to master, and the teacher has the role of supporting this task in collaboration with the learner. The skills practiced can be either technical or non-technical in nature. New technological applications, such as VR and game-based learning platforms, offer immersive contexts for SBL, providing high realism targeting to afford learning experience as authentic and engaging as possible [46]. The type of simulation depends a lot on each learning context and has its benefits in being an environment that can be tailored according to the learning needs [45]. Simulations may evoke strong and powerful emotions with authenticity, and thus, increase learning engagement in behavioural, cognitive and emotional dimensions [47].

In vocational education, simulations are implemented to enable a better connection between the educational setting and the professional skills needed in the field; however, very little yet is known from the student's perspective [48]. Jossberger et al. [48] argue that the presence and guidance of the teacher plays an essential role in the simulation process and, further, they point out that even though simulations demand self-direction and commitment, the learning activities and processes are not sufficiently promoted and supported. In our empirical simulation case studies,

Fig. 14.1 Practicing mechanized harvesting [49]. Photo taken by Auli Dahlström

we particularly explored learner-teacher interaction and meaningful moments of learning during simulator training [49]. A multi-method approach was created to capture learners' experiences during a simulation experiment. We examined the complex nature of the learners' individual experiences and interaction with a teacher, combined with physiological reactions of the body (heart rate measurements) and brain electrophysiological activation by electroencephalogram measurements (EEG) [43, 49]. The approach enables exploration of learning situations in a natural context from different aspects and the integration of individual experiences, emotions, and physiological and neurophysiological reactions during learning (Fig. 14.1).

The context of this case study is forestry simulations in vocational education, where SBL is integrated into the curriculum of forest harvester operator training. In this vocational education programme, students may also use the simulators alone or with peers in their free time as much as they want. As many of the students lived on campus, they had good opportunities for independent training. The simulator itself offered instructions and feedback relating to each training task, which supported independent and joint training. In this case study, six students and two teachers formed six dyads and participated in an SBL situation consisting of three pedagogical phases: an introduction to a simulation case, actual simulation tasks, and a debriefing discussion with the teacher. During the tasks, each student used HTC T3-D virtual glasses for a more authentic experience and performed four tasks that dealt with typical activities of mechanized harvesting, such as the different actions of a forwarder and a harvester, selecting the right trees to be cut, collecting cut trees, and piling up trees (Fig. 14.2). The tasks were selected by the teacher and became gradually more demanding so that the fourth task—cutting down large trees in the correct directions—was presumably a challenging task for all the students, as none had hardly any previous experience.

Fig. 14.2 Screenshot of the simulator during a mechanized harvesting task [49]

Before each task, the students received both text-based instructions and video-based examples directly from the simulator. After each task, the students received feedback from the simulator based on their performance in the tasks and discussed the simulator feedback with the teacher. Thereafter, together with the teacher, the students asked, discussed and negotiated, for example, solutions for challenges that emerged during the session. They also had a short debriefing session with the teacher after the training, during which the video recording of the simulator was used to stimulate discussion. In our case study, the students were interviewed individually after the SBL training situation and, with video recordings of the tasks, a stimulated recall method was used to stimulate the student's memory and to discuss the experience in detail. As we were interested in the students' experiences regarding their learning, the students annotated their videos of the tasks with an emphasis on episodes they defined as memorable and considered meaningful for their learning. In addition, the students described emotions they experienced during the training and commented on the successes and challenges of the episodes that they felt were meaningful. Further, they evaluated how it is to drive a simulator compared to a real forwarder or harvester and justified their arguments and preferences. The use of VR glasses was also discussed, and the students carefully explained the benefits and challenges of their use. The students also examined their perceptions of student–teacher interaction and its role in that particular SBL situation, while the teachers shared their views of the interaction on a general level during their individual interviews.

This case study highlighted the strength of SBL to offer students opportunities to practice forestry alone, together with other students, and with the teacher. Through the VR environment, the immersive experience of realistic forestry machines and the forest site were created. VR-enhanced SBL was a new learning experience for the students. In their study programme, similar activities and actions are typically practiced with real forestry machines. In this case study, the simulator instructed them during the tasks and gave automatic feedback to the students after each task performance. It became visible that the students could influence their own training activity, choose suitable tasks, and evaluate their performance with the help of the feedback provided by the simulator. Thus, both the student and the teacher monitored the learning process, and when necessary, the teachers further guided the students, interacting with the device. Therefore, the simulator was a central part of the student–teacher interaction process, altogether supporting learning. In general, in simulation-based learning contexts, the aim is to empower students to take an active role in reflecting and guiding their own learning processes. Studies have shown that teachers applying SBL methods and VR technology are adopting student-centred approaches [50].

14.5 Constructing and Exploring Minecraft and Vivecraft with VR Glasses

The second case example presents Vive-Minecraft as an XR environment for creative, collaborative, gamified learning processes in K12 education. Currently, there is an increasing interest in implementing games in an educational context [7, 51]. The affordances of games as a meaningful pedagogical context go beyond their motivational potential, they can facilitate engagement on cognitive, affective, and sociocultural levels [52]. Connolly et al. [53] found in their systematic literature review that playing computer games is linked to a range of perceptual, cognitive, behavioural, affective, and motivational impacts and outcomes. However, previous studies have shown that the game environment itself does not guarantee deep learning and meaningful learning experiences [54, 55]. The challenge is that many educational games follow simple designs that are only narrowly focused on academic content and provide drill and practice methods [7]. Careful pedagogical design is needed to implement an educational game as a holistic problem-solving environment. For example, game design elements can provide opportunities for learners' self-expression, discovery, and control. These types of playing activities can create a learning environment that supports students' cognitively effortful and meaningful learning, for example, in terms of programming skills, creativity, and problem solving [7, 56], and engagement [57].

The use of Minecraft in education taps into two dimensions of game-based learning [58, 59]: bringing popular existing games into the classroom and providing the learners with an opportunity to create their own game environments. In many cases, the pedagogical potential of creating games can be greater than that of merely playing them, as game-making entails engagement in collaboration and active knowledge construction [6, 60, 61]. Previous studies on the use of Minecraft in educational settings have found its pedagogical potential both in terms of student engagement and the acquisition of various skills and knowledge [6, 51, 62, 63].

In this case study, we designed a learning project related to the topic of energy effectiveness and sustainable development [64]. The project was implemented as a collaborative effort between teachers and teacher students who jointly created a game-based learning environment for the pupils. The design-based learning process of the 7–10-year-old pupils focused on planning and implementing a sustainable town or village. The pupils' tasks, supported by teacher students and their own teachers, consisted of information seeking, planning, and finally constructing Minecraft environments and exploring them with Vivecraft and VR glasses [64]. The pupils designed their own villages and began to collaborate (in a self-directed manner), and some villages were linked by railway or using joint energy sources. The case study showed that the collaborative and open-ended nature of Minecraft provides opportunities for student engagement, creative problem solving and learning different skills and knowledge [6, 51], however, it also challenges teachers to rethink their role in guiding and supporting the pupils' learning process. This entails, for example, actively supporting the learners' agency and self-regulation, and identifying and building on so-called teachable moments [64, 85] that emerge from the activities. To conclude, this case provided an example of a constructivist gaming experience in which players can play, modify the game, or even create their own games for learning [60].

14.6 Pair Programming as Collaborative Creative Coding

A third case example presents pair programming with Scratch [65–67]. Collaboration and programming have come as close to one another as ever, especially in primary and secondary education via pedagogical initiatives such as the creative computing movement [8] and digital fabrication and the maker culture [10]. On this front, we have come to see the rise of increasingly popular graphical programming tools such as Scratch, which was originally developed in 2009, to be more meaningful and social than other existing programming environments. Scratch has evolved to facilitate the design of various kinds of media projects, such as interactive digital games, stories, and animations, by encouraging learners' creative design, self-expression, and personal interest areas. Beyond this, it is also a social platform where young programmers can code together, share their projects, and examine, use, and build on each other's shared projects [68]. In schools, Scratch is encouraged for use in social constructivist or constructionist settings via problem-project based approaches to design media projects that are thematically connected to different curricular areas [69, 70]. A key collaborative element in Scratch among other environments comes in the form of *pair programming*, where two or more students can work together at the same computer towards a shared goal (one "driving", that is, using the computer, and the other one "navigating", that is, assisting in reviewing the design process). Pair programming has several known educational advantages, including enhancing conceptual learning [71], increasing enjoyment [72], and improving the quality of design, especially in complex tasks with novice programmers [73].

We designed a case study for K–9 education, where 4th grade students (N = 58) participated in an introductory Scratch programming course. The introductory course lasted for four months and was organized as one lesson per week. The participants formed dyads or small groups and programmed up to 14 different kinds of Scratch projects (Fig. 14.3). All Scratch projects (N = 339) turned in by students during the course were collected as data and analysed [66, 67]. Additionally, student dyads were video recorded while they programmed their final open-ended and creatively planned interactive Scratch games or stories. The research findings from this case study [67] highlighted known key interactional and socio-emotional issues, which are important for consideration in programming pedagogy. For example, a student, seemingly typically the "navigator," becoming detached from the shared programming process may be a result of a creative disagreement, a temperament mismatch among the collaborating students, established social roles, or an incidental effect caused by a dysfunctional organization of the "driver" and "navigator" roles. A distortion in the amount and quality of active participation in and decision-making regarding the shared problem-solving process (and thus, the thinking work required and potential learning) may be born. This can be manifested as, for example, inequity in the amount and quality of talk (e.g., more or less negotiating or one-sided decision-making when making creative decisions) [74]. Also, our findings suggested that the physical environment, namely, the formation of desks and chairs, can either support or hinder the quality of collaboration in pair programming with Scratch at the primary school level (see also [75]).

Altogether, the weight of different kinds of factors influencing the quality of pair programming can be shaped by several elements in versatile learning contexts and the miscellaneous interactions of different people (e.g., peers and instructors) taking part in the learning process [76]. However, as elaborated above, the functional interrelationship of a collaborating dyad or a student group seems to effectively determine whether the programmatic problem-solving work and knowledge construction

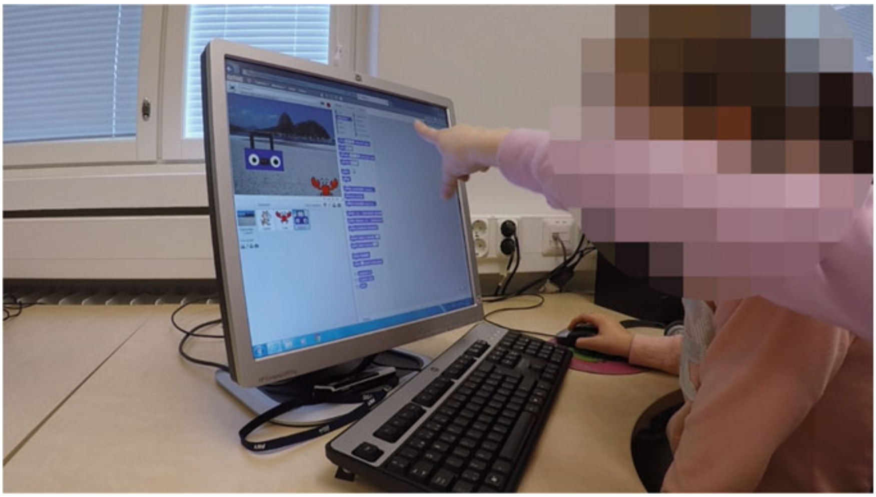


Fig. 14.3 Students programming an open-ended Scratch project in pairs [65, 67]

is truly collaborative or cooperative, or perhaps adverse to collaboration or cooperation, and whether it skews key elements, such as motivation, engagement, ownership, and agency, in socially emphasized learning contexts. An important question arises: How can teachers support primary school students' engagement and learning through meaningful participation in multifaceted and dynamic, creativity-focused and design-led pair programming processes? Another critical aspect in which social and socio-emotional issues display their importance is assessment. Can we entirely rely on the relatively common practice of assessing artefacts collectively programmed by several students as valid indications of each student's learning? Automated assessment by cognitive tutors that provide smart, timely feedback is gaining popularity in programming education [77], and they hold the potential to support students' conceptual understanding in programming. However, a fundamental question is: How could the complex social and socio-emotional reality and students' engagement within a group be included in developing reliable assessment? The findings from this case example [65–67] provide further insight regarding such questions in this relatively young but ever-growing research topic.

14.7 Discussion

This book chapter provides examples of the pedagogical and technological implementation of different emerging learning environments, namely, simulations applying VR/XR, constructing and exploring Vive/Minecraft environments and pair programming with Scratch. These environments have a great potential to function as support for collaborative learning and interaction [11, 77]. How well people learn together when using these environments cannot be explained only by how they process information, but requires taking into account social and emotional processes. The important questions are how learners interact, relate, and engage with each other when learning together as a group with the affordances of the learning environment [16, 20, 29]. Emotional experiences and expressions are particularly recognized as central resources in successful collaborative learning [79, 80]. The use of potential technological enhancements in collaboration necessitates an interdisciplinary understanding of the social factors and emotional dynamics influencing the learning and interaction processes [18]. We argue that when affective interactions are more thoroughly accounted for and enhanced through technology, they can have positive implications for cognitively effortful and meaningful collaborative engagement, thus contributing to better competence building and participation in group work.

All these learning environments presented by our case examples provide opportunities for making learning and interaction more tangible and, in addition, afford teachers the possibilities to view ongoing learning processes and guide, support, and provide feedback accordingly [81]. This, however, may be challenging when the teacher lacks the prior experience to implement such environments for learning. When the instructional goal is to provide possibilities for collaborative learning, teachers may need to learn how to organize and support collaborative processes and to flexibly adjust the degree of student responsibility [58, 82]. Sometimes this may mean adding more structures, however, it may also mean picking up the right moments, so-called teachable moments, and steering the process from there. For example, when spontaneous and self-directed activities emerge (such as when the groups began to build connections between their villages in the Minecraft project), it opens up an opportunity to address and discuss the learning content in a context that is meaningful and approachable for the learners. Furthermore, even though modern tools, such as simulators, are currently created for providing automated guidance and feedback for the learners, too often simulator feedback is not easily understandable and may require elaborating in a form of teacher feedback to make sure that the feedback is supportive for the training needs of the learner. The same can be seen with programming environments, where feedback often manifests as programmatic errors (i.e., "bugs") without further explanation as to where the learners, drawing from their mental models, have made a mistake. Often, particularly in safety–critical contexts, technology cannot fully replace the need for real human interaction, given that these technologies need to be further developed to avoid misunderstandings and risks of not using failures correctly for learning purposes.

As we observed the clear benefits of VR simulations, there are also potential risks in applying VR technology in education. A recent survey by Kamińska et al. [83] pointed out that one of the risks in VR education might still be the lack of flexibility. During traditional education, the student has more freedom in interacting with the natural environment, asking questions, discussing, and interacting with teachers. Further, VR headsets have their physical restrictions, even though these are developing towards lighter and more user-friendly versions. The role and importance of a social environment, teacher, or peer-learners should not be overlooked by over-relying on technology [17]. There is too much focus being placed on hard skills over soft skills in, for example, workplace-related learning, which occurs with excessive focus on education technology and forgets human interaction, mentoring and teacher-student relationships [83]. Vesisenaho et al. [43] described how differently each student physiologically reacted in the VR experiences. However, we deduce that one of the key issues of VR simulations is preserving both their social and technological benefits, which can be achieved by integrating the principles of simulation pedagogy into VR simulation-based learning. Thus, the supportive role of guidance and building a common understanding in the learning situation is acquired, rather than leaving the teaching task to technology alone.

The use of simulators, game-based VR/XR environments and programming as arenas for pedagogical activities has motivational potential from the perspective of learning and teaching, providing interesting arenas for future studies. In creative design-focused, open-ended collaborative settings, such as in programming experiments, learners' personal creativity-focused goals may need to be reconciled with shared goals. This requires generic collaboration skills, emotional intelligence, and argumentation skills. In general, new methods and approaches are needed to study social knowledge construction, as well as opportunities for adapting known methods (e.g., interaction and discourse analysis) to emerging technological contexts (e.g., creative coding and digital fabrication). A detailed analysis of the interaction between learners or the student and the teacher will offer information on the learners' engagement in a group task. Further analysis could also detect simulations' and teachers' roles in supporting students' engagement in a learning process. Likewise, an introduction to a simulation case, feedback given by the teacher, and joint discussions during the tasks, as well as a debriefing discussion, will provide possibilities to study the instructor's guidance and support of the student during a VR-enhanced SBL situation. One specific context for further research is teacher education. Teacher education students are in a key position to develop digital learning opportunities in their prospective teaching work [40]. Student teachers' motivational orientations in gamified learning contexts have been found to emphasize social interaction and altruistic purposes [84, 85]. Collaborative, immersive activities are likely to motivate these types of users [85], and as these aspects are an inherent part of XR environments, we can expect them to be a meaningful learning context for student teachers as well.

As the corpus of available digital learning tools and environments grows, it is becoming all the more necessary to communicate the big picture of learning and interaction to educational practitioners, technology developers, and learners themselves. To improve learning, teaching and innovation, technology-based tools, such as *virtual reality simulations, gaming and programming,* should be designed and experimented to filter and open up opportunities, as well as to consolidate them into transferable ideas and processes that may be picked up and used as innovations between different user groups [86]. Further, the outcomes of the cases presented here can be implemented in developing new advanced technological solutions, such as, artificial intelligence that can recognize and adapt to learners' and teachers' reactions and interactions, providing support during learning.

References

1. J. Blascovich, J. Bailenson, Immersive virtual environments and education simulations, in *Virtual Decisions: Digital Stimulations for Teaching Reasoning in the Social Sciences and Humanities*, ed. by S. Cohen, K.E. Portney, D. Rehberger, C. Thorsen (Lawrence Erlbaum Associates, 2006), pp. 229–253
2. L.F. Johnson, A.H. Levine, Virtual worlds: Inherently immersive, highly social learning spaces. Theory Pract. **47**, 161–170 (2008)
3. K.W. Lau, P.Y. Lee, The use of virtual reality for creating unusual environmental stimulation to motivate students to explore creative ideas. Interact. Learn. Environ. **23**(1), 3–18 (2015)
4. J. Radianti, T.A. Majchrzak, J. Fromm, I. Wohlgenannt, A systematic review of immersive virtual reality applications for higher education: design elements, lessons learned, and research agenda. Comput. Educ. 147 (2019)
5. K.E. Stavroulia, A. Lanitis, Enhancing reflection and empathy skills via using a virtual reality based learning framework. Int. J. Emerg. Technol. Learn. **14**(7), 18–36 (2019)
6. Y. Baek, E. Min, S. Yun, Mining educational implications of Minecraft. Comput. Sch. **37**(1), 1–16 (2020)
7. M. Qian, K.R. Clark, Game-based learning and 21st century skills: a review of recent research. Comput. Hum. Behav. **63**, 50–58 (2016). https://doi.org/10.1016/j.chb.2016.05.023

8. K. Brennan, M. Resnick, New frameworks for studying and assessing the development of computational thinking, in *AERA 2012*, Vancouver, BC (2012)
9. G.V. Georgiev, I.M. Sánchez, D. Ferreira, A framework for capturing creativity in digital fabrication. Des. J. **20**, 3659–3668 (2017). https://doi.org/10.1080/14606925.2017.1352870
10. M. Iwata, K. Pitkänen, J. Laru, K. Mäkitalo, Exploring potentials and challenges to develop twenty-first century skills and computational thinking in K-12 maker education. Front. Educ. (2020). https://doi.org/10.3389/feduc.2020.00087
11. H. Jeong, C.E. Hmelo-Silver, Seven affordances of computer-supported collaborative learning: how to support collaborative learning? How can technologies help? Educ. Psychol. **51**, 247–265 (2016). https://doi.org/10.1080/00461520.2016.1158654
12. J. Roschelle, Learning by collaborating: convergent conceptual change. J. Learn. Sci. **2**, 235–276 (1992)
13. M.T.H. Chi, Active-constructive-interactive: a conceptual framework for differentiating learning activities. Top. Cogn. Sci. **1**, 73–105 (2009). https://doi.org/10.1111/j.1756-8765.2008.01005.x
14. P. Dillenbourg, Introduction: what do you mean by collaborative learning?, in *Collaborative Learning: Cognitive and Computational Approaches*, ed. by P. Dillenbourg (Elsevier Science, Oxford, 1999), pp. 1–19
15. J. Laru, P. Näykki, S. Järvelä, Four stages of research on the educational use of ubiquitous computing. learning technologies. IEEE Trans. **8**(1), 69–82 (2015)
16. S. Ludvigsen, R. Steier, Reflections and looking ahead for CSCL: digital infrastructures, digital tools, and collaborative learning. Int. J. Comput. Support. Collab. Learn. **14**, 415–423 (2019). https://doi.org/10.1007/s11412-019-09312-3
17. J. Isohätälä, P. Näykki, S. Järvelä, M. Baker, K. Lund, Social sensitivity in CSCL. Int. J. Comput. Support. Collab. Learn. (2021). https://doi.org/10.1007/s11412-021-09344-8
18. S. Järvelä, D. Gasevic, T. Seppänen, M. Pechenizkyi, Bridging learning sciences, machine learning, and affective computing for understanding cognition and affect in collaborative learning. Br. J. Edu. Technol. (2020). https://doi.org/10.1111/bjet.12917
19. V. Marin, P. Jääskelä, P. Häkkinen, M. Juntunen, H. Rasku-Puttonen, M. Vesisenaho, Seamless learning environments in higher education with mobile devices and examples. Int. J. Mobile Blended Learn. **8**(1), 51–68 (2016). https://doi.org/10.4018/IJMBL.2016010104
20. P. Näykki, J. Laru, E. Vuopala, P. Siklander, S. Järvelä, Affective learning in digital education–case studies of social networking systems, games for learning and digital fabrication. Front. Educ. (2019). https://doi.org/10.3389/feduc.2019.00128
21. C. Kaendler, M. Wiedmann, N. Rummel, H. Spada, Teacher competencies for the implementation of collaborative learning in the classroom: a framework and research review. Educ. Psychol. Rev. **27**(3), 505–536 (2015)
22. M. Laal, M. Laal, Collaborative learning: what is it? Procedia Soc. Behav. Sci. **31**, 491–495 (2012)
23. R. Huang, J.M. Spector, J. Yang, *Educational Technology* (Springer, 2019)
24. J. Roschelle, S.D. Teasley, The construction of shared knowledge in collaborative problem solving, in *Computer-Supported Collaborative Learning*, ed. by C. O'Malley (Springer, Berlin, 1995), pp. 69–97. doi:https://doi.org/10.1007/978-3-642-85098-1_5.
25. B. Barron, When smart groups fail. J. Learn. Sci. **12**(3), 307–359 (2003). https://doi.org/10.1207/S15327809JLS1203
26. J. Isohätälä, P. Näykki, S. Järvelä, Cognitive and socio-emotional interaction in collaborative learning: exploring fluctuations in students' participation. Scand. J. Educ. Res. **64**(6), 831–851 (2020). https://doi.org/10.1080/00313831.2019.1623310
27. P. Näykki, J. Isohätälä, S. Järvelä, J. Pöysä-Tarhonen, P. Häkkinen, Facilitating socio-cognitive and socio-emotional monitoring in collaborative learning with a regulation macro script–an exploratory study. Int. J. Comput. Support. Collab. Learn. **12**(3), 251–279 (2017). https://doi.org/10.1007/s11412-017-9259-5
28. L. Linnenbrink-Garcia, T.K. Rogat, K.L.K. Koskey, Affect and engagement during small group instruction. Contemp. Educ. Psychol. **36**(1), 13–24 (2011). https://doi.org/10.1016/j.cedpsych.2010.09.001

29. N. Miyake, P. Kirschner, The social and interactive dimensions of collaborative learning, in *The Cambridge Handbook of the Learning Sciences: Cambridge Handbooks in Psycholog*y, ed. by Sawyer R. (Cambridge University Press, 2014), pp. 418–438. https://doi.org/10.1017/CBO9781139519526.026
30. S. Järvelä, H. Järvenoja, P. Näykki, Analyzing regulation of motivation as an individual and social process–a situated approach, in *Interpersonal Regulation of Learning and Motivation: Methodological Advances*, ed. by S. Volet, M. Vauras (Routledge, New York, 2013), pp. 170–187
31. P. Näykki, S. Järvelä, P. Kirschner, H. Järvenoja, Socio- emotional conflict in collaborative learning–a process-oriented case study in a higher education context. Int. J. Educ. Res. **68**, 1–14 (2014)
32. S. Ucan, M. Webb, Social regulation of learning during collaborative inquiry learning in science: how does it emerge and what are its functions? Int. J. Sci. Educ. **37**(15), 2503–2532 (2015). https://doi.org/10.1080/09500693.2015.1083634
33. S. Volet, M. Summers, J. Thurman, High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? Learning and Instruction, 19(2), 128–143 (2009)
34. E. Vuopala, P. Näykki, J. Isohätälä, S. Järvelä, Knoweldge co-construction activities and task-related monitoring in scripted collaborative learning. Learning, culture and social interaction, 21, 234–249 (2019)
35. A.F. Hadwin, S. Järvelä, M. Miller, Self-regulation, co-regulation, and shared regulation in collaborative learning environments, in *Handbook of Self-Regulation of Learning and Performance*, 2nd edn., ed. by D.H. Schunk, J.A. Greene (Routledge, New York, NY, 2018), pp. 83–106
36. J. Van de Pol, N. Mercer, M. Volman, Scaffolding student understanding in small-group work: students' uptake of teacher support in subsequent small-group interaction. J. Learn. Sci. **28**(2), 206–239 (2019). https://doi.org/10.1080/10508406.2018.1522258
37. J.A. Fredricks, P.C. Blumenfeld, A.H. Paris, School engagement: potential of the concept, state of the evidence. Rev. Educ. Res. **74**(1), 59–109 (2004)
38. S. Sinha, T.K. Rogat, K.R. Adams-Wiggins, C.E. Hmelo-Silver, Collaborative group engagement in a computer-supported inquiry learning environment. Int. J. Comput. Support. Collab. Learn. **10**(3), 273–307 (2015)
39. N.M. Webb, M.L. Franke, M. Ing, J. Wong, C.H. Fernandez, N. Shin, A.C. Turrou, Engaging with others' mathematical ideas: interrelationships among student participation, teachers' instructional practices, and learning. Int. J. Educ. Res. 63, 79–93 (2014)
40. P. Häkkinen, S. Järvelä, K. Mäkitalo-Siegl, A. Ahonen, P. Näykki, T. Valtonen, Preparing teacher students for 21st century learning practices (PREP 21): a framework for enhancing collaborative problem solving and strategic learning skills. Teach. Teach. Theory Pract., 1–17 (2017)
41. C. Hmelo-Silver, H.S. Barrows, Facilitating collaborative knowledge building. Cognition and Instruction. 26(1), 48–94 (2008)
42. L. Pedro, C. Barbosa, C. Santos, A critical review of mobile learning integration in formal educational contexts. Int. J. Educ. Tech. High. Educ. **15**, 1–15 (2018). https://doi.org/10.1186/s41239-018-0091-4
43. M. Vesisenaho, M. Juntunen, P. Häkkinen, J. Pöysä-Tarhonen, J. Fagerlund, I. Miakush, T. Parviainen, Virtual reality in education: focus on the role of emotions and physiological reactivity. J. Virtual Worlds Res. **12**(1) (2019). https://doi.org/10.4101/jvwr.v12i1.7329
44. C. Kwon, Verification of the possibility and effectiveness of experiential learning using HMD-based immersive VR technologies. Virtual Real. **23**(1), 101–118 (2019)
45. O. Chernikova, N. Heitzmann, M. Stadler, D. Holzberger, T. Seidel, F. Fischer, Simulation-based learning in higher education: a meta-analysis. Rev. Educ. Res. **90**(4), 499–541 (2020)
46. F. Lateef, Simulation-based learning: just like the real thing. J. Emerg. Trauma Shock **3**(4), 348 (2010)
47. V.R. LeBlanc, The relationship between emotions and learning in simulation-based education, simulation in healthcare. J. Soc. Simul. Healthc. **14**(3), 137–139 (2019). https://doi.org/10.1097/SIH.0000000000000379

48. H. Jossberger, S. Brand-Gruwel, M.W. van de Wiel, H. Boshuizen, Learning in workplace simulations in vocational education: a student perspective. Vocat. Learn. **11**(2), 179–204 (2018)
49. M. Silvennoinen, M. Vesisenaho, M. Manu, T. Kullberg, A. Malinen, T. Parviainen, Methodology development in adult learning research: combining physiological reactions and learning experiences in simulation-based learning environments, in *EDULEARN20 Proceedings. 12th International Conference on Education and New Learning Technologies, EDULEARN Proceedings. IATED*, ed. by L. Gómez Chova, A. López Martínez, I. Candel Torres (2020), pp. 5037–5046. https://doi.org/10.21125/edulearn.2020.1316
50. T. Keskitalo, Teachers' conceptions and their approaches to teaching in virtual reality and simulation-based learning environments. Teach. Teach. Theory Pract. **17**(1), 131–147 (2011)
51. S. Nebel, S. Schneider, G.D. Rey, Mining learning and crafting scientific experiments: a literature review on the use of minecraft in education and research. Educ. Technol. Soc. **19**(2), 355–366 (2016)
52. J.L. Plass, B.D. Homer, C.K. Kinzer, Foundations of game-based learning. Educ. Psychol. **50**(4), 258–283 (2015). https://doi.org/10.1080/00461520.2015.1122533
53. T.M. Connolly, E.A. Boyle, E. MacArthur, T. Hainey, J.M. Boyle, A systematic literature review of empirical evidence on computer games and serious games. Comput. Educ. **59**(2), 661–686 (2012)
54. S.Y. Lye, J.H.L. Koh, Review on teaching and learning of computational thinking through programming: what is next for K-12? Comput. Hum. Behav. **41**, 51–61 (2014). https://doi.org/10.1016/j.chb.2014.09.012Mayer2015
55. R.E. Mayer, On the need for research evidence to guide the design of computer games for learning. Educ. Psychol. **50**, 349–353 (2015). https://doi.org/10.1080/00461520.2015.1133307
56. C. Kazimoglu, M. Kiernan, L. Bacon, L. Mackinnon, A serious game for developing computational thinking and learning introductory computer programming. Procedia Soc. Behav. Sci. **47**, 1991–1999 (2012)
57. N. Pellas, Exploring interrelationships among high school students' engagement factors in introductory programming courses via a 3D multi-user serious game created in open sim. J. UCS **20**(12), 1608–1628 (2014)
58. T. Nousiainen, M. Kangas, J. Rikala, M. Vesisenaho, Teacher competencies in game-based pedagogy. Teach. Teach. Educ. **74**, 85–97 (2018)
59. R. Van Eck, Digital game-based learning: It's not just the digital natives who are restless. Educ. Rev. **41**(2), 16–18 (2006)
60. Y.B. Kafai, Q. Burke, Constructionist gaming: understanding the benefits of making games for learning. Educ. Psychol. **50**(4), 313–334 (2015)
61. N. Vos, H. van der Meijden, E. Denessen, Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. Comput. Educ. **56**(1), 127–137 (2011)
62. M. Checa-Romero, G. Pascual, Minecraft and machinima in action: development of creativity in the classroom. Technol. Pedagog. Educ. **27**(5), 625–637 (2018). https://doi.org/10.1080/1475939X.2018.1537933
63. D.M. Díaz, J.L. Saorín, C. Carbonell-Carrera, J. de la Torre Cantero, Minecraft: three-dimensional construction workshop for improvement of creativity. Technol. Pedagog. Educ. **29**(5), 665–678 (2020)
64. M. Kyllönen, M. Vesisenaho, M. Manu, P. Häkkinen, OpenDigi-hankkeen satoa: opettajat, opettajankouluttajat ja opiskelijat yhteiskehittämässä digipedagogista osaamista, in *Merkityksellistä oppimista etsimässä-oppimisympäristöjen moninaisuus nyt ja tulevaisuudessa*, ed. by A. Veijola, O.-P. Salo, S. Roos (toim.). Jyväskylän normaalikoulun julkaisuja, 16, 163–180 (2020)
65. J. Fagerlund, A study on the assessment of introductory computational thinking via scratch programming in primary schools, in *Proceedings of the 2018 ACM Conference on International Computing Education Research (ICER '18)*, ed. by L. Malmi, A. Korhonen, R. McCartney, A. Petersen (ACM, New York, 2018), pp. 264–265

66. J. Fagerlund, P. Häkkinen, M. Vesisenaho, J. Viiri, Assessing 4th grade students' computational thinking through scratch programming projects. Inf. Educ. **19**(4), 611–640 (2020)
67. J. Fagerlund, M. Vesisenaho, P. Häkkinen, Fourth Grade Students' Computational Thinking in Pair Programming with Scratch: A Holistic Case Analysis (in review)
68. J. Maloney, M. Resnick, N. Rusk, B. Silverman, E. Eastmond, The Scratch programming language and environment. ACM Trans. Comput. Educ. **10**(4), 1–15 (2010). https://doi.org/10.1145/1868358.1868363
69. B. Garneli, M. Giannakos, K. Chorianopoulos, Computing education in K-12 schools: a review of the literature, in *2015 IEEE Global Engineering Education Conference, Tallinn, Estonia* [Conference Paper] (2015)
70. G. Robles, J.C.R. Hauck, J. Moreno-León, M. Román-González, R. Nombela, C. Grease von Wangenheim, On tools that support the development of computational thinking skills: Some thoughts and future vision, in *Proceedings of the International Conference on Computational Thinking Education 2018*, ed. by S.C. Kong, D. Andone, G. Biswas, T. Crick, H. U. Hoppe, T. C. Hsu, R. H. Huang, K. Y. Li, C. K. Looi, M. Milrad, J. Sheldon, J. L. Shih, K. F. Sin, M. Tissenbaum, J. Vahrenhold (The Education University of Hong Kong, Hong Kong, 2018)
71. J. Denner, L. Werner, S. Campe, S. Ortiz, Pair programming: under what conditions is it advantageous for middle school students? J. Res. Technol. Educ. **46**(3), 277–296 (2014)
72. J. Liebenberg, E. Mentz, B. Breed, Pair programming and secondary school girls' enjoyment of programming and the subject Information Technology (IT). Comput. Sci. Educ. **22**(3), 219–236 (2012). https://doi.org/10.1080/08993408.2012.713180
73. E. Arisholm, H. Gallis, T. Dybé, D.D. SjAberg, Evaluating pair programming with respect to system complexity and programmer expertise. IEEE Trans. Software Eng. **33**(2), 65–86 (2007). https://doi.org/10.1109/TSE.2007.17
74. C. Lewis, N. Shah, How equity and inequity can emerge in pair programming, in *Proceedings of the Eleventh Annual International Conference on International Computing Education Research (ICER '15)* (ACM, New York, NY, 2015), pp. 41–50
75. M. Ally, F. Darroch, M. Toleman, A framework for understanding the factors influencing pair programming success, in *Extreme Programming and Agile Processes in Software Engineering*. XP 2005, ed. by H. Baumeister, M. Marchesi, M Holcombe. Lecture Notes in Computer Science, vol. 3556 (Springer, 2005). https://doi.org/10.1007/11499053_10
76. R. Scherer, F. Siddiq, V.B. Sánchez, A meta-analysis of teaching and learning computer programming: effective instructional approaches and conditions. Comput. Hum. Behav., 109 (2020)
77. J. Moreno-León, G. Robles, M. Román-González, Dr. Scratch: automatic analysis of scratch projects to assess and foster computational thinking. Revista de Educación a Distancia **15**(46), 1–23 (2015)
78. C.P. Rosé, N. Law, U. Cress, S. Ludvigsen, Highlighting tools and technologies for collaborative learning. Int. J. Comput. Support. Collab. Learn. **14**, 1–6 (2019). https://doi.org/10.1007/s11412-019-09297-z
79. M.J. Baker, J. Andriessen, S. Järvelä, *Affective Learning Together: Social and Emotional Dimension of Collaborative Learning* (Routledge, 2013). https://doi.org/10.4324/9780203069684
80. P. Näykki, J. Isohätälä, S. Järvelä, You really brought all your feelings out–scaffolding students to identify the socioemotional and socio-cognitive challenges in collaborative learning. Learn. Cult. Soc. Interact. (2021)
81. H. Järvenoja, J. Malmberg, S. Järvelä, P. Näykki, H. Kontturi, Investigating students' situation-specific emotional state and motivational goals during a learning project within one primary school classroom learning. Res. Pract. **5**(1), 4–23 (2019). https://doi.org/10.1080/23735082.2018.1554821
82. P. Näykki, H. Kontturi, V. Seppänen, N. Impiö, S. Järvelä, Teachers as learners–a qualitative exploration of pre-service and in-service teachers' continuous learning community OpenDigi. J. Educ. Teach. Int. Res. Pedag. (2021). https://doi.org/10.1080/02607476.2021.1904777

83. D. Kamińska, T. Sapiński, S. Wiak, T. Tikk, R.E. Haamer, E. Avots, G. Anbarjafari, Virtual reality and its applications in education: survey. Information **10**(10), 318 (2019)
84. H. Fischer, M. Heinz, M. Breitenstein, Gamification of learning management systems and user types in higher education, in *Proceedings of the 12th European Conference on Game-Based Learning (ECGBL 2018)* (Academic Conferences and Publishing Limited, 2018), pp. 91–98
85. T. Nousiainen, M. Vesisenaho, E. Ahlström, M. Peltonen, S. Fort, G.M. Sacha, Gamifying teacher students' learning platform: information and communication technology in teacher education courses, in *Proceedings of the Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'20) (Salamanca, Spain, October 21–23, 2020)* (ACM, 2020). https://doi.org/10.1145/3434780.3436659
86. M. Vesisenaho, P. Dillon, S. Havu-Nuutinen, T. Nousiainen, T. Valtonen, R. Wang, Creative improvisations with information and communication technology to support learning: a conceptual and developmental framework. J. Teach. Educ. Educ. **6**(3), 229–250 (2017). http://jtee.org/document/issue14/article1.pdf
87. W.R. Watson, C.J. Mong, C.A. Harris, A case study of the in-class use of a video game for teaching high school history. Comput. Educ. **56**(2), 466–474 (2011)

Chapter 15
Gamification and the Internet of Things in Education

Georgios Pappas, Joshua Siegel, Ioannis N. Vogiatzakis, and Konstantinos Politopoulos

Abstract Gamification and the Internet of Things will impact education in a manner previously impossible. Gamified tools built upon game engines will offer opportunities in the development of innovative virtual labs and other interactive experiences for students. The Internet of Things can provide real-world data visualization in near real-time. Combining these fields, it becomes possible to develop realistic and safe simulation environments with real life data or triggering systems taking the student learning experience in whole new levels.

Keywords Gamification · Serious games · Education · Learning · Multiplayer · Pseudo-multiplayer · Internet of things · IoT · Iotrigger · Distributed systems · Emerging technologies · Machine-to-machine · Connected systems

15.1 Introduction

Gamification is considered to be one of the most engaging ways to educate or train students in class or remotely in distance learning. At the same time, the Internet of Things is one of the deep technologies [1] that will disrupt many parts of our lives. Integrating Internet of Things implementations with gamified applications or tools and gamification will offer some unique and user-student approaches in education.

G. Pappas (✉) · J. Siegel
Michigan State University, Michigan, USA
e-mail: georgios.pappas@ouc.ac.cy

J. Siegel
e-mail: jsiegel@msu.edu

K. Politopoulos
National Technical University of Athens, Athens, Greece
e-mail: policent@central.ntua.gr

I. N. Vogiatzakis
Open University of Cyprus, Nicosia, Cyprus
e-mail: ioannis.vogiatzakis@ouc.ac.cy

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_15

In the present chapter, we introduce the concept of gamification and then provide an overview of the Internet of Things. Next, we showcase an example of how our team designed and developed a training gamified tool applied in the field of environmental studies and how this is integrated with the Internet of Things to enable triggers in a virtual 3D space. Following this, we will provide information on how this innovation was used in a real distance-learning class for Master's degree students.

15.2 Gamification

15.2.1 Serious and Simulation Games in Education and Training

Gamification and serious games have proved to be valuable in training and education [2–4]. These games or gamified tools aim [5] to simulate realistic virtual environments in safe and accessible conditions and scenarios in which users and particularly students are able to interact in an engaging manner [6]. At the same time, the students not only acquire knowledge in their fields [7], but also learn in a "serious" fun way [8]. Some serious games can be used as virtual labs where experimentation can take place and based on this digital experience [9] and students can be assessed by their instructors [10]. This way, institutions can lower their operating expenses by limiting the purchases in expensive, specialized equipment since students will be using reusable enabling technology to generate flexible digital and simulated equipment. Using this kind of equipment the risk of damage from improper use is also eliminated. Another advantage that this simulated virtual environments offer is that they could be used in students' personal computers, transforming them in remote labs accessible anywhere, any day and anytime.

Studies have shown that advanced and high quality simulators have managed not only to train humans but also Artificial Intelligence (AI) models, in a human-to-machine and machine-to-machine approach [11–15].

15.2.2 Game Engines

Game development has changed in recent years. Importantly, developers—especially the "indies" or small studios, can buy commodity game development tools rather than creating everything from scratch. In the industry, there are several game engines that make development work easier. This is because most of them offer **advanced physics systems** including **particle systems, scripting** in popular or custom programming languages, **collider** and **detection systems**, **input management**, **rendering** and in-game **Artificial Intelligence** for non-player characters (NPCs) [16].

Some of the most popular and widely used are:

- **Unity3D**: This is one of the most powerful engines. It requires programming in C# or JavaScript. Unity has a large developer community which is a powerful source of help and information. There are abundant free or commercial assets in the Unity Asset Store that can potentially speed up the development process. It has both a free and a professional version [17].
- **Unreal**: Together with Unity, Unreal is considered one of the top choices for game developers. It uses C++ as a programming language and also offers blueprints for non-programmers to work and design logic. Many popular AAA titles are made using Unreal [18].
- **GameMaker**: GameMaker has been a popular choice for non-programmer game developers since it does not require programming skills to create a game with it [19].
- **Godot**: Godot is a free and open-source engine that uses its own programming language GDScript which is similar to Python [20].
- **CryEngine**: CryEngine is another high-end engine and it uses C++, C#, Lua Script Bindings and Flowgraphs as programming languages [21].

15.3 The Internet of Things (IoT)

15.3.1 What is the IoT?

The Internet of Things (IoT) is a network of people, devices, and services [22] that can sense, connect to one another, make inferences, and act(uate) at scale [23, 24] with in excess of 30 billion IoT devices deployed globally today [25]. Sensing allows devices and services to measure themselves and their environments; connectivity allows information to be moved to where it may be aggregated, where it is most useful, and/or where it is easiest to process. Inference turns information into insight, and action and actuation allow insight to affect a system so as to form a closed control-loop based on near realtime and abundant data. This network of connected smart devices leverages pervasive sensing, connectivity, and computation to improve quality of life and deliver social, economic, and other value [26]. The IoT is a Deep Technology that was impossible a few short years ago and is now easily feasible, pervasive, and invisible [1], made feasible by advances in sensing, storage, remote computing, and more [26].

Today, tools exist to ease computer interaction with and among connected devices [27] and to simplify the development of analytical tools and feedback systems. These tools drive the development of novel applications at the intersection of traditional products, services, and knowledge silos, leading to increased adoption of the IoT in an ever-accelerating virtuous cycle. In the broadest-possible terms, IoT is a design language and a vocabulary focused on technology and industry convergence and enablement [28] with key tenants being data generation and use at scale.

15.3.2 The Impact of IoT

More people and things join the Internet of Things every day [29]. From these people and things, it is possible to generate more data from more places, allowing for the creation of a growing number of (data informed) products, services, and analytics at the intersection of those existing [30]. Measurement and data capture from diverse systems can lead to enhanced understanding of those systems, their environments and contexts, and the world at large [31].

One example of data measurement, capture, and analysis takes the form of "Digital Twins", which mirror physical systems mathematically within remote computing environments [26]. These Twins can be used for predictive analytics, or more simply, to enable compelling interactive visualizations taking the form of 2D dashboards, 3D rendered desktop applications, or even Virtual Reality [32]. These environments combine with other technological affordances to create opportunities for individuals to engage in experiences otherwise infeasible. IoT has the potential to create new industries, new modes of interaction, and a newly, immersive and responsive world. These worlds need not be purely physical. For example, IoT can combine with technologies such as eXtended Reality (XR) to allow individuals to transcend the limitations of the physical, to engage in experiences taking place in dynamic and responsive virtual environments [10], allowing for participants to engage in new and unique experiences in comfort and safety of their own home.

Beyond smarter visualizations and analytics, the Internet of Things also creates opportunities through broad-scale data collection enabled by pervasive sensing, connectivity, and ubiquitous computing. Data collection, sharing, analysis, and action at scale [29] may include systems ranging from consumer devices to critical infrastructure [33–35] such as smart factories and automation systems [36–38]. IoT has also been used to monitor equipment [39] and to embed intelligence into "dumb" systems [40, 41]. The net result is that IoT combines with other technological affordances such as Big Data and AI to create smarter, more responsive environments ranging from homes to factories, often building upon the "power of 1%" at scale (e.g. small savings in one factory are insignificant, but when multiplied across an industry, the impact is radical).

15.3.3 IoT Devices and Sensors

Sensors are less expensive, lower power, more accessible, and more pervasive than ever. Sensors can measure parameters about the sensing system itself, or the sensing system's environment. Parameters measured may include environmental data, such as temperature and humidity, contextual data, such as location, acceleration, and rotation, or rich data sources such as audio, images, or video capture. These sensors upload data to constrained computing systems with battery, bandwidth, and storage limitations, though algorithms for data cleaning and analysis are ever-improving to allow for operation on low-power, low-resource systems. The net result is that the IoT is capturing and acting upon more data than would've been feasible a few short years ago, leading to smarter and more engaging systems.

15.3.4 Connectivity and Security

Connectivity allows data and intents (commands) to move across system boundaries, both for small-scale networks (few devices somewhat locally operated) and large-scale networks (a large number of potentially-diverse devices operating at massive geographic scale). Connectivity is important for data collection and aggregation, as well as in moving information from constrained-compute systems to environments where enhanced computation is feasible, such as the Cloud, Fog, or Edge. The ability to move data offers huge potential benefits to analytics and system optimization, though scale also brings about risk. Maximizing the benefit of data aggregation requires thoughtful platform design, standards, and resource-aware IoT implementations. Siegel [30] while ensuring security necessitates thoughtful design inclusive of security from the start [33–35]. Selecting an appropriate architecture can make deploying IoT safely and secure in more places feasible [22, 29, 30].

15.3.5 Industry Examples of IoT-Enabled Training and Education

The presence of technology in classrooms has become the norm; today, it transcends taking notes on laptops and additionally includes more cutting-edge capabilities such as gamification. Gamification provides a means to motivate learning and to provide high-engagement, interactive instruction motivating collaboration, teamwork, communication, and goal-seeking using element of challenge and motivation to encourage positive learning behaviors [42]. Increasingly, digital gamification plays an intentional—rather than incidental—role in higher education. Gamified learning, in combination with game-based learning, can support higher education with great benefits across disciplines for teachers and students alike [43].

Promising results in higher education have led to the exploration of digital gamification in industry, too, with application to professional education in disciplines such as engineering [44]. Studies have shown a positive effect by making subjects more manageable, and increasing student motivation to learn.

More recently, the idea of pairing existing gamification approaches with other emergent technologies such as the Internet of Things, XR, and easy-to-use game engines has started appearing in the industry with application to education. One example of such development is what PTC is doing for training, in using this methodology for worker training or remote worker supervision. Also, some efforts towards this direction have been made by Realism.io, which is an educational organization that creates virtual laboratories to expand student access to educational resources at low per-user cost and with minimal health and safety risks.

15.4 Environmental Studies Gamified Tool

15.4.1 Design and Development Methodology of the Environmental Studies Gamified Tool

Starting from a simple sketch and some notes (Fig. 15.1) on the needed educational elements and 3D objects, we started to design our serious gamified tool with an expectation to simulate a somehow realistic environment [4]. In order to design our tool to be suitable for environmental studies educational purposes and thus, generate a meaningful [45] interactive learning experience to our students, we worked using the research-creation method [46].

For the development part of our gamified tool, we worked using the Scrum model [47] of the Agile methodology of software engineering. Our team arranged meetings after specific elements were developed and stable builds were exported. We worked in sprints and continuously iterated [48] on development aspects until we reached a working beta build.

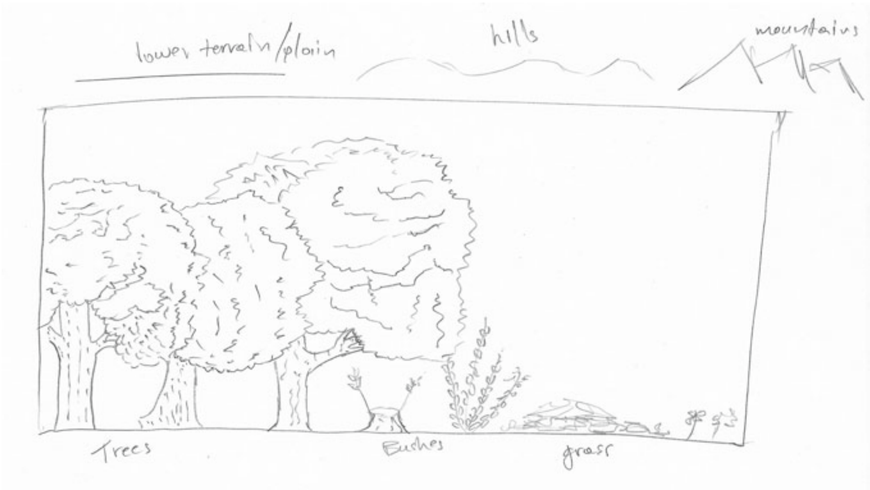


Fig. 15.1 Initial sketch ideation and notes on the gamified tool

15.4.2 Developing the Environmental Studies Gamified Tool

The gamified tool is built upon a powerful Game Engine, Unity [17]. As discussed in Sect. 15.2.2, Unity is one of most popular engines in the field of game development and features a physics system suitable for our case and most importantly, a great commercial add-on asset to generate the needed types of terrains. Below, we explain the development of the tool.

Levels—Scenes: The gamified tool contains a main menu (Fig. 15.2), a loading screen (Fig. 15.3) and a main area environment (Figs. 15.4 and 15.5). The main menu handles the scene transitions and the loading screen works as the waiting screen between the main menu and the main area environment.

Fig. 15.2 Main menu

Fig. 15.3 Loading screen

Fig. 15.4 Main area screenshot 1

Fig. 15.5 Main area screenshot 2

Features and Mechanics: Once the gamified tool is loaded in the main environment, the user can explore in a **first-person perspective** (first person controller) a **virtual environment** of 4 km^2 (2 km × 2 km terrain). This terrain was developed using a purchased add-on. This way, we created a **land mass** (including hills), a **lake**, **different kinds of plants** and a **forest**. We have also developed a **simulated weather system**.

The square area of the environment is also bounded with invisible colliders, placed near its limits (about ten meters inside each side). This way users always remain between the necessary area and there is no chance to "fall off" the level.

The tool also contains three user interface (UI) elements at the right side of the screen (Figs. 15.4 and 15.5). These include a **compass**, a **coordinate system viewer** and a **mini-map**. The compass helps the users identify the correct direction for their movements while the coordinate system viewer is providing the in-game coordinates and current location of the player's avatar (first-person camera). The mini-map just gives a small top-down preview of the neighboring area.

In addition to the mini-map that just gives an essence of a certain area, a more powerful **virtual drone system** was implemented too. This system was developed using RenderTextures and UI Panels and gives the opportunity to users for a top-down view of certain areas. Selecting different buttons from the keyboard, it can provide a larger or smaller predefined area (Table 15.1 and Figs. 15.6, 15.7, 15.8, 15.9, 15.10, 15.11 and 15.12). An important characteristic of this feature is that these drones can move or rotate along with the users' movement.

Lastly, we also created a **teleport system** where users can change locations immediately and go to predefined coordinates where instructor-triggered events are taking place (see Sect. 15.4.3).

Table 15.1 Drone system and button configuration

Drone	Area covered	Keyboard button
Drone view 1	100 m^2 (10 m × 10 m)	U
Drone view 2	400 m^2 (10 m × 10 m)	I
Drone view 3	1,600 m^2 (10 m × 10 m)	O
Drone view 4	6,400 m^2 (10 m × 10 m)	P
Drone view 5	14,400 m^2 (10 m × 10 m)	J
Drone view 6	25,600 m^2 (10 m × 10 m)	K
Drone view 7	40,000 m^2 (10 m × 10 m)	L

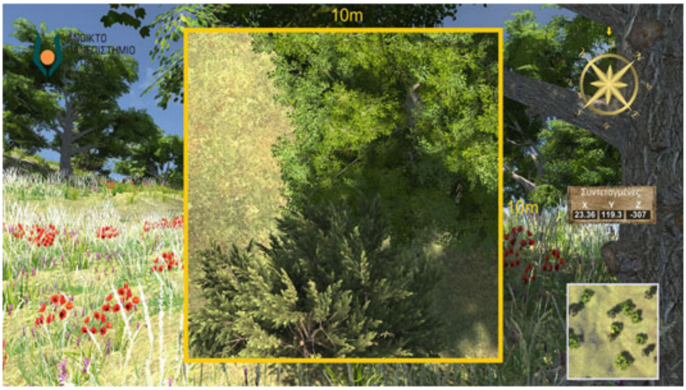


Fig. 15.6 Drone view 1 (10 m × 10 m area)

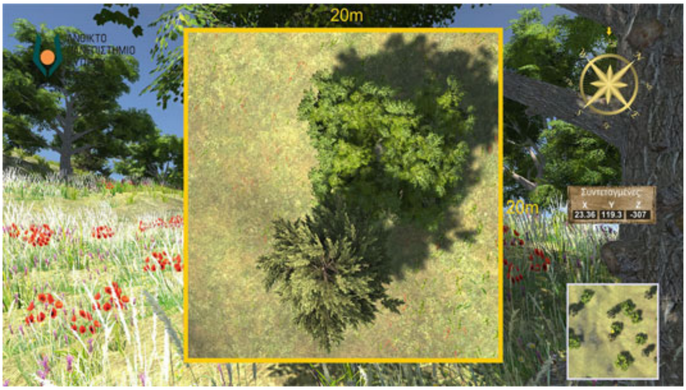


Fig. 15.7 Drone view 2 (20 m × 20 m area)

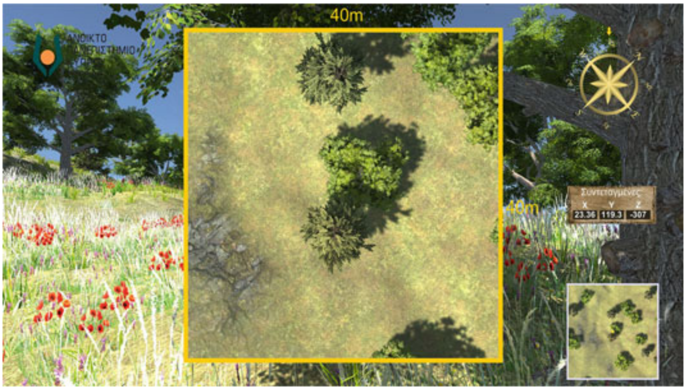


Fig. 15.8 Drone view 3 (40 m × 40 m area)

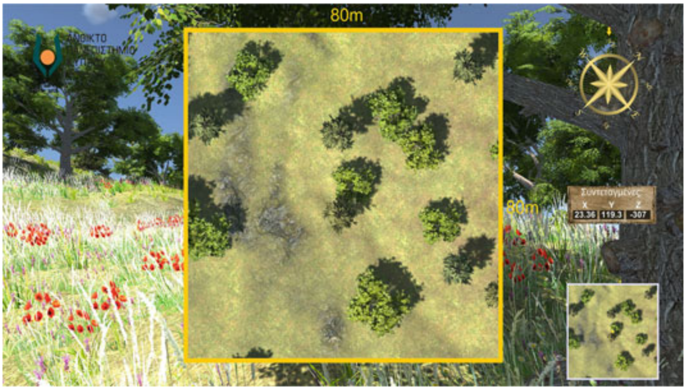


Fig. 15.9 Drone view 4 (80 m × 80 m area)

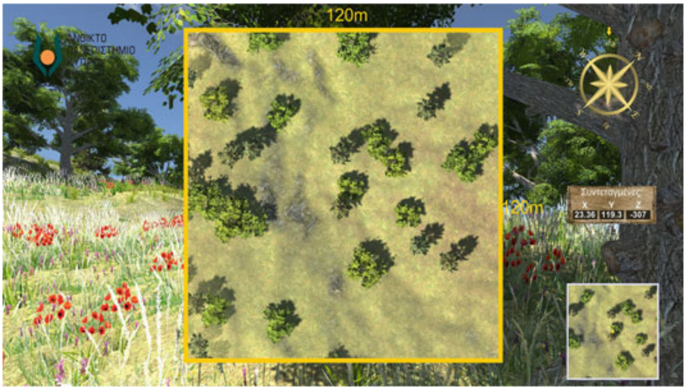


Fig. 15.10 Drone view 5 (120 m × 120 m area)

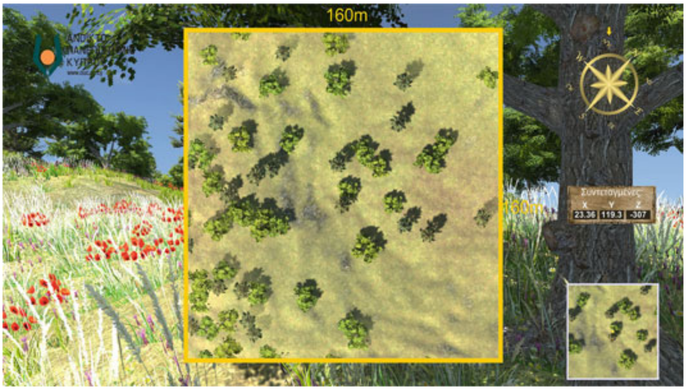


Fig. 15.11 Drone view 6 (160 m × 160 m area)

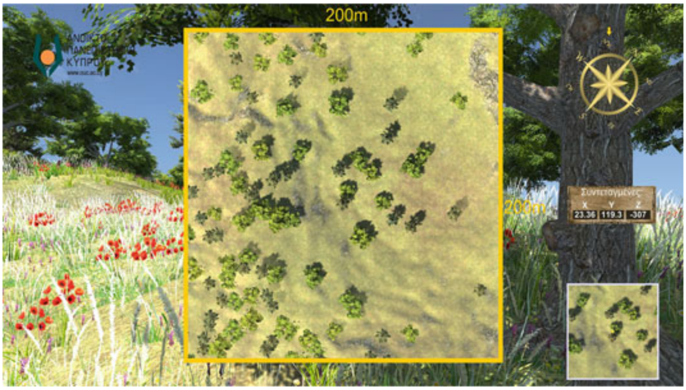


Fig. 15.12 Drone view 7 (200 m × 200 m area)

15.4.3 The IoT Implementation

After the main tool was developed as described in Sect. 15.4.2, we developed an IoT implementation. To do so, for the hardware part, we used a breadboard, a microcontroller and a button. The microcontroller was powered via a micro-USB cable connected to a computer. The circuit schematic is presented in Fig. 15.13 and was created with the tool "Fritzing" and a photo of the actual implementation is shown in Fig. 15.14.

The microcontroller that we were using is named "Photon" and it is designed by the IoT company "Particle". It has a pre-installed WIFI shield and thus, after setting it up we managed to connect it with the web-based IDE and the cloud platform of Particle.

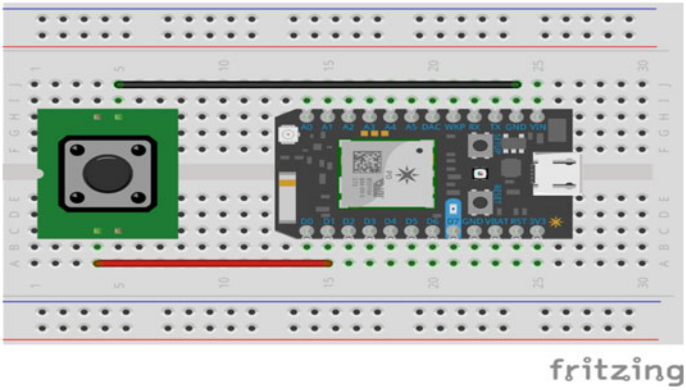


Fig. 15.13 Schematic of the IoT implementation

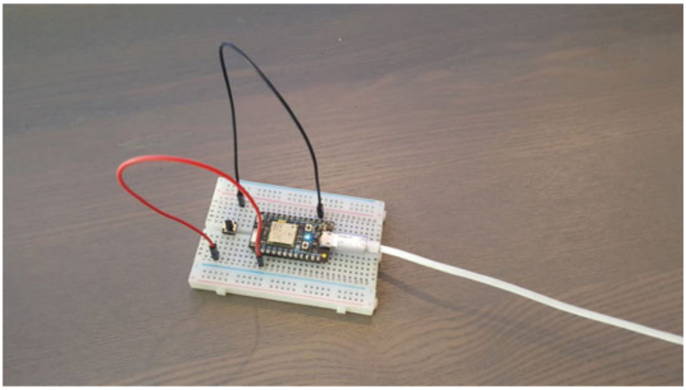


Fig. 15.14 The IoT Implementation in reality

After our device was connected online via WIFI, we programmed our microcontroller in C++, similarly to an Arduino and "flashed" it via the IDE. Our code can be found in Fig. 15.15. In short, the code gets the value of the button and translates it into "ON" and "OFF" states. The "ON" state represents when the button is pressed and the "OFF" when it is not. When the circuit is powered on, these values are uploaded constantly to the cloud via WIFI with an interval of $t_d = 2000$ ms (2 s) between each measurement (Fig. 15.16).

```
int led = D7;
int pushButton = D2;

void setup(){
    pinMode(led, OUTPUT);
    pinMode(pushButton, INPUT_PULLUP);
}

void loop(){
    int pushButtonState;
    pushButtonState = digitalRead(pushButton);
    //String Button_Status = pushButtonState;


 // Particle.variable("Button_Status", pushButtonState);


   if(pushButtonState == LOW){
        digitalWrite(led, HIGH);
        Spark.publish("Button_Status","ON",60,PRIVATE);
//        Particle.variable("Button_Status", pushButtonState);

        delay(2000);
   }
    else{
        digitalWrite(led, LOW);
        Spark.publish("Button_Status","OFF",60,PRIVATE);
  }
}
```

Fig. 15.15 Microcontroller code

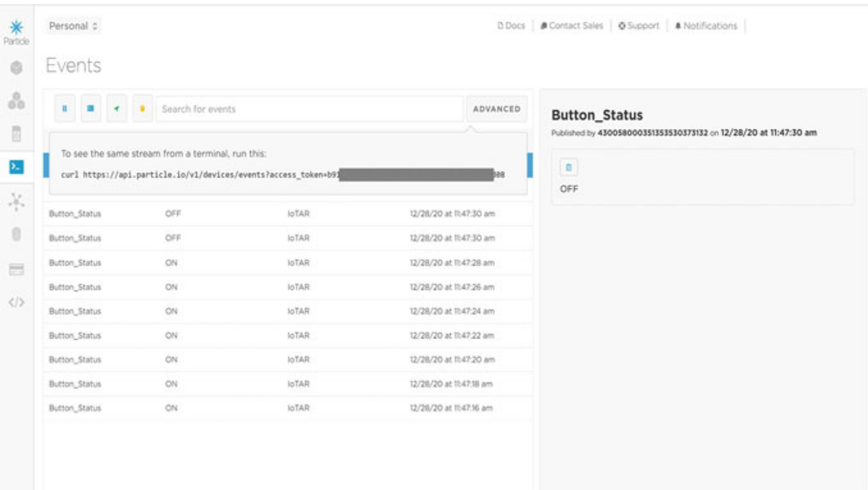


Fig. 15.16 ON–OFF Values as uploaded to the cloud platform

In order to get these values and import them into our gamified tool with C#, we are using the stream link provided. This link also contains an access token (shown but greyed out in Fig. 15.16) and uses a security method [49] since our data are not public but private [50]. Practically, we are using the authorization method OAuth [51] which is pre-installed on server side. Using the REST API we are getting the values in the form of JSON (JavaScript Object Notation) files [52].

15.4.4 Overview of IoT-Enabled Gamification

In the Fig. 15.17, we can see how this integration works. While the IoT implementation is powered on and connected to the internet, the instructor presses or releases the button switch. Then, via the WIFI, this information ("ON" - "OFF") is uploaded to the cloud platform. We have programmed our gamified tool in C# to get the secure stream of data. In addition to the 3D environment, the UI elements, the audio and the other C# scripts needed for the tool's development, we are getting the "ON"-"OFF" states. These states are not used as text anywhere, but they are used as triggers, the "IoTriggers", as we named them. While developing the gamified tool, we have also created a fire particle system along with a course-related 3D world space image (Fig. 15.18). Both the particle system and the image are Unity gameObjects that we had set to be inactive unless the tool gets the "ON" state indication. When the instructor presses the button, they enable these gameObjects and thus, both the fire and the course material show up. When they release the button and thus, the IoT implementation is transmitting an "OFF" indication, these gameObjects are programmed to be set inactive once more and the virtual environment will return to its original state. In order to get these values and import them into our gamified tool with C#, we are using the stream link provided. This link also contains an access token (shown but greyed out in Fig. 15.16) and uses a security method [49] since our data are not public but private [50]. Practically, we are using the authorization method OAuth [51] which is pre-installed on server side. Using the REST API we are getting the values in the form of JSON (JavaScript Object Notation) files [52].

This way, we have on the one hand the **asynchronous** character of the tool, where students can explore the virtual environment or they can work and get measurements with the drone system for their assignments locally and at their own time and the safety of their houses. On the other had, we have transformed it into a very powerful **synchronous** tool for lectures using the IoT. Using this method, every student that uses the application and is located near the virtual coordinates that the fire incident is taking place can actually view the fire and the additional course material **simultaneously** with their classmates. That is why we had implemented the teleport system (see Sect. 15.4.2, to help students move immediately to the appropriate location for the IoTriggers. This way, a tutor can use the tool while lecturing and provide students with a very engaging interactive experience. We named this mode "pseudo-multiplayer", because even though it is a type of a multiplayer, it differs from a regular game's multiplayer mode (see Sect. 15.4.5).

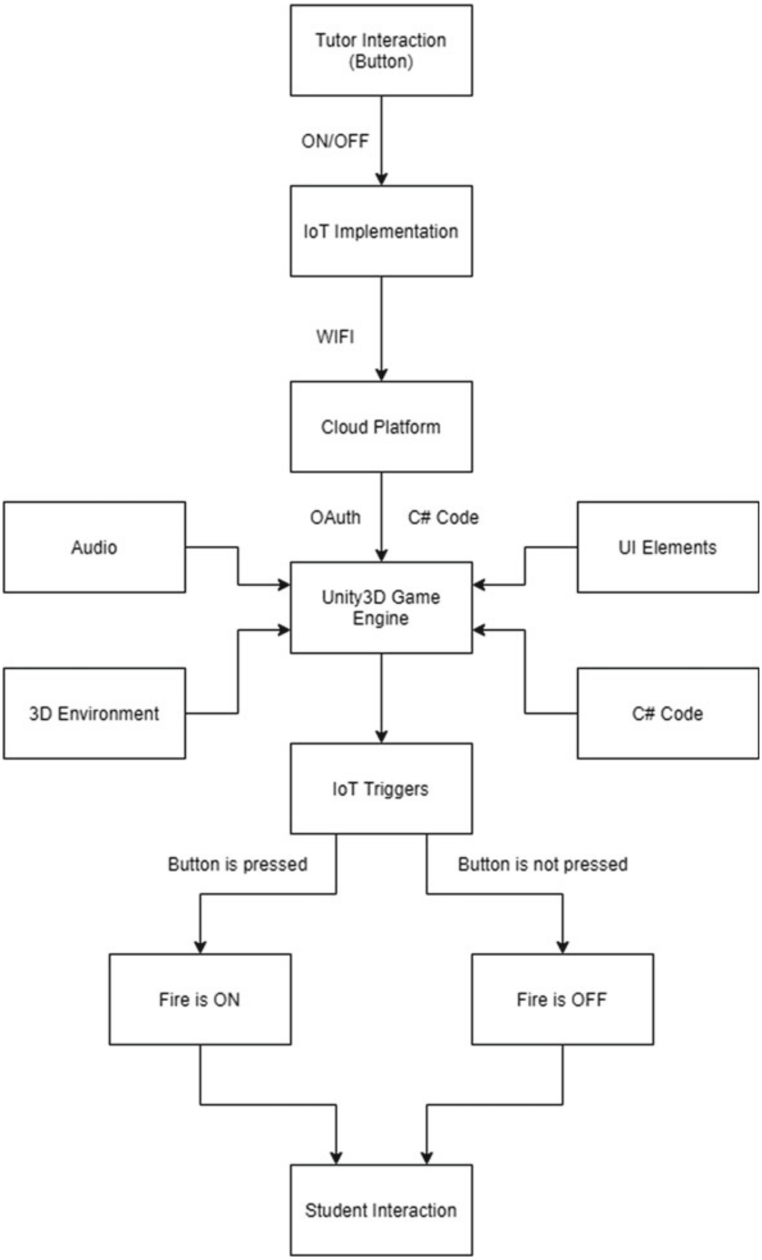


Fig. 15.17 Holistic diagram of gamification and IoT integration

Fig. 15.18 When the button is pressed, the fire starts burning the trees and the virtual book is appearing—IoTriggers

15.4.5 Multiplayer versus IoT-Enabled Pseudo-Multiplayer

Multiplayer is a common mode in modern games. When users are playing multiplayer, they are interacting with other users along with the game itself. Depending on the game, the users are viewing the other users' avatars and they can see them moving or performing various actions. Using modern game development techniques (excluding the game streaming services like Google Stadia [53] and others), users have locally installed games and after they are connected to a server and then a lobby, they are just streaming the position, rotation and scale attributes of other users in their lobby in order to be able to see them moving. At the same time, for other events viewable in multiplayer the Remote Procedure Calls (RPCs) are taking place. This way the packets transmitted between users are limited to the essential ones and thus, are easier to be handled over the network and the performance is better since the ping remains quite low.

The pseudo-multiplayer mode we implemented, does not require our users to be connected to a game server or a specific lobby. Every copy of the gamified tool works as an independent receiver of the IoT information. All students can simultaneously view the events when they are taking place, but even though they could be near or even at the same virtual coordinates with their classmates, they do not see each other. This way, they can attend a lecture and use the tool without even having distractions with each other and by getting a simultaneous by custom instructor-to-student experience.

15.4.6 *The Use of Environmental Studies Tool in Class*

Once the development phase and the major beta testing of the gamified tool were complete, it was uploaded to the moodle-based online platform of the Open University of Cyprus, named “eClass” (Fig. 15.19). Along with it a short manual explaining the game controls and the general usage was created and uploaded too. Shortly, after being available online to students, the tool was demonstrated to students during a synchronous meeting of the class in a Blackboard Collaborate session (Fig. 15.20).

This tool is primarily designed for distance learning purposes. More specifically, it is incorporated in Terrestrial Ecosystem Management module of the MSc program of Environmental Conservation and Management to facilitate online teaching of standard field-based methods for ecology and physical geography.

The use of the tool, provided solutions to a number of practical teaching issues and fostered a new learning experience for the students. As is the case in distance learning, students are located in many and different geographical areas. Some are living in major cities and smaller towns, with minimal or no immediate access to semi-natural landscapes. In addition, and since student fieldwork should be done in pairs for health and safety reasons, any related assignment to real world conditions remains problematic (e.g. vegetation sampling/survey).

At the same time, for an instructor it may be hard to create assignments and assess students with no \common ground” for measurements between their class. All the above issues were solved or improved using the environment studies tool.

Some types of activities which are now undertaken using the tool, directly or indirectly, in the aforementioned MSc module include:

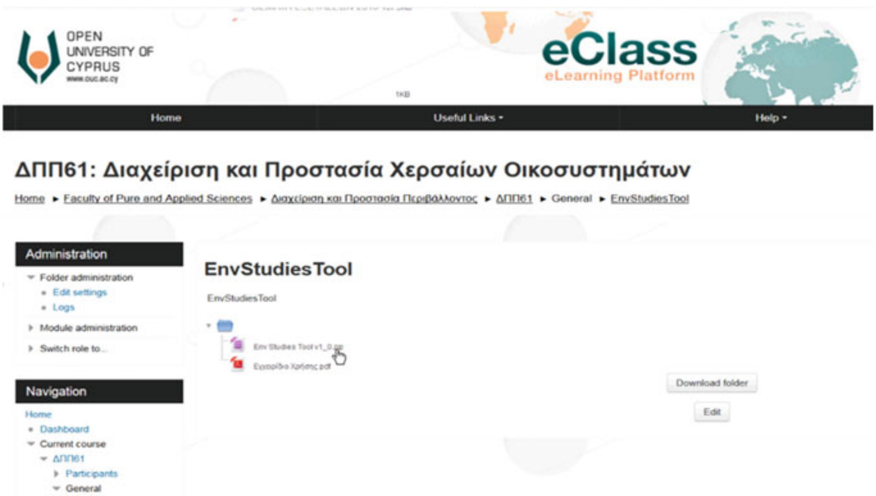


Fig. 15.19 The gamified tool on eClass

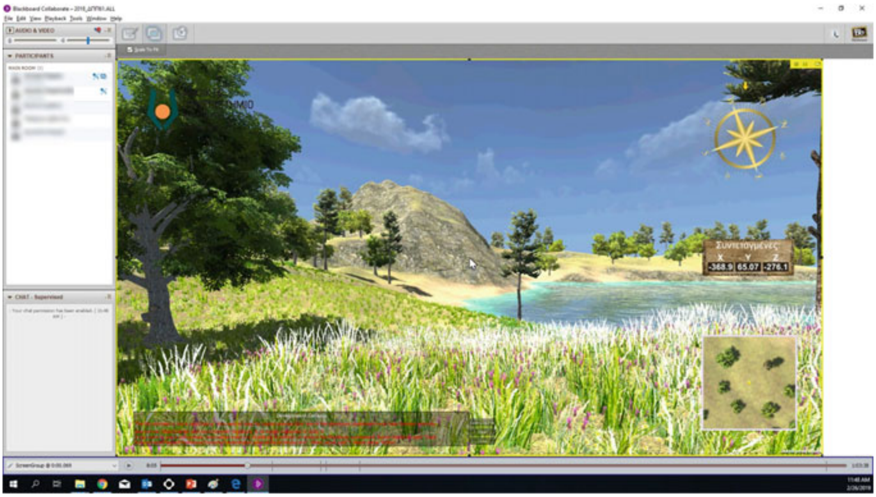


Fig. 15.20 Live demonstration of the tool in Blackboard Collaborate

- **Measurement of species abundance**: presence/absence vs qualitative data: using any species of the ones present in the virtual terrain.
- **Biodiversity indices calculation**: using all different species identified in the virtual terrain.
- **Choice of sampling plots size and the minimal area curve**: This activity includes the seven set drone views and two different life forms of the virtual terrain (trees vs grasses).
- **Estimation of species population**: based on the use of pine trees.
- **Landscape Character Assessment**: using land cover and landform and assumed differences in geology of the virtual terrain.

15.4.7 Student Survey and Results

Before making the tool a part of the course core material, we needed to get some feedback from the students. So, after uploading the tool to the eClass platform students, we asked students to download it locally and test it on their computers. Then, we created a user experience (UX) and anonymous research survey. The UX research methodology we used, was survey-based. This is because we wanted to give the participants the flexibility of testing and providing their feedback at their own time, since they are students of an Open University where asynchronous methodology is the norm. Instead of having interviews on specific difficulties, bugs or errors they came across or suggestions the students had, we gave them the opportunity to include these at the end of our short questionnaire in a comment textbox.

Table 15.2 Survey ratings on various aspects of the tool

Participant	Statement 1	Statement 2	Statement 3	Statement 4	Statement 5	Statement 6	Statement 7
Participant 1	★★★☆☆	★★★☆☆	★★★☆☆	★★★★☆	★★★☆☆	★★★★☆	★★★★★
Participant 2	★★★★☆	★★★☆☆	★★★☆☆	★★★☆☆	★★★☆☆	★★★☆☆	★★★★☆
Participant 3	★★★☆☆	★★★☆☆	★★★★★	★★★★★	★★★★★	★★★★★	★★★★☆
Participant 4	★★★☆☆	★★★★☆	★★★☆☆	★★★★☆	★★☆☆☆	★★★★★	★★★★★

Regarding our sample, the average age of the MSc students is 35 years, with a wide range of backgrounds, mostly on science related disciplines. All of them are working in government or private entities dealing with environmental management, located either in Cyprus or Greece in different geographical setting i.e. both in large urban centers and rural areas. The students which took part in this assessment did so on a voluntary basis.

By the time this research was conducted, the tool had not been associated with learning objectives yet but students were informed about its goals and the IoT part was explained, so the focus is mainly on the use of the tool. In some statements of the survey, students just give their insights on the upcoming learning goals and tool association. Specifically, students had to give their ratings from 1 to 5 (1 represents the lowest value) for the following statements. At the end, they were also given the option to write a few suggestions for updates and future releases or report any bugs they may have had and difficulties they may have faced. The results on survey statements are presented in Table 15.2 and we got feedback from four students.

- **Statement 1**: My interaction of the tool was pleasant.
- **Statement 2**: My exploration in the virtual environment was easy.
- **Statement 3**: The tool is quite related with the objectives of the course.
- **Statement 4**: The tool will help me better understand the course material.
- **Statement 5**: Having the tool at my own computer and without the need of getting outside for sampling purposes or for taking pictures making helps me in my overall learning process.
- **Statement 6**: The tool offers a new and innovative learning experience.
- **Statement 7**: The use of such tools in more courses would make my university experience more interesting.

For the IoT part, students had to answer the following statement and the results are presented in Table 15.3.

- **Statement**: The tool is programmed to connect with IoT implementations (including sensors) and the data visualization can take place within its virtual environment and this can be triggered by your instructor. Thus, during the synchronous lectures you will be able to view the changes in real time on your computers.

Table 15.3 Survey results on the IoT-related statement

Participant	This will improve my overall learning experience	My learning experience will remain the same	I am not interested in this capability of the tool
Participant 1	✓		
Participant 2	✓		
Participant 3	✓		
Participant 4		✓	

In some comments the participants left, they suggested adding more 3D features like roads, rivers or more types of bushes and trees. Also, some other custom feature suggestions include more information on the types of plants or rocks. On the other hand, some problems they faced, had to do with some application crashes and slow player movement. This is explained by the fact that the tool is quite demanding in resources for graphics and some low-end computers may face difficulties in performance and thus, users may have a worse experience interacting with the tool than others. Further, despite having implemented a teleport system that moved the users to predefined locations, they requested an implementation that would freely move them in specific virtual coordinates by just placing the set of the needed coordinates. Lastly, since the drone system is a core element of the tool, some users suggested adding more views but smaller this time (2 m × 2 m and 4 m × 4 m).

Overall, as shown at the previous Tables 15.2 and 15.3 and the feedback we got from the students was really good revealing that gamification and IoT-enabled Triggers will definitely improve the overall student learning experience.

15.5 Conclusions and Future Work Conclusions

As we showcased, gamification can help both students and the academics in various ways. It can provide a really interactive and engaging environment for learning and at the same time, it provides the medium to teach or get measurements that would otherwise be a hard, dangerous or quite expensive task. In addition to this, the IoT offers the opportunity to get sensor measurements (or button indications in our case) that can be visually viewed (sensor data visualization) or can work as triggers, like our "IoTriggers". Using this IoT-enabled gamification approach, we showcased how it can be used effectively with a very positive impact in students' learning experience both in synchronous and in asynchronous learning context.

In the future, for the gamification part, we plan to further develop the 3D environment and add more elements like more kinds of plants and even animated animals created with the photogrammetry methodology. We also plan to include some student suggestions and include more information within this 3D space and add a new teleport system that will enable them to move freely just by entering values of the needed coordinates. Also, we will make some improvements towards performance and load the 3D elements more efficiently for low-end computers. Furthermore, we intend to create a Virtual Reality version of the tool for a full immersion. In terms of the IoT part, we are planning to start using the learning material aspect in a large scale adding a lot more gameObjects (like images) associated with the course curriculum. After doing this, we may use multiple IoT implementations that will be visualizing actual sensor data –and not just button triggers- installed on a real environment showing information like temperature and humidity.

References

1. J. Siegel, S. Krishnan, Cultivating invisible impact with deep technology and creative destruction. J. Innov. Manag. **8**(3) (2020)
2. J.B. Hauge, B. Pourabdollahian, J.C.K.H. Riedel, Workshop on the use of serious games in the education of engineers. Proced. Comput. Sci. **15**, 341–342 (2012). ISSN 1877–0509. https://doi.org/10.1016/j.procs.2012.10.098
3. S.L.C. D R Michael, *Serious Games: Games that Educate, Train, and Inform* (Muska & Lipman/Premier-Trade, 2005)
4. M. Ott, A. De Gloria, S. Arnab, F. Bellotti, K. Kiili, S. Freitas, R. Berta, *Designing Serious Games for Education: From Pedagogical Principles to Game Mechanisms*, vol. 2011 (2011)
5. L. von Ahn, Games with a purpose. Computer **39**(6), 92–94 (2006). ISSN 0018–9162. https://doi.org/10.1109/MC.2006.196
6. Y. Yang, Y. Asaad, Y. Dwivedi, Examining the impact of gamification on intention of engagement and brand attitude in the marketing context. Comput. Human Behav. **73**, 459–469 (2017). ISSN0747–5632.https://doi.org/10.1016/j.chb.2017.03.066
7. B. Wolfenden, Gamification as a winning cyber security strategy. Comput. Fraud Secur. **2019**(5), 9–12 (2019). ISSN 1361–3723.https://doi.org/10.1016/S1361-3723(19)30052-1
8. N. Lazzaro, *Why we Play Games: Four Keys to More Emotion without Story*. Game Dev Conf (2004)
9. J. Moizer, J. Lean, E. Dell'Aquila, P. Walsh, A.A. Keary, D. O'Byrne, A. Di Ferdinando, O. Miglino, R. Friedrich, R. Asperges, L.S. Sica, An approach to evaluating the user experience of serious games. Comput. Educ. **136**, 141–151 (2019). ISSN 0360–1315. https://doi.org/10.1016/j.compedu.2019.04.006
10. G. Pappas, P. Peratikou, J. Siegel, K. Politopoulos, C. Christodoulides, S. Stavrou, Cyber escape room: An educational 3d escape room game within a cyber range training realm, in *INTED2020 Proceedings, 14th International Technology, Education and Development Conference*. IATED (2020). ISBN 978–84–09–17939–8. ISSN 2340–1079, 2621–2627.https://doi.org/10.21125/inted.2020.0788
11. G. Pappas, J.E. Siegel, K. Politopoulos, Y. Sun, A Gamified Simulator and Physical Platform for Self-Driving Algorithm Training and Validation. (2021). https://doi.org/10.3390/electronics10091112
12. B. Walther-Franks, J. Smeddinck, P. Szmidt, A. Haidu, M. Beetz, R. Malaka, Robots, pancakes, and computer games: designing serious games for robot imitation learning. in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI '15. Association for Computing Machinery*, (New York, NY, USA, 2015). ISBN 9781450331456, 3623–3632. https://doi.org/10.1145/2702123.2702552
13. C. Weaver, The new driver's ED: Game developers teach Cruise's autonomous vehicles to understand gestures made by people on the street. IEEE Spectrum **57**(9), 32–37 (2020). ISSN 1939–9340 VO - 57. https://doi.org/10.1109/MSPEC.2020.9173901

14. S.R. Richter, V. Vineet, S. Roth, V. Koltun, *Playing for Data: Ground Truth from Computer Games* (2016)
15. A. Shafaei, J.J. Little, M. Schmidt, *Play and Learn: Using Video Games to Train Computer Vision Models* (2016)
16. K D, The Top 10 Video Game Engines (2020)
17. Unity. Unity3D, https://unity.com/
18. Unreal Engine, https://www.unrealengine.com/en-US/
19. GameMaker, https://www.yoyogames.com/gamemaker
20. Godot, https://godotengine.org/
21. CryEngine, https://www.cryengine.com/
22. J.E. Siegel, S. Kumar, S.E. Sarma, The future internet of things: Secure, efficient, and model-based. IEEE Internet Things J. (2017)
23. S. Tedeschi, J. Mehnen, N. Tapoglou, R. Roy, Secure iot devices for the maintenance of machine tools. In Procedia Cirp, vol 59. (Elsevier, 2017), pp 150–155
24. Office USGA, Internet of things: Enhanced assessments and guidance are needed to address security risks in DOD (2017)
25. A. Nordrum A, Popular internet of things forecast of 50 billion devices by 2020 is outdated (2016). (Dosegljivo, 2017). https://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-ofthings-forecast-of-50-billion-devices-by-2020-is-outdated [Dostopano:11 8 2017]
26. J.E. Siegel, CloudThink and the Avacar: Embedded design to create virtual vehicles for cloud-based informatics, telematics, and infotainment. Ph.D. thesis, Massachusetts Institute of Technology (2013)
27. S. Mayer, J. Siegel, Conversations with connected vehicles. In Internet of Things (2015)
28. J. Siegel, S. Krishnan, B. Subirana, S. Sarma, J. Merritt, L. Joseph, R. Arias, Realizing the internet of things: A framework for collective action. In World Economic Forum (2019)
29. J.E. Siegel, S. Kumar, Cloud, context, and cognition: Paving the way for efficient and secure IoT implementations. in *Handbook of Integration of Cloud Computing, Cyber Physical Systems and Internet of Things*. (Springer Switzerland AG, 2020)
30. J.E. Siegel, Data proxies, the cognitive layer, and application locality: enablers of cloud-connected vehicles and next-generation internet of things. Ph.D. thesis, Massachusetts Institute of Technology (2016)
31. J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami, Internet of things (IoT): A vision, architectural elements, and future directions. Fut. Gener. Comput. Syst. **29**(7), 1645–1660 (2013). ISSN 0167–739X. https://doi.org/10.1016/j.future.2013.01.010 Including Special sections: Cyber-enabled Distributed Computing for Ubiquitous Cloud and Network Services Cloud Computing and Scientific Applications ˆa Big Data, Scalable Analytics, and Beyond
32. G. Pappas, J. Siegel, K. Politopoulos, VirtualCar: Virtual Mirroring of IoT-enabled Avacars in AR, VR and Desktop Applications (2018)
33. J. Siegel, Cognitive protection systems for the internet of things. Homeland Defense Secur. Inf. Anal. Center J. **5**(4), 16–20 (2018)
34. J. Siegel, S. Sarma, A cognitive protection system for the internet of things. Secur. Privacy **17**(3) (2019)
35. J. Siegel, S. Sarma, Using open channels to trigger IoT's invited, unintended consequences. Secur. Privacy 17(3) (2019)
36. Y. Sun, A. Armengol-Urpi, S.N.R. Kantareddy, J. Siegel, S. Sarma, Magichand: interact with IoT devices in augmented reality environment In IEEE VR Workshop on Novel Input Devices and Interaction Techniques (2019).https://doi.org/10.1109/VR.2019.8798053,1738-1743
37. Y. Sun, S.N.R. Kantareddy, J. Siegel, A. Armengol-Urpi, X. Wu, H. Wang, S. Sarma, Towards industrial iot-ar systems using deep learning-based object pose estimation. in *2019 IEEE 38th International Performance Computing and Communications Conference (IPCCC)*. (IEEE, 2019, pp 1–8)
38. T. Mustapää, J. Autiosalo, P. Nikander, J.E. Siegel, R. Viitala, Digital metrology for the internet of things. In 2020 Global Internet of Things Summit (GIoTS). (IEEE, 2020)

39. B.T. Kumaravel, R. Bhattacharyya, J. Siegel, S. Sarma, N. Arunachalam, Development of an internet of things enabled manufacturing system for tool wear characterization. in *2017 IEEE 3rd International Symposium in Robotics and Manufacturing Automation (ROMA)*. (IEEE, 2017, pp 1–6)
40. J. Siegel, S. Pratt, Y. Sun, S. Sarma, Real-time deep neural networks for internet-enabled arc-fault detection. Eng. Appl. Artif. Intell. **74**, 35–42 (2018)
41. J. Siegel, Y. Sun, S. Sarma, Automotive diagnostics as a service: An artificially intelligent mobile application for tire condition assessment. In *Lecture Notes in Computer Science: Artificial Intelligence and Mobile Services (AIMS)* (2018)
42. B.E. Wiggins, An overview and study on the use of games, simulations, and gamification in higher education. Int. J. Game-Based Learn. (IJGBL) **6**(1), 18–29 (2016)
43. S. Subhash, E.A. Cudney, Gamified learning in higher education: a systematic review of the literature. Comput. Human Behavior **87**, 192–206 (2018). ISSN 0747–5632. https://doi.org/10.1016/j.chb.2018.05.028
44. A.P. Markopoulos, A. Fragkou, P.D. Kasidiaris, J.P. Davim, Gamification in engineering education and professional training. Int. J. Mech. Eng. Educ. **43**(2), 118–131 (2015). https://doi.org/10.1177/0306419015591324
45. K. Salen, EZ No Title. In rules of play: game design fundamentals, chapter Chapter 3: Meaningful play. (MIT Press)
46. E. Lelièvre, Research-creation methodology for game research. Working paper or preprint (2018)
47. S. Jesse, *The Art of Game Design: A Book of Lenses*. (AK Peters/CRC Press, 2014)
48. E. Zimmerman, *Play as Research: The Iterative Design Process* (2003)
49. M.A. Khan, K. Salah, IoT security: Review, blockchain solutions, and open challenges. Future Generation Computer Systems (2017). ISSN 0167–739X. https://doi.org/10.1016/j.future.2017.11.022
50. E. Torroglosa-Garc´ıa, A.D. P´erez-Morales, P. Martinez-Julia, D.R. Lopez, Integration of the OAuth and Web Service family security standards. Comput. Netw. **57**(10), 2233–2249 (2013). ISSN 1389–1286. https://doi.org/10.1016/j.comnet.2012.11.027
51. D. Guinard, V. Trifa, Building the Web of Things: With Examples in Node. Js and Raspberry Pi. Manning Publications Co., USA, 1st edn (2016). ISBN 1617292680
52. K. Afsari, C.M. Eastman, D. Castro-Lacouture, JavaScript Object Notation (JSON) data serialization for IFC schema in web-based BIM data exchange. Automation in Construction 77(Supplement C):24–51 (2017). ISSN 0926- 5805. https://doi.org/10.1016/j.autcon.2017.01.011
53. Google Stadia, https://stadia.google.com/, url = https://stadia.google.com/

Chapter 16
Communication-Driven Digital Learning Environments: 10 years of Research and Development of the Campus Platform

Luís Pedro and Carlos Santos

Abstract In this chapter we will underline the importance of communication concepts and affordances in the research and development of a digital learning environment, the Campus platform. We will argue that its overall design and features reflect a position that finds support in socioconstructivist and connective approaches to learning, approaches that value the social construction of knowledge, the importance of networks, collaboration and sharing. As its uses are very different from content-driven platforms such as the traditional Learning Management Systems, we will also defend that the active promotion of these features contributes to a redefinition of the knowledge construction process, namely in what self-regulated learning is concerned. Along the chapter we will present results of evaluation studies of the platform that allowed us to characterize it as an open communication ecosystem for effective dialogue, participation and engagement.

Keywords Campus · Technology · Digital media · Social media · Communities · Participation · Interaction · Engagement

16.1 Introduction

In educational and training contexts there is a clear opposition between the use of technologies that express a closed and atomized view of education and knowledge and technologies that put forward an open, social and holistic one. This on-going discussion epitomizes much of the discussion in the Educational Technology community in the past dozen years and indicates a tension [1] that is as related to technology as it is related to one's epistemological perspective of knowledge.

L. Pedro (✉) · C. Santos
Digimedia, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
e-mail: lpedro@ua.pt

C. Santos
e-mail: carlossantos@ua.pt

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_16

On the one hand, the use of Learning Management Systems (LMS) or other Virtual Learning Environments (VLE) outlines a particular educational and epistemological view. The use of these systems materializes some educational and knowledge construction practices that rely heavily on tight management and access control to content, on a compartmentalized organization of knowledge, and on the lack of widespread social and transdisciplinary discussion and interaction.

On the other hand, social media approaches are seen as technological proposals that may be used to promote concepts like openness, participation, collective intelligence and social interaction [2].

These opposing views result on different perspectives and practices regarding the way we learn, teach and, foremost, in the way we design technologies to be used in educational and training contexts.

We argue that Communication Sciences concepts have been absent from these discussions and that they bring to the conversation important contributions, namely in terms of the affordances of technology, i.e., how the design of technology can potentially determine the "action possibilities" [3] of educational agents.

We will explore and discuss these issues in the next sections, and while doing it we will contextualize the importance of some underlying concepts for the development of a social media platform designed for use in educational and training contexts: the Campus platform.

16.2 Learning as a Social Activity

The learning concept is not an easy one to grasp in all its complexity. Due to that multidimensionality, it has been the subject of a thorough discussion that crosses multiple scientific disciplines. It is easier, though, to discuss its current consensual definition. According to Illeris [4] all learning "comprises two simultaneous processes so that the learner does not experience them separately: an interaction process between learners and the social and/or material environment which provides them with some impressions and an acquisition process whereby these impressions are assessed, elaborated and taken in". Illeris [4] further elaborates this claim arguing that "all learning always comprises three dimensions: the content dimension, which is usually, but not always, cognitive; the incentive dimension, which includes engagement, interest and motivation and is mainly emotional; and the interaction dimension, which is social (also when it is a text, a picture, a film or the like) and may have many layers, ranging from the immediate situation, the local, institutional, environmental, national and other conditions to the global context in general".

This more consensual definition is very different from the initial learning theory proposals put forward during the first sixty years of the twentieth century. Those proposals conceptualized learning as essentially an individual activity in which meaning making (assimilation and accommodation), emotion and interactions were excluded.

The works of Ausubel, Bandura and other scholars definitely humanized learning, moving it away from the mechanical views of behaviourism and conceptualizing it as an experiential, social and contextual activity. Wenger [5] and Lave and Wenger [6] put it best when they defined learning as an interaction between meaning-making (experience), practice (doing), community (belonging) and identity (becoming).

The humanization of the learning concept contributed to some major advances in education, such as the acceptance of learning preferences, the assumption of the learner as an active constructor of knowledge and of importance of motivation and engagement (cf. [7] for more information on the latter).

From an epistemological standpoint, the view of the learner as an active constructor of knowledge is an important landmark. This view, summarized in the constructivist proposals of the 1960s that extended the cognitivist theories of learning, emphasizes the importance of "internal mental constructions and the influence of others on an individual's learning" [8]. This position is very relevant as it opens the door to a discussion of the importance of knowledge representations and meaning making that result from the interaction of the learner with the environment.

Social constructivism adds additional layers to these assumptions, bringing along a multifaceted view on what the environment really is. By doing so, learning is conceptualized as the process of internal knowledge representation and meaning making that results from the interaction of the learner with the social, cultural and media environment. Knowledge is then postulated as a mediated co-constructed representation in which the learner is an active participant when he engages in social and cultural interactions.

According to a systematic review of literature by Hill et al. [9], social learning constructs include context, culture and community and learner characteristics and every single one of these constructs can be applied in technological-mediated educational scenarios.

These mediated scenarios are to be found in the current digital age, as individuals use technology on a daily basis for communicate, access to information and learning.

New learning theories such as connectivism acknowledge this and put forward new perspectives on what learning really is. In the next section, we explore the connectivist approach, especially in what its connection with technology is concerned.

16.3 Learning as a Connective Activity

In his seminal work on connectivism, Siemens [10] states that "[t]he Achilles heel of existing [learning] theories rests in the pace of knowledge growth", as some of technologies' affordances are precisely the acceleration of knowledge dissemination, discussion and co-creation. By claiming the inadequacy of past learning theories to deal with the current pace and flow of knowledge creation, Siemens argues that the learner "offloads some of the processing and interpreting functions of knowledge flow to nodes within a learning network".

Connectivism appears publicly in the beginning of the 00 s decade and puts forward a perspective on knowledge and learning that assumes that knowledge “resides in the collective” [10] and that learning is more than a knowledge acquisition activity, being the ability to form personal networks between resources (nodes) that are available in the environment. These new learning ecologies assume that technology has a vital role in the creation, redesign and repurpose of the learner’s personal network, as knowing where and knowing who are suddenly more important that knowing how and knowing what.

This perspective is commonly regarded as a deepening of socioconstructivist theories of learning as it argues that learning is a user-centric, distributed and knowledge-pull activity and that technology performs a role of augmentation of learners’ social and collaborative skills, hosting and enabling an environment where people, practices, values and technologies ecologically connect [11].

This perspective actually reflects current positions on learning and knowledge creation that are broadly subsumed as emergent learning practices, i.e., “learning which arises out of the interaction between a number of people and resources, in which the learners organise and determine both the process and to some extent the learning destinations, both of which are unpredictable. The interaction is in many senses self-organised, but it nevertheless requires some constraint and structure. It may include virtual or physical networks, or both” [12].

The network concept is paramount in the connectivist approach. The knowledge construction process is conceptualized as a flow that establishes connection through a network that includes nodes that can be other individuals, communities, resources or technologies. These networks are, in turn, both internal and external to the individual, i.e., they are external as they can subsume entities (nodes) that do not reside in the learner, but they are also internal as learning is a process of creating connections and patterns of understanding in the learner’s mind [13].

These claims, however, did not go without criticisms. Bell [14] points out very clearly some of those issues and summarizes her approach by claiming that connectivism is insufficient both as a learning theory and as a perspective regarding human activity within our current sociotechnical environment. Gros [13] also argues that other theories, such as the Actor-Network Theory by Latour or theories that are more focused on social-personal interaction processes (such as andragogy, heutagogy or peeragogy) propose a better integration between the social, natural and technological dimensions of learning. This association between technology and learning has also been extensively studied in the context of self-regulated learning. Several studies report that the increase use of online environments in the context of formal and informal learning activities should include a reflection self-regulating learning skills by the students as “the control of learning is shifted from the educational institutions and cultures to the individual—often isolated—learner [15]”.

So, what is exactly this sociotechnical environment that shapes much of our daily activities? Nowadays, the idea of technology as a medium has been replaced by the idea of technology as a platform, one where knowledge is created, shared, remixed and repurposed [11]. Technology is, then, an enabler of personal knowledge ecologies [12] and an ever-evolving learning environment.

16.4 Technology as (the) Learning Environment

Humans have always used technologies to learn [8]. However, as Gros [13] states, technology is now pervasive and ubiquitous and is not seen any more as something external to the learning process. Technology is now both the enabler and the context where learning takes place and that is a major difference in terms of its role and potential affordances.

This dual role of technology is self-evident in the concept of Personal Learning Environments (PLE). PLE are conceptualized as both a learning approach and a technological system or, as Casquero et al. [15] propose, "a mainstream pedagogical and technological concept that is supposed to enable (…) education institutions to adopt and adapt the patterns learned from Web 2.0 and social media in order to fit into the new networked and learner-centered model of learning".

This merging role of technology implies that these tools both frame and afford the emergence of educational approaches that are user-centric, dynamic and flexible and of new roles both for learners and teachers more focused in participation, interaction and engagement.

The aforementioned concepts—participation, interaction and engagement—are important concepts in the realm of Communication Sciences and Technologies but are also processes that are (re)gaining importance in the context of education. As Halverson argues, there is an emerging bond between the evolution of cognitive and sociocultural views on knowledge and learning and the design of learning environments [16].

Although the interchanges between these two fields are, sometimes, affected by siloed research agendas, in a knowledge-based society they share far more than admitted.

The first common concept that is relevant to clarify due to its two folded use in the fields of communication and education is related to the difference between technology and media. Although these two terms are often used interchangeably, Bates [17] distinguishes them by arguing that technologies are tools or systems that carry a message while media implies intermediation and interpretation, i.e., require an active act of creation and activation by its users. To put it briefly, "media depend on technology, but technology is only one element of media" [17].

In this line of thought, it is important to underline that, contrary to technologies, media are not neutral as they mediate communication and convey subjective symbols, beliefs and choices. We will revisit this topic in the next section, contextualizing it within the choices that were made in the development of the Campus platform.

The second concept that is important to define is the concept of participation. Participation can be defined as a social act or process initiated by individuals and one that, in the context of learning communities, supports their discourse, their social presence and their sense of belonging to a larger whole [18]. But as important as the social dimension, participation also has a very strong cultural dimension. Jenkins [19] defines a participatory culture as "one in which members believe their contributions matter and feel some degree of social connection with one another".

Being a relevant human capability, participation is sometimes confused with interaction. However, much like the aforementioned distinction between technologies and media, interaction depends on participation, but participation is only a part of interaction. In a common dictionary, interaction is defined as a situation in which two or more entities act upon one another to produce a new effect and, as so, it implies additional layers of mediation and intersubjectivity that we seldom encounter on a simple participation.

Both concepts are clear social affordances of most technologies used nowadays, be it in the form of quick reactions that signal our participation in a group or community, be it in the form of more elaborated kinds of interaction that may vary from one-to-one, to one-to-many and many-to-many interaction patterns [20].

Finally, a concept that is both used in the Communication and Education fields is the concept of engagement. Engagement is defined by Kahu [21] as an overarching meta-construct that has evolved and encapsulates a more intrinsic and individual perspective and a more external and socio-cultural perspective. From a communication standpoint engagement implies communication, agency and bidirectionality. From an educational standpoint, student engagement is defined as "(…) a psycho-social process, influenced by institutional and personal factors, and embedded within a wider social context (…)".

All these concepts—participation, interaction and engagement—are believed to be promoted by current technologies/media as they emphasize the importance of user-driven approaches to learning, of creating networks and interacting with peers and of actively collaborating in learning and societal challenges.

A rising body of research expresses positive results of the application of social media in educational contexts (see Garrison and Anderson [19] for a comprehensive review on the subject). There is, however, an important issue that crosses these studies: typically, the application of these media is teacher-driven and teacher-pushed and it is implemented with technologies that are outside the technological offers of educational institutions.

This issue is not new and several authors [15, 22] have signaled this apparent paradox. New learning approaches promote students-pulled learning environments, which explore social affordances (such as the creation of networks, massive participation and interaction) of media and are controlled and configured by the students themselves inside a siloed, institutional and teacher-driven technological culture.

In the next sections we present the Campus platform as our response to this conundrum, tracing the rational of its evolution since 2010.

16.5 Campus: A Social Media Platform for Learning

Back in the end of the 00 s decade, the process of providing and promoting the use of social media in institutional environments—largely configured by tight control and supervision of educational practices—was a challenge.

Although several authors advocate that the adoption of social media can be instrumental in reconceptualizing the main principles underlying teaching and learning, there is a known natural inertia and resistance to change in educational institutions that has to be taken into account (see [23] for a thorough discussion on this topic).

This contributes to the known phenomenon of "adding" instead of "integrating" technologies in the learning environment [23], a phenomenon that highlights the mismatch between the students' typical open culture and the resistance to change that builds on the natural inertia of educational institutions agents, practices, procedures and technologies.

One underlying cause for this inertia is the existence of different perspectives on openness. Some studies argue that students use open technologies in their everyday life, choosing and naturally changing them according to their interests, and as a result of the free choices made by informal (interest, practice and/or learning) communities in which they are integrated (cf. [24, 25]). According to those studies students also tend to privilege freely accessible content, aggregating, participating and following sources that provide free and reusable information. Educational institutions are typically slow in their reaction to these emergent needs and the implementation of technologies that answer these patterns "represent a complex challenge in terms of institutional culture and structure" [15].

One other underlying cause for this resistance to change is more profound and is related with different views on the nature of knowledge, i.e., it is an epistemological issue.

The opposition between technologies that embody a close and atomized view of education and knowledge and, on the other hand, technologies that put forward an open, social and holistic one epitomizes much of the current discussion in the EdTech community of, at least, the past 10 years.

The use of Learning Management Systems (LMS), for instance, outlines a particular educational and epistemological view. The use of these systems materializes some educational and knowledge construction practices that rely heavily on tight management and access control to content, on subject matter and compartmentalized organization of knowledge, and on the lack of widespread social and transdisciplinary discussion and interaction. Being closed systems that only grant access to current students through strict authentication rules, LMS also seem to endanger important enterprises such as Lifelong Learning that is promoted by open access to open content.

On the other hand, social media are seen as a set of tools that promote concepts like openness, participation, collective intelligence and social interaction. As stated by Casquero et al. [15], despite many LMS "support the affordances of Web 2.0 and social media with more or less success, many users would be reluctant to abandon the external web services they are already using because they see them as more innovative or because they are connected to their own communities or personal networks through them".

As stated in the previous section, PLE were emerging in the turn to the 10 s decade as a way to bring together these "two separate and loosely connected spheres: the

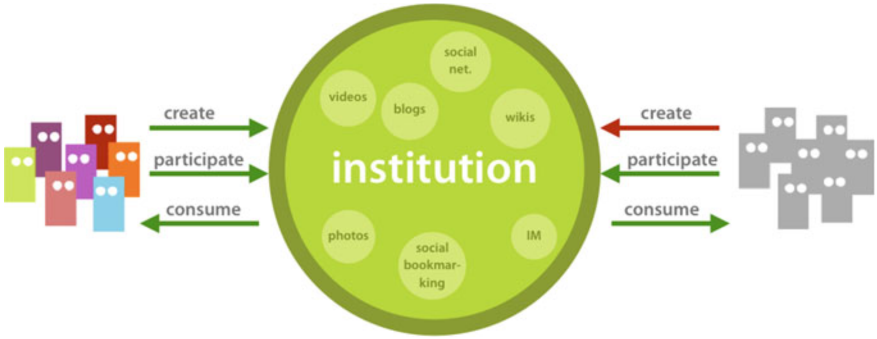


Fig. 16.1 Conceptual diagram of the Campus platform in 2010

institutional and the personal one" [15]. So, between 2009 and 2010, the Campus platform was designed and launched as a platform comprised of several Web 2.0 services and a dedicated tool to support the construction of an institutionally supported PLE. From a conceptual point of view, the platform could be seen as a Web 2.0 platform whose primary objective was the promotion of concepts such as openness, sharing and collaboration. Upon an independent and open set of social core services (photo and video sharing, blogs, wiki, social bookmarking) lied a set of aggregation services (RSS reader, portfolio, assessment, presence manager) integrated in a widget-based platform that provided a core technological framework to build an institutionally supported PLE (Fig. 16.1).

With this design the platform tried to balance and compromise institutional concerns and responsibilities with an open, personal and social learning experience.

As discussed earlier, the adoption of this technological solution required that institutions (in our case, the University of Aveiro) showed some flexibility to change some of their control and supervision policies in the usage of technological tools and services. Among them were, for instance, hierarchy policies. In the Campus platform all users in the community were equal and shared the same privileges. This approach ensured that every user could access the same type of services as well as the same type of data. One important result from this assumption was that change-tracking mechanisms could not exist in this non-hierarchical digital community, thus ensuring user privacy.

In this line of thought, core services were open and free to all the community, without prior requirements or bureaucracies. All content was open to people outside the institution and, by default, non-registered users were able to participate and get involved in discussions. This wide-open consumption and participation of (and in) core services meant everyone, everywhere, could view and talk about content, tearing down the metaphorical walls that typically surrounded the institutional space.

This first version of the platform is still available but had quite a few limitations.

Its authentication mechanisms, for instance, were integrated with core technological services of the University of Aveiro and its use by other educational institutions implied a major architectural revision. In terms of user experience, although the

PLE component of the platform was clearly user-driven, there was a clear mismatch with the service-driven experience that users had of the integrated Web 2.0 services. Finally, the platform was clearly designed for use in higher education institutions what caused an obvious problem of scalability.

In these two years, besides the design and development of the platform, the delivery of research documents was also a clear goal of the team. In this phase, two master's degree dissertations were developed, related to the specification, development and assessment of specific features within the overall development of the platform [26, 27].

We always adopted a vision that the platform should be continuously updated through an iterative and user-driven participatory design development process, based on the feedback of the community, the involvement of graduate students in the development team and the inputs from our funding partner (SAPO). This led to an important decision, in 2011, to begin a major redesign of the platform.

That redesign was organized around three main ideas: develop a platform that could be used by educational institutions of all levels, improve the overall user experience of the platform with an evolution towards a social network approach, and develop new services (such as a gamification tool, a portfolio tool, and a user and content recommendation system) that the research in the field was suggesting as relevant in educational platforms.

The development process of the version 2 of the platform took around 18 months as a major technical overhaul was made in terms of the technologies used. These technologies supported an also major interface redesign, more user-centered and based in the newsfeed metaphor of other social media applications and very strict privacy rules that resulted from the decision of making the Campus platform available for all teaching levels.

With the support of our funding partner, the launching of the platform occurred in 2013 in a limited format, for 5 selected school clusters. This controlled launching allowed us to test the platform with actual users and collect valuable data that would be used to make important updates before the public launching of the platform. This version already featured a gamification tool (see Costa [28] for more information on the decision-making process in this tool) and other relevant tools such as user recommendations, support for the creation of groups and file storage (Fig. 16.2).

Once more we carried on with a quite intensive research agenda while developing the platform between 2011 and 2014. In this timespan a total of seven master's dissertations were developed, whose themes ranged from the validation of the gamification tool and the recommendation system integrated in the platform to impact studies related to the appropriation of the platform in vocational learning [29–32].

The Campus platform was now available to all educational levels and contexts. Its main purpose remained the support to the natural interaction that occurs inside and beyond the classroom walls, allowing the development of a sharing and collaborative environment between the community. Campus' users had its personal area where the content they have published is automatically aggregated. Each user had the possibility to follow other users, establishing a connective network based on common/shared interests and enabling a connective knowledge construction.

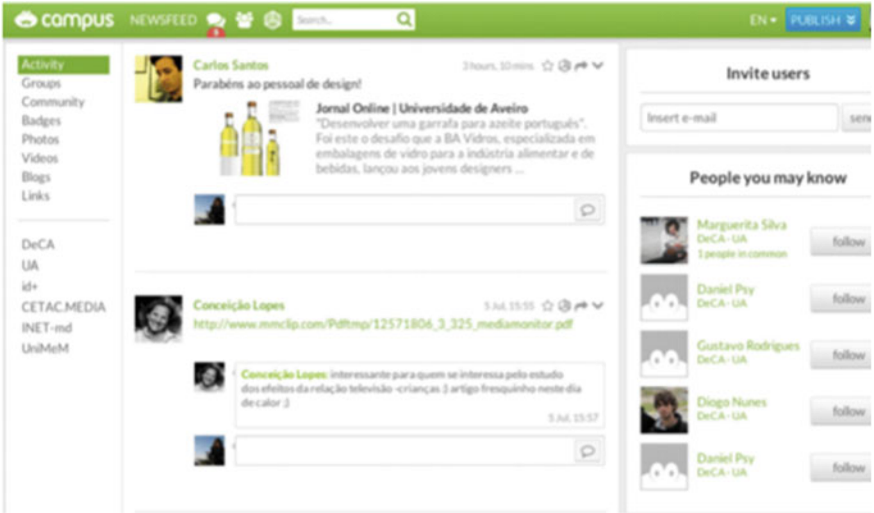


Fig. 16.2 Newsfeed page of the Campus platform in 2013–14

The content shared by the platform's users was automatically aggregated and displayed on the school's newsfeed area, where the user could also access recommendations, notifications and favorite content. This social dimension was always a major part of the platform, thus, beyond the possibility of following other users' activity and access the content they're publishing, Campus' users had also the possibility to integrate and create groups based on their interests. These groups or communities are composed of a number of people sharing the same objects or desires, governed by rules and usually divide tasks among their participants. The interaction created around the groups of users with similar interests has the potential to join motivated individuals aiming to achieve their goals through collaboration and sharing. With these core principles, the Campus platform opens up the possibility of creating different groups based in different interests, where each user is able to establish different connections with different purposes, intensities and goals.

The public launching of this version and the interaction with the platform user's community allowed us to begin a new and different phase regarding its development. This phase was more focused in collecting data from the different profiles of users (teachers, students of all education levels, parents, educational community) that allowed us to surgically update some of the platform's features and overall performance.

This was the case, for instance, with the gamification tool.

Several authors were reporting in the beginning of the 10 s decade that the strengths of gamification and schools could be complementary and that bringing education and game elements together could lead to results that were especially important to develop twenty-first century skills [33–36].

These authors argued that the application of game elements in educational contexts could motivate and engage learners and give teachers better tools to guide and reward students [33]. Badges, particularly, were seen as a game element that "allow users to view their achievements compared to those of others in the same community—also creating a sense of belonging to a similar minded group and competition among them" [34].

Taken these growing body of research into account, the Campus team developed and implemented a badging system supported by the Mozilla Open Badges technology and comprising two main types of attribution: a manual attribution system and an automatic attribution system.

In the manual attribution system school members were able to create badges and some pre-designed badges were already available for members to use.

To make possible the creation of badges a badge creation tool with a set of elements (frames, backgrounds and images) was created, which allowed different combinations (Fig. 16.3). Hence, the platform user could customize and adjust the badge to the context in which is being used.

Beyond the possibility of creating badges, the platform also provided a set of predefined badges that could be used by the institutions. Each badge represented a challenge that should be overcome by users in order to earn that badge. Our main goal was to connect the formal and informal activities occurring in the schools with

Fig. 16.3 Campus platform Badge creation tool

the Campus digital environment, thus promoting challenges that tested and rewarded users' mastery and proficiency in both activities occurring in school (for instance: participate in or win a poetry contest) as within the platform (for example: share the best picture of the school).

This automatic system for badges attribution was implemented as a challenge-based introductory tutorial that aimed to lead the user to explore the main areas and functionalities of the platform. The tutorial was composed of two major challenges: explore and socialize. To earn the first badge (explorer badge), the user had to visit and explore the main areas of the platform: the school page, the newsfeed, his profile page and the settings area. In order to earn the second badge (socializer badge), the user had to visit the profile, follow and mention at least one user and make at least one comment, beginning, in this way, the development of its own network based on his personal interests.

The automatic badge feature was abandoned as a result of several tests with users and the manual badge attribution became a staple of the platform (see [2, 37, 38] for more information regarding its evolution and testing).

A quite intensive research agenda was also pursued. While continuously developing the platform between 2014 and 2018, a total of 2 PhD thesis [39, 40] and one master's dissertation [41] were developed. One of the PhD thesis was particularly relevant. It was the PhD thesis of the main responsible for the conceptualization and development of the platform and encapsulated, at the time, eight years of research and development of the Campus platform [39]. During this period the development of the platform was also tested by the change of our funding partner, SAPO. This private company was very important to the project since its beginning and the idea of the Campus platform as a research and development project outside its immediate control is a sure test of the vision, boldness and unconditional support of its Executives.

From 2018 until now a third version of the platform was developed. The main objective underlying the development of this version was a mobile-first concern, echoing the growing importance and use of mobile access to educational technologies.

While maintaining its core blueprint as a customizable social networking platform solution focused on collaboration, sharing and communication, this new version is characterized by a tenant-oriented architecture to create new platforms and a reusable infrastructure and technology that allows an independent product page and modular features for each platform, preserving all privacy control for communities, groups and users.

This multi-tenant approach can be seen in the launching of new services that leverage the principles of the platform and apply them to new contexts, such as bringing together the Portuguese research diaspora in a common platform [42] and creating digital communities to elderly citizens (miOne community—https://mione.altice.pt).

It is available since 2019 and is being used by schools, private foundations and research projects as a tool that carries on with the same objectives it had more than ten years ago: to answer the communication and collaboration needs of the learning and research communities, guaranteeing the privacy of the publications that are shared and facilitating the teaching and learning process through a diverse set of tools, including social and multimedia features such as blogs, files, videos, photos, chat and task management tools.

Research-wise, the development team has recently three more master's dissertations, focusing in new areas of research and development within the platform: exploring a chat system with intelligent cyberbullying detection services and features [43], a tool that allows the creation of content pages inside communities [44], a global redefinition of the gamification strategy environment in order to meet the specific needs of the Campus multi-tenant approach platform and its diverse online communities [45] and an upcoming work related to the development of a tool for smart reactions, connecting artificial intelligence and interfaces in order to promote more and better interaction between users and content.

16.6 A Brief Overview of the Evaluation of the Platform

As a research and development project, the Campus platform has been subject to different kinds of evaluations in these past 10 years. In terms of scientific areas, most of the research produced was in the area of Communication Sciences and Technologies, although some of the research projects are to be traced in the areas of Educational Technology and Marketing (Fig. 16.4). This is an important feature. The Campus platform has always welcomed different and complementary research approaches that could make it better in terms of being a more solid (communication) product but also to be more adequate to its target area (Education).

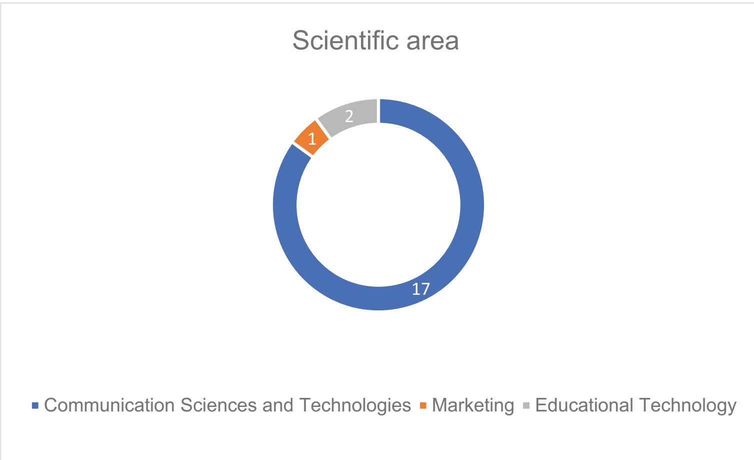


Fig. 16.4 Campus platform: research projects by scientific area

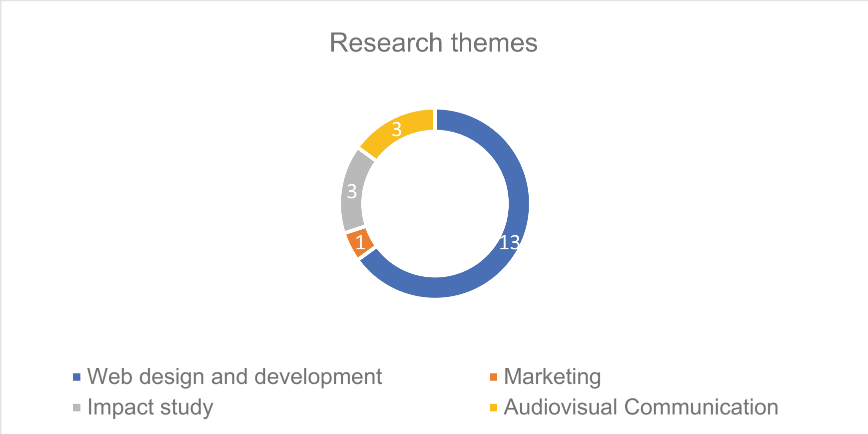


Fig. 16.5 Campus platform: research projects by research theme

In what research themes are concerned there is a relevant focus on Web design and development (Fig. 16.5). Educational media are, in the twenty-first century, Web products and a great deal of their research and development is dedicated to design good learner experiences to its users. However, we should also underline the importance of the impact studies that were conducted. These studies were longer than the others and tested the platform's adoption and appropriation by teachers and students of different teaching levels. Other research focused on digital marketing themes and audiovisual communication and were related to the dissemination strategy of the platform.

In terms of research typologies, the predominant type of research was framed by development-driven MSc research, followed by longitudinal funded research projects and PhD-related work (Fig. 16.6).

Finally, in Fig. 16.7 we can see that there was always some kind of research that was being developed with the platform since 2009. This is a strong indicator that the overall rational of the Campus platform is research-driven and that a good balance was achieved with its product side.

16.7 Conclusions

In this chapter we presented and discussed relevant communication concepts that nowadays are seen as essential when discussing education in a digital age. Participation, interaction and engagement are seen as important processes as learning is increasingly acknowledged as a social and connective activity and in which digital learning environments, and namely social media, are an integral part of the learner's knowledge network ecologies.

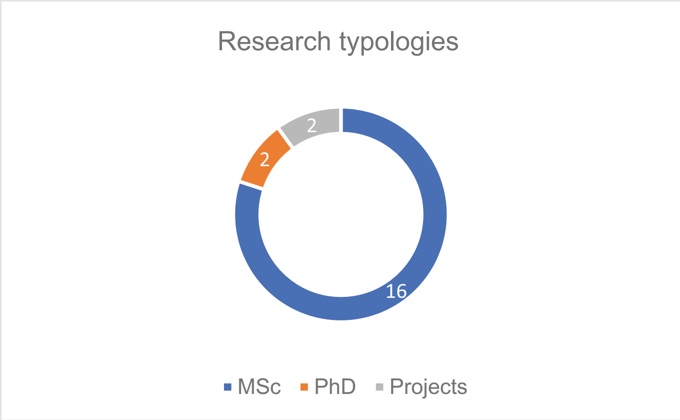


Fig. 16.6 Campus platform: research projects by research type

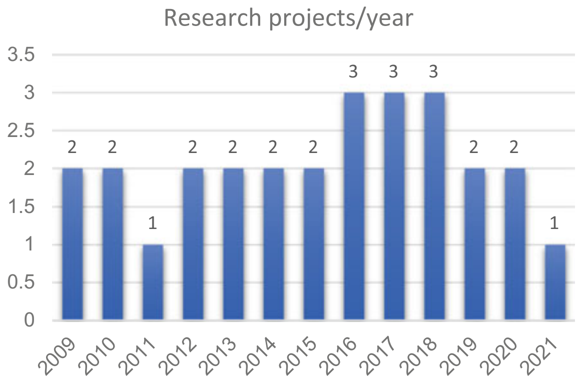


Fig. 16.7 Campus platform: research projects by year

Social media are an important feature in today's learning environments and according to Spector [46] they provide a space for the formation of communities, interaction with peers and a seamless integration of informal, non-formal and formal educational communities.

More importantly, we described, in some detail, the research and development of a social media platform—Campus—since the end of the 2000 decade until 2020. The platform began as a blend of Web 2.0 services and a PLE tool and evolved to a social media tool with institutional support for use in all educational levels.

The successive versions of Campus not only reflected the evolution of technology but, most of all, the evolution of the practices of its users. A few major changes can be signaled. One important change is related to a temporal dimension of learning that technologies tend to resgnify. The admission that constructive debate, conflict and discussion are relevant learning strategies and that they can happen anytime and anywhere are a powerful affordance of technology. The monitoring of the use of synchronous and asynchronous communication features of the Campus platform taught us exactly that. Some of the most dynamic and participated activities that occurred in the platform took place on weekends or way beyond regular school hours. One other relevant change is related to the use of technology to form groups and the importance of the interactions that occur in these groups. A growing body of research shows that students tend to participate more in social media groups that in institutional LMS (see [47] and [48] for a review on this issue). The fact that the Campus platform made available a tool to create groups, respecting privacy and security in an institutional environment for all education levels reflected this trend. Finally, the evolution towards mobile access to contents and discussions, the idea of quick publishing and acknowledges and of the use of gamified strategies in the learning process were also educational trends that the literature mentioned, that our user community demanded and that were included in the platform.

We are now, for the worst reasons, witnessing the importance of these features as teachers and students try to navigate a distance education scenario imposed by the covid-19 pandemic. More importantly than ever, digital learning environments are now a tool that must empower educational agents to proceed with learning activities, connecting users and communities and giving them all the opportunities to communicate, interact and (socially) construct knowledge.

As we reflect on this journey, besides the gratitude towards everyone that worked on the project, we have a clear notion that this is (always) an unfinished body of work. As the use of the platform by the platform's users evolve, so must evolve the ways in which we acknowledge that, the way we research and develop solutions and the ways in which the platform must transform itself to serve its users.

Acknowledgements The authors would like to express their gratitude to all Campus team members since the beginning of the project in 2008. This platform is a reflection not only of their commitment but also of their shared goal of improving educational technology and make it available to the larger public. We sincerely hope that we have not forget anyone on this (alphabetic) list: Alexandre Gamelas, Alexandre Neves, Bruno Abrantes, Carlos Silva, Catarina Silva, Cátia Amador, Daniel Rodrigues, Dinis Simões, Fábio Maricato, Firmino Alves, Francisco Regalado, Guilherme Cabral, Hadi Zadeh, Helder Santos, Henrique Silva, Hugo Silva, Inês Araújo, João Abreu, João Brandão, João Campos, João Freitas, João Pina, Jorge Braz, José Cunha, José Dias, José Mário Seabra, José Pedro Saraiva, Liliana Vale, Luís Couto, Miguel Antunes, Nuno Simaria, Paulo César, Pedro Correia, Pedro Figueiredo, Ricardo Martins, Rodolfo Costa, Sara Almeida, Sónia Machado, Tânia Pires, Tiago Almeida, Tim Koch-Grunberg and Vasco Silva. We would like also to acknowledge David Oliveira, Fátima Pais and Mónica Aresta as researchers that helped us so much in the assessment and development of the platform. Finally, we want to thank our funding partners throughout these years represented by Benjamin Junior (SAPO), Celso Martinho (SAPO), Bernardo Cardoso (Altice Labs), Paulo Garcez (Fundação Altice) and FCT.

Thank you all for being part of the family!

References

1. M. Weller, The centralisation dilemma in educational IT. Int. J. Virtual Personal Learn. Environ. **1**(1), 1–9 (2010)
2. L. Pedro, M. Aresta, C. Santos, S. Almeida, Peer-supported badge attribution in a collaborative learning platform: the SAPO Campus case. Comput. Hum. Behav. **51**, 562–567 (2015)
3. D. Norman, *The Design of Everyday Things* (Basic Books, New York, 2013)
4. lleris, An overview of the history of learning theory. Eur. J. Educ. **53**(1), 86–101 (2018)
5. E. Wenger, *Communities of Practice: Learning, Meaning and Identity* (Cambridge University Press, Cambridge, MA, 1998)
6. J. Lave, E. Wenger, *Situated Learning: Legitimate Peripheral Participation* (Cambridge University Press, New York, NY, 1991)
7. K. Renninger, S. Hidi, *The Power of Interest for Motivation and Engagement* (Routledge, London, 2016)
8. R. Huang, J. Spector, J. Yang, *Educational Technology: A Primer for the 21st Century* (Springer Nature, Springer, 2019)
9. J. Hill, L. Song, R. West, Social learning theory and web-based learning environments: a review of research and discussion of implications. Am. J. Distance Educ. **23**(2), 88–103 (2009)
10. G. Siemens, *Knowing Knowledge*. Lulu.com (2006), ISBN: 978–1–4303–0230–8
11. M. Chatti, M. Jarke, D. Frosch-Wilke, The future of e-learning: a shift to knowledge networking and social software. Int. J. Knowl. Learn. **3**(4/5), 404–420 (2007)
12. R. Williams, R. Karousou, J. Mackness, Emergent learning and learning ecologies in Web 2.0. Int. Rev. Res. Open Distance Learn. **12**(3), 39–59 (2011)
13. B. Gros, The dialogue between emerging pedagogies and emerging technologies. Eds. By B. Gros, M. Kinshuk, *The future of ubiquitous learning: lecture notes in educational technology*. (Springer, Berlin, Heidelberg, 2016). https://doi.org/10.1007/978-3-662-47724-3_1
14. F. Bell, Connectivism: its place in theory-informed research and innovation in technology-enabled learning. Int. Rev. Res. Open Dist. Learn. **12**(3), 98–118 (2011)
15. H. Fournier, R. Kop, G. Durand, Challenges to research in MOOCs. J. Online Learn. Teach. **10**(1), 1 (2014)
16. O. Casquero, J. Romo, M. Benito, R. Ovelar, Participation and interaction in Learning Environments: a whole-network analysis. *Utilizing Virtual and Personal Learning Environments for Optimal Learning*. IGI Global, 111–131 (2016https://doi.org/10.4018/978-1-4666-8847-6.ch006
17. E. Halverson, Participatory media spaces. Eds. by C. Steinkuehler, K. Squire, & S. Barab *Games, Learning, and Society: Learning and Meaning in the Digital Age (Learning in Doing: Social, Cognitive and Computational Perspectives)* (Cambridge University Press, Cambridge, 2012), pp 244–268. https://doi.org/10.1017/CBO9781139031127.020
18. A.W. Bates, *Teaching in a Digital Age: Guidelines for Designing Teaching and Learning* (University of British Columbia, BCcampus, 2019)
19. D. Garrison, T. Anderson, *E-Learning in the 21st Century: A Framework for Research and Practice* (Routledge Falmer, London, 2003)
20. H. Jenkins, R. Purushotma, K. Clinton, M. Weigel, A. Robison, *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century* (John D. and Catherine T. MacArthur Foundation, Chicago, 2009)
21. J. Dron, T. Anderson, *Teaching Crowds: Learning and Social Media* (AU Press, Athabasca University, Edmonton, AB, 2014)
22. E. Kahu, Framing student engagement in higher education. Stud. High. Educ. **38**(5), 758–773 (2013). https://doi.org/10.1080/03075079.2011.598505
23. C. Santos, L. Pedro, Campus SAPO: promocionar la idea de PLE con tecnologías sostenidas desde las instituciones. eds. by L. Castañeda y, J. Adell, *Entornos Personales de Aprendizaje: Claves para el ecosistema educativo en red*. (Alcoy, Marfi, 2013), pp 161–165

24. W. Lim, H. So, S. Tan, eLearning 2.0 and new literacies: Are social practices lagging behind? Interact. Learn. Environ. **18**(3), 203–218 (2010). https://doi.org/10.1080/10494820.2010.500507
25. A. Couros, Developing personal learning networks for open and social learning. eds. by G. Veletsianos, *Emerging Technologies in Distance Education.* (Edmonton, AB, AU Press, Athabasca University, 2010), pp 109–128
26. S. Wheeler, Open Content, Open Learning 2.0: Using Wikis and Blogs in Higher Education, in *Changing Cultures in Higher Education.* ed. by D. Ehlers, D. Schneckenberg (Springer-Verlag, Berlin, 2010), pp. 103–114
27. B. Abrantes, *Concepção e desenvolvimento de um ambiente de aprendizagem pessoal baseado em ferramentas WEB 2.0: estudo de caso da plataforma SAPO Campus.* Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2009). http://hdl.handle.net/10773/1221
28. R. Costa, *Implementação de mecanismos de avaliação da participação online: um estudo na plataforma SAPO Campus.* Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2009). http://hdl.handle.net/10773/1230
29. Santos, C., Almeida, S., Pedro, L., Aresta, M., Koch-Grunberg. T. (2013). Students' perspectives on badges in educational social media platforms: The case of SAPO Campus tutorial badges. In *Proceedings of the IEEE 13th International Conference on Advanced Learning Technologies.* China: Beijing, pp. 351–353.
30. A. Neves, *E-portefólios para a gestão da identidade digital: estudo de caso da plataforma Sapo Campus Escolas.* Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2011). http://hdl.handle.net/10773/6200
31. T. Koch-Grünberg, *Gameful connectivism: social bookmarking no SAPO Campus.* Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2011). http://hdl.handle.net/10773/7506
32. F. Alves, *Sistema de recomendações no SAPO Campus: desenvolvimento e avaliação.* Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2013). http://hdl.handle.net/10773/12312
33. D. Oliveira, *A apropriação das ferramentas de uma rede social pelos alunos: um estudo com o SAPO Campus.* Master dissertation in Multimedia in Education. University of Aveiro, Aveiro, 2013). http://hdl.handle.net/10773/12301
34. J. Lee, J. Hammer, Gamification in education: what, how, why bother? Acad. Exchange Quart. **15**(2), 146–151 (2011)
35. S. O'Donovan, *Gamification of the Games Course, CS12–04–00.* Technical report of the Department of Computer Science, University of Cape Town (2012)
36. F. Groh, Gamification: State of the art, definition and utilization. *Proceedings of the 4th Seminar on Research Trends in Media Informatics*, ed. by. N. Asaj et al. (Ulm University: Institute of Media Informatics, 2012), pp 39–46
37. E. Knight, C. Casilli, Case Study 6: Mozilla Open Badges, in *Game Changers: Education and Information Technology.* ed. by D. Oblinguer (Educause Publications, Educause, 2012), pp. 279–284
38. I. Araújo, C. Santos, L. Pedro, J. Batista, An analysis of the use of badges in the SAPO Campus platform: the perspective of communities' administrators. Revista Lusófona de Educação **41**, 83–98 (2018)
39. I. Araújo, C. Santos, L. Pedro, J. Batista, Digital Badges on Education: Past, Present and Future. in ed. by. A. Skarzauskiene, N. Gudeliene, *Proceedings of the 4th European Conference on Social Media (ECSM 2017).* (Sommon Common, UK, 2017), pp 27–35
40. C. Santos, *Estudo, concepção e desenvolvimento de uma plataforma integrada de serviços Web 2.0 para utilização em contextos de ensino superior*. PhD thesis in Information and Communication in Digital Platforms. (University of Aveiro, Aveiro, 2016). http://hdl.handle.net/10773/18603
41. M.F. Ferreira, *SAPO Campus: aprendizagem, ensino e pessoas em rede.* PhD thesis in Multimedia in Education. (University of Aveiro, Aveiro, 2016). http://hdl.handle.net/10773/15855

42. G. Cabral, *Exportação de dados para análise de redes sociais: implementação e avaliação de uma ferramenta*. Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2016). http://hdl.handle.net/10773/17802
43. J. Marques, G. Bressan, C. Santos, L. Pedro, D. Marçal, R. Raposo, Investigating the potential of data from an academic social network (GPS). in ed. By. O. Gervasi et al. *ICCSA 2020. Lecture Notes in Computer Science*, vol 12249. (Springer, Cham, 2020). https://doi.org/10.1007/978-3-030-58799-4_55
44. V. Silva, Campus Chat: deteção de emoções e sua aplicação em plataformas digitais de contexto educativo. Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2019). http://hdl.handle.net/10773/30074
45. M. Antunes, Integração de funcionalidades de CMS numa rede social para ambiente educativo: o Campus. Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro, 2019). http://hdl.handle.net/10773/28562
46. J.H. Silva, (in press) Gamification for all em ambiente multi-tenant: o caso das plataformas Campus by fundação Altice e miOne. Master dissertation in Multimedia Communication. (University of Aveiro, Aveiro)
47. J. Spector, *Foundations of Educational Technology: Integrative Approaches and Interdisciplinary Perspectives* (Routledge, New York, 2015)
48. S. Manca, M. Ranieri, Is Facebook still a suitable technology-enhanced learning environment? An updated critical review of the literature from 2012 to 2015. J. Comput. Assist. Learn. **32**(6), 503–528 (2016)
49. M. Thai, N. Sheeran, D. Cummings, We're all in this together: the impact of Facebook groups on social connectedness and other outcomes in higher education. Internet Higher Educ **40**, 44–49 (2019)

Chapter 17
Educational Computer Games and Social Skills Training

Margarita Stankova, Daniela Tuparova, Polina Mihova, Tsveta Kamenski, Georgi Tuparov, and Krista Mehandzhiyska

Abstract This chapter presents the application of educational computer games aiming to improve emotional understanding in children with ASD. A game, designed specifically for children with ASD and based on the ability model of emotional intelligence [22], is introduced. This model suggests that emotional intelligence is based on our four focus areas: perceived emotions, use of emotions to facilitate thought, understanding emotions and managing emotions. We selected this model because it draws a specific focus to understanding emotions through verbal and non-verbal interventions.

The game consists of seven modules:

1. Completion of a sentence with target pictures, denoting emotion;
2. Matching verbal exclamation with the corresponding picture denoting emotion;
3. Finding two identical emoticons;
4. Matching emoticons with situational picture-based emotions;
5. Matching pictured emotion with an emoticon;
6. Finding identical emotions in different pictures; and
7. Matching the sentence describing an emotion with a picture.

The game offers participants a specific combination of visual representation and auditory perception of nominated emotions. In addition, it offers the opportunity for the emotion to be depicted and accessible on target pictures—facial expressions and adapted situational images. The Chapter discusses the principles of game development and its seven components. Data collected from the pilot testing with two groups of children—typically developing and children with ASD—are systematized. Enhancement of social skills and emotional intelligence and its key components,

M. Stankova (✉) · P. Mihova · T. Kamenski · G. Tuparov
Department of Health Care and Social Work, New Bulgarian University, 21, Montevideo str. Sofia, Bulgaria
e-mail: mstankova@nbu.bg

D. Tuparova · K. Mehandzhiyska
South-West University "Neofit Rilski", Blagoevgrad, Bulgaria
e-mail: ddureva@swu.bg

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*, Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_17

namely, emotion perception and understanding, is a fundamental part of direct and indirect interventions that support the development of children with ASD. Such skills would widen the opportunities for the children to establish and build relationships with peers, be better accepted in society and reach an improved functional level.

Keywords ASD · Educational computer games · Social skills · Emotional intelligence

17.1 Introduction

17.1.1 Autism Spectrum Disorders

Autism spectrum disorders (ASD) include problems in social communication and repetitive behaviours with a genetic or other cause. In today's world, many people with ASD are able to develop the ability to function independently, but some are still unable to live on their own. Successful medical practices and behavioural interventions that positively influence children with ASD, especially those with comorbidity, remain the focus of practitioners and researchers [1]. Autism is a heterogeneous disorder. Current classifications introduce the term ASD using additional clinical descriptions to differentiate individuals [2]. The latest version of DSM-V places the focus on diagnosis and includes two domains. The first is related to social communication, and the second includes restricted, repetitive or unusual sensory-motor behaviours. A differentiation scale to assess the severity of the symptoms is also introduced. Problems in the development of social skills in individuals with ASD may include the following symptoms observed in multiple contexts: social reciprocity disorders, non-verbal communication disorders and disorders in developing, maintaining and understanding relationships [3].

People with ASD display different behaviours in the context of their disturbances in social development and emotional organization. Some children have no desire for social communication and avoid it; others are actively looking for interaction, but do not have the know-how, empathy and skills [4]. People with ASD have difficulties recognizing and understanding the emotions of others, expressing their own emotions, recognizing emotional expressions, and understanding them through the faces of others, as they are likely to see the individual elements of the face rather than the expression as a whole [5].

There is a delay in the development of facial expressions processing in children who show ASD features [6], including slow recognition of emotions [7], difficulties interpreting emotional cues and body language [8] different patterns of brain responses to emotional stimuli [9] and weak reliance on emotional information observing the face, probably resulting in difficulties in understanding social situations [10]. These changes are probably related to many environmental factors, incl. adverse childhood events that may impair the development of emotional information processing and lower the focus on understanding facial expression [11]. Difficulties in recognizing facial expression of emotions depend on children's age, as children between 2 and 4 years of age are more likely to confuse emotion when relying on human faces [12].

ASD individuals have problems solving tasks for analysis of social situations and complex emotions in feature films. They may experience difficulties in some aspects of empathy processing, where language-based interventions are suggested as therapeutic strategies [13].

Computer technology can be used in working with individuals with ASD, especially in the development of verbal skills as well as to support the exchange of information between people, improve the overall quality of life [14], and develop social skills [15]. Computer training can hone emotion recognition and the development of social cognition [16]. Emotional recognition skills acquired through computer-based training can be successfully transferred into everyday life [17]. The application of computer games is perceived positively by children and their parents [18, 19]. Supporting the development of social skills and their application in life is a key factor for individuals with ASD, as it will enable them to have normal relationships with other people [20].

17.1.2 Emotional Intelligence (EI)

Emotions include feelings, thoughts and reactions of the nervous system, as well as physiological changes in the body and changes in behaviour. Emotions are of great importance for our functioning in the socium and response to certain events; therefore, emotions serve many functions [21].

Emotional intelligence (EI) has been defined by Salovey & Mayer as the "subset of social intelligence that involves the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" (p. 189) [22]. The authors also comment on "interpersonal intelligence", which includes the ability to observe the emotions of others and their moods and attempts to predict their behaviour.

EI includes verbal and nonverbal understanding and expression of emotions, regulation and use of emotional content for problem solving [23]. EI is the ability to understand, identify and manage emotions in such a way as to overcome anxiety, communicate efficiently, solve problems and manage conflicts. The Ability EI model emphasizes the relationship between cognition and emotion and the skills of perception, recognition and management of emotions [24]. EI includes the ability of a person to be involved in processing their own emotions, as well as the emotions of others, and to use this information as a guide for thinking and behaviour. People with high emotional intelligence can manage their emotions and possess adaptive skills [25].

The Ability EI model includes four branches that focus on the ability to perceive, use, understand and manage one's own emotions and the emotions of others. The first involves the ability to perceive one's own emotions and the emotions of others, including the ability to identify emotions through language, appearance and behaviour. The second branch includes emotional facilitation of thinking—the individual's ability to incorporate emotions into prioritized areas of thinking by focusing on important things. The third branch is related to understanding and analyzing emotions, the ability to nominate emotions, to understand their meaning and to distinguish them when similar words and expressions are used to denote them, and to understand the states associated with a combination of emotions. The fourth branch represents the ability to manage emotions and the impact of this regulation on the emotional and intellectual growth [26].

Additionally, the modified version of the model includes an expansion of the section "Understanding Emotion," which initially includes the ability to identify emotions and know their causes and to understand complex emotions. An assessment of the ability of emotional forecasting has been added to that section [25].

Emotions contain and carry information (e.g., happiness leads to a desire to socialize with other people, anger leads to a desire to attack others, fear leads to a desire to run away). Each emotion contains a message and a probable action associated with it. Understanding emotional messages and the potential actions associated with them helps individuals to integrate into society and to create satisfying relationships [27].

Emotional recognition includes the ability to understand the expressions of others that represent their feelings, including the use of non-verbal channels (e.g., face, body, voice). This is directly related to the possibilities for interactions and appropriate behavior [28].

17.1.3 Computer Game for the Development of Social Skills in Children with ASD

The aim of the game is to improve children's social skills by teaching them to recognize emotions, to increase children's knowledge of emotions, and to expand their knowledge of situations related to these emotions. The facial and physical expressions of people who experience emotions are also a point of focus. We believe that this would increase the social capacity of children with autism and improve their daily interactions with other people [29], their ability to manage their own emotions and the emotions of others [30], their inner experiences and outer relationships [26], and promote successful communication and understanding of thought as well as their orientation towards certain goals [31].

The ability EI model suggests that emotional intelligence is a pivotal skill in one's life, and an important element of this model is the understanding of emotions, including their verbal representations [25].

Improving the understanding of emotions in children with autism and their emotional intelligence can be achieved through several means, such as the following:

- The use of plot pictures emphasizing the expression of emotion and its nomination;
- The use of different types of tasks with multiple choice options aimed at promoting the recognition of a set of emotions.
- The use of situational pictures containing both people and emoticons to differentiate emotions with the same name;
- The search for matches between emoticons and facial expressions in humans;
- The reiteration of the emotion with both the correct and incorrect answer to create a visual image related to the verbal naming.

Interventions suitable for teaching children with ASD have been used in preparing the games. In the games, multiple visual stimuli and the same target emotion are presented in several ways, and children are tasked with completing a sentence in context, recognizing the emotion in multiple pictures, combining identical emotions, searching for a match between an emoticon and a picture, and recognizing the image in a picture and matching it to its name. The emotion is presented in different ways, and there is an opportunity to improve visual recognition and match the visual representation of the emotion with its name.

Another approach is the random presentation of the tasks in each group. Each time the child starts the game, a different order of tasks is presented to prevent the child from learning the answers or getting bored. The random presentation of the individual tasks is expected to increase the motivation for multiple repetitions of the game and promote learning.

17.1.4 Educational Game—Framework

The aim of the game is to improve emotion recognition, especially in themed (social) situations, and allow children to develop social/soft skills and to focus on the emotions of the other participants in the situation.

Voice instruction is used in the games, and emotions are provided both in the instructions and the correct/wrong answer. Thematic pictures containing children, adults, and emoticons are displayed on the screen. The emotion is depicted in color and the rest of the picture in black and white, so the focus is placed on the target group in color, denoting the emotion. In this way, the skills of children with ASD are used to focus on details but at the same time to present the emotion in a social context/plot picture. By transferring this knowledge to real situations, where they hear the name of the emotion or observe the emotion visually, children can improve their performance skills.

The verbal description of the emotional state or the situation has to be matched to the thematic picture/emoticon by the child. When a correct answer is given, the speaker names the related emotion, and the child is reinforced verbally by "Well done! You did it!" When the answer is wrong, the speaker names the emotion and prompts the child with "Try again!" For a better learning experience, the emotion is named after the choice, and this naming is combined with the feedback for the correct or wrong answer. The game is targeted at children who can understand the task instructions, which are read aloud.

The record of each player's achievements displays the number of correct and incorrect answers and the time taken to answer the questions as well as the number of attempts used to listen to the condition, which is an important factor in the application of the game to children with ASD. Numerous listening attempts indicate difficulties in understanding the instructions and/or difficulties in understanding the name of the emotion, which is a very important measure. Motivation is maintained through the relatively small number of answer options, which increases the chance of a correct answer, even with the random choice of answers. This also supports learning as it provides positive feedback and focuses children's attention on naming and expressing emotion.

The games are provided sequentially in order to gradually complicate the tasks. The first mini-game starts with a sentence that explains a social situation and gives three possible emotions as answer options. The second game is an emotional exclamation and a situation prompting the user to choose between four different pictures depicting an emotional situation. The third task involves recognizing the same emotions with emoticons, and the correct answer is provided after the user's selection. The fourth task contains instructions for combining a picture with an emoticon. In this task, there are four possible situations denoting the same emotion, presented in two columns of four. The last task includes a description of an emotion and a search for a match between four pictures.

Each game includes several tasks with the same degree of complexity. Some techniques for working with children with ASD were used to improve learning and understanding: **the instructions are clearly articulated at a slow rate and contain only words with unambiguous meanings; sentences are short and clear with adequate pauses in between; the reinforcement for answering correctly is immediate; and the name of the emotion is reiterated.**

17.2 Game Description

17.2.1 Tasks—Mini-Game 1

Mini-Game 1 consists of 11 tasks displayed in different/consecutive panels each consisting of three pictures.

Setting: The child hears a sentence describing a particular situation related to a feeling or emotion. He/she has a choice of three thematic pictures and has to choose the one that best describes the emotion to complete the sentence. When answering correctly, the child hears the word denoting the emotion and is given verbal reinforcement as well. The aim is for the child to relate the situation described in the sentence to the emotion in order to identify the correct emotion and hear it stated verbally.

The expected result in this game is to improve the recognition of the emotions and the feelings of the others in various situations and develop skills for understanding their behaviors.

Example:

Instruction:
Choose the picture that best denotes the emotion to complete the sentence.

1. When something nice happens to us …
   The answers to choose from are:

   - We feel ashamed;
   - We feel pain;
   - We feel happy.

   The correct answer is "We feel happy" (Figs. 17.1 and 17.2).
   The sentences to be completed in Game 1 and the corresponding answers are as follows:
2. When we achieve something, we feel... Options containing answers and pictures related to emotions: we feel love; we feel proud; we feel scared.
3. When we see something unpleasant, we feel... Options containing answers and pictures related to emotions: disgusted; surprised; angry;
4. When we misbehave, we feel... Options containing answers and pictures related to emotions: scared, ashamed; in pain;
5. When something scary happens to us, we feel... Options containing answers and pictures related to emotions: upset; entertained; frightened;
6. When we do something, we enjoy, we feel.... Options containing answers and pictures related to emotions: disgusted; entertained; frightened;
7. When someone breaks something that belongs to us, we feel... Options containing answers and pictures related to emotions: upset; entertained; love;
8. When we fail to achieve something, we feel... Options containing answers and pictures related to emotions: surprised; love; frustrated;
9. When we get injured, we feel... Options containing answers and pictures related to emotions: pain; frustrated; frightened;
10. When someone does something unexpected, we feel... Options containing answers and pictures related to emotions: ashamed; surprised; sad;
11. When we are unable to do the things that we want, we feel... Options containing answers and pictures related to emotions: entertained; frightened; sad.

17.2.2 Tasks—Mini-Game 2

Mini-Game 2 contains 11 tasks displayed in consecutive panels in a random order on the screen.

Fig. 17.1 Screenshots of "Game 1"

Setting: There are four pictures on the screen. The child hears a verbal expression related to a feeling or emotion. The aim here is for the child to choose the picture that best corresponds to the emotion in the sentence. When the given answer is wrong, the child hears the word denoting the emotion and a statement that it does not correspond to the verbal expression as per the instructions.

The expected result is an improved ability to relate verbal expressions that explain the emotions to the picture that corresponds to the emotion.

Example:

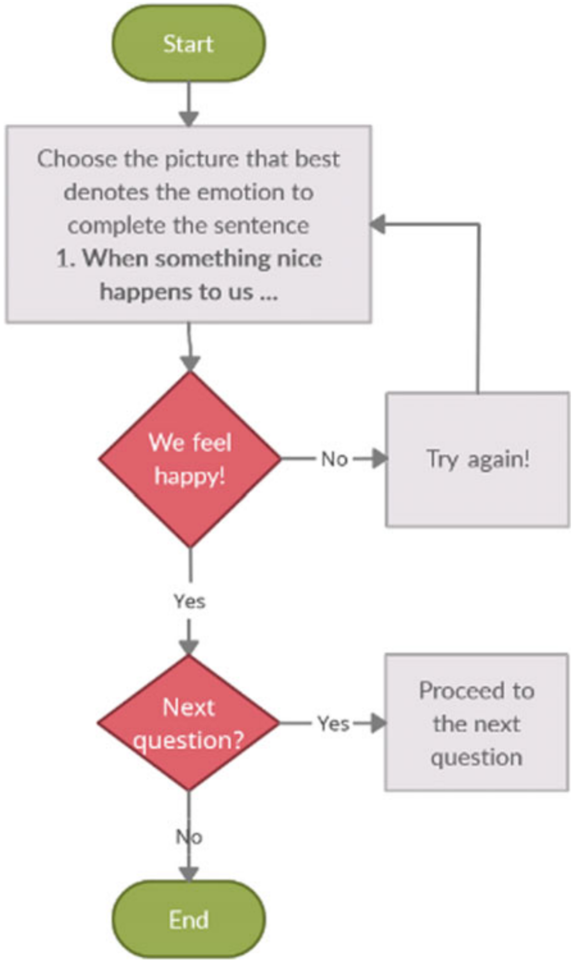
Instruction:

Choose the picture that best matches the exclamation.

1. Ugh, this is disgusting!

   The answers to choose from are:

Fig. 17.2 Flowchart diagram of "Game 1"



- I am disgusted;
- I am angry;
- I am happy;
- I love you.

The correct answer is "I am disgusted" (Figs. 17.3 and 17.4).

The examples Mini-Game 2 include the following verbal exclamations:

2. Ugh! I am so angry! Possible answers and pictures related to emotions: I am scared; I am angry; I am surprised; I am in pain;

Fig. 17.3 Screenshot of "Game 2"

3. Ouch! It hurts! Possible answers and pictures related to emotions: I am in pain; I am angry; I am happy; I love you;

   I cannot do this; it is too difficult! possible answers and pictures related to emotions: i am ashamed; i am scared; i am in difficulty; i am afraid;

5. Aah, I am so scared! Possible answers and pictures related to emotions: I have fun; I am in pain; I am disgusted; I am scared;
6. Ooops, I am so sorry... Possible answers and pictures related to emotions: I have fun; I am in pain; I am ashamed; I am proud (of);
7. Wow, this is so much fun! Possible answers and pictures related to emotions; I am proud (of); I am in difficulty; I have fun;
8. Whoa, such a wonderful surprise! Possible answers and pictures related to emotions: I am surprised; I am scared; I love you; I have fun;
9. Yahoo! I am so proud; I did it! Possible answers and pictures related to emotions: I am in pain; I am in difficulty; I am proud (of); I am angry;

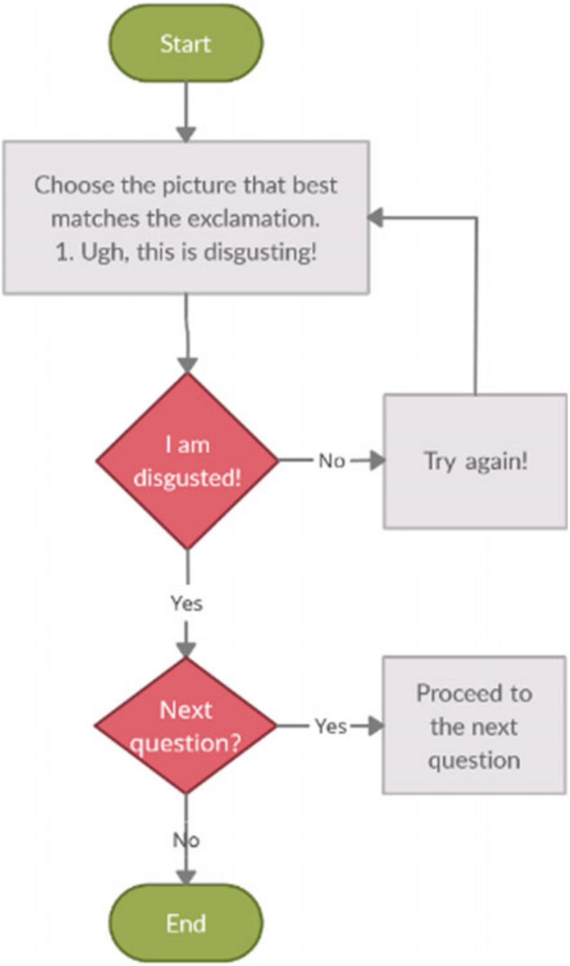


Fig. 17.4 Flowchart diagram of "Game 2"

10. Aah, you got me scared! Possible answers and pictures related to emotions: I am scared; I am sad; I love you; I am ashamed;
11. I love you! Possible answers and pictures related to emotions: I am happy; I am surprised; I love you; I have fun.

17.2.3 Tasks—Mini-Game 3

Mini-Game 3 contains five tasks displayed in a random order in consecutive panels on the screen.

Setting: There are eight emoticons on the screen, and the child is seeking to find the two identical ones among them. The task is to recognize the identical emotions denoted by emoticons. Instructions are given verbally without naming the emotion. After the successful completion of the task, there is verbal feedback naming the emotion and verbal reinforcement.

Example:

Instruction:

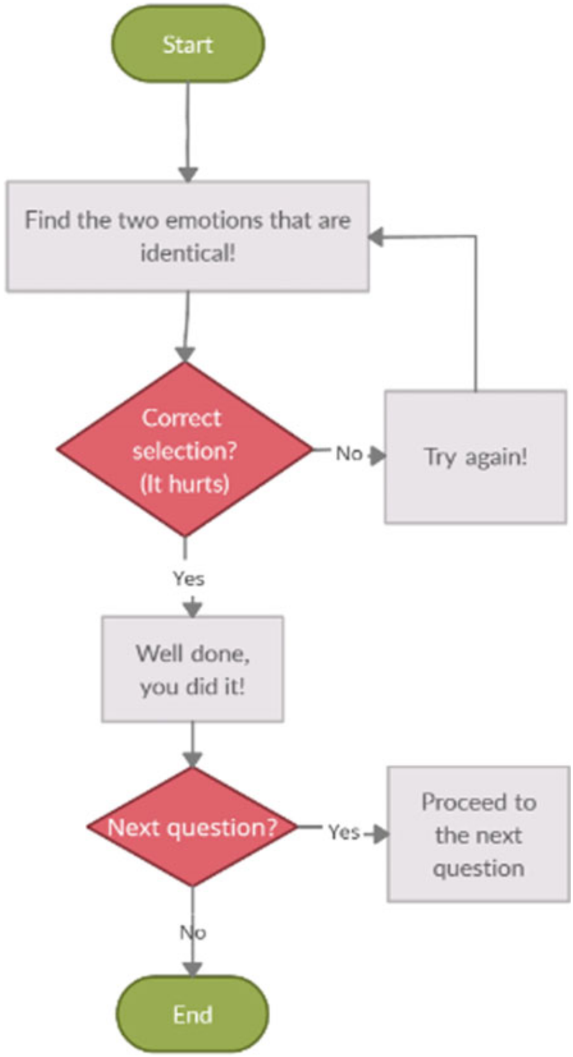
Find the two emotions that are identical.

Correct answer: "It hurts."

Reinforcement: "Well done, you did it!" (Figs. 17.5 and 17.6).

Fig. 17.5 Screenshot of "Game 3"

Fig. 17.6 Flowchart diagram of "Game 3"



17.2.4 Tasks—Mini-Game 4

Mini-Game 4 contains two tasks displayed in consecutive panels on the screen.

Setting: The child has to match a thematic picture denoting an emotion with the corresponding emoticon. After the successful completion of the task, there is verbal feedback naming the emotion and verbal reinforcement.

The aim of the task is to discover the emotion denoted in the thematic picture and recognize the same emotion denoted by the emoticon. When the answer given is wrong, there is an opportunity to teach the child the right emotion.

Fig. 17.7 Screenshots of "Game 4"

Example:

Instruction:

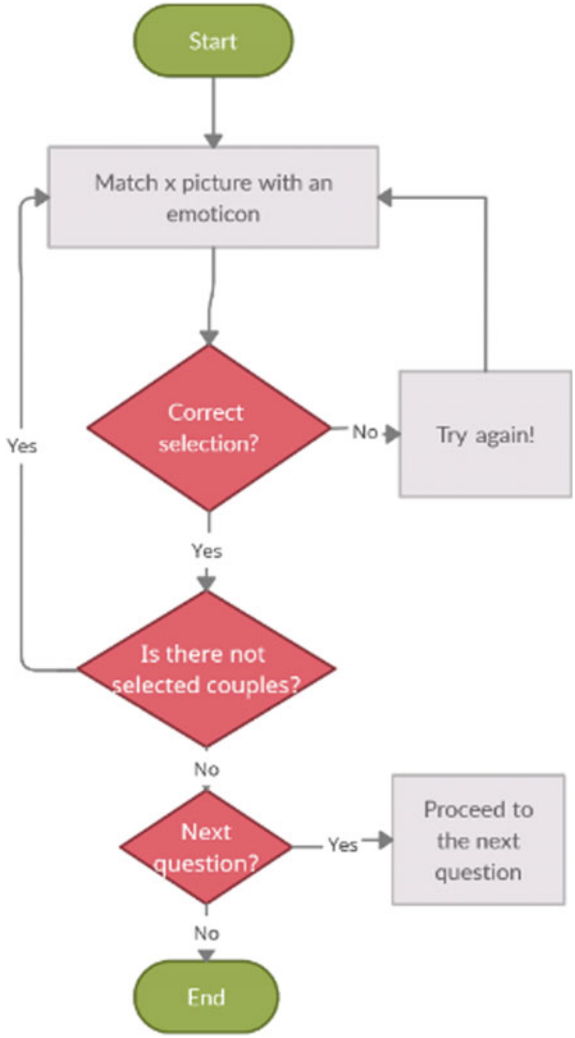
Match x picture with an emoticon (Figs. 17.7 and 17.8).

17.2.5 Tasks—Mini-Game 5

Mini-Game 5 consists of six tasks displayed in a random order in consecutive panels on the screen.

Settings and aim: To introduce a thematic picture denoting an emotion and match it to the relevant emoticon in an array of four emoticons. This task develops the skill of emotion recognition, represented both by a thematic picture and an emoticon.

Fig. 17.8 Flowchart diagram of "Game 4"



After the successful completion of the task, there is verbal feedback naming the emotion and verbal reinforcement. If the child fails to match the items, the emotion is repeated, and the child hears "Try again!".

Example:

Instruction:

Which emoticon best matches the emotion shown in the picture?

The answers to choose from are:

- I am in difficulty;
- I am happy;

Fig. 17.9 Screenshots of "Game 5"

- I am surprised;
- I am in pain.

The correct answer is "I am in pain" (Figs. 17.9 and 17.10).

17.2.6 Tasks—Mini-Game 6

Mini-Game 6 consists of three tasks displayed in a random order in consecutive panels on the screen.

Setting and aim: To recognize identical emotions shown in different thematic pictures. Four coupled emotions and eight thematic pictures are shown on the same

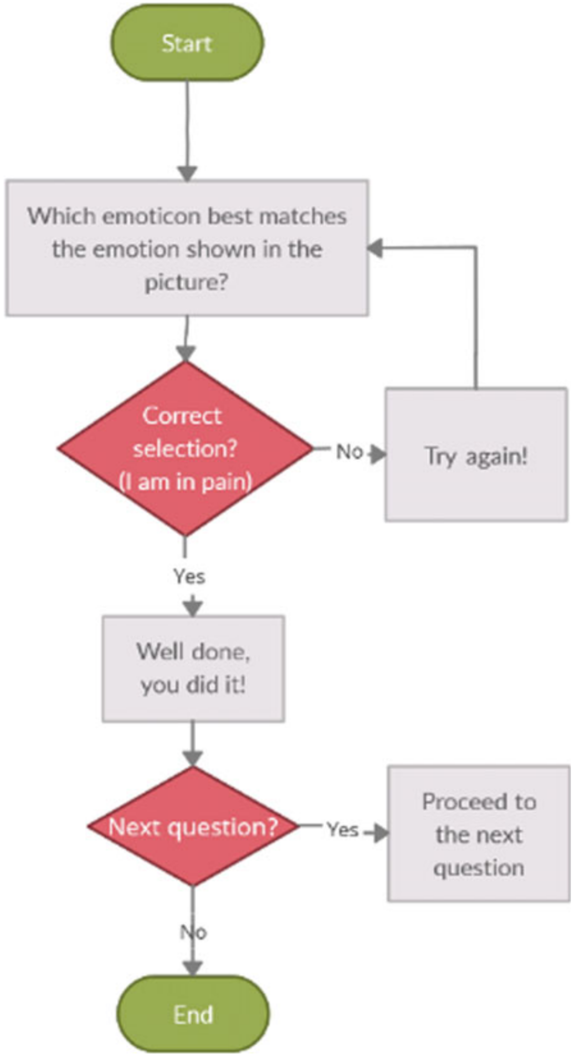


Fig. 17.10 Flowchart diagram of "Game 5"

screen. The task is successfully completed when two identical emotions are recognized and selected. The emotion is stated verbally, and the participant is verbally reinforced.

Example:

Instruction:

Match the pictures denoting identical emotions (Figs. 17.11 and 17.12)!

Fig. 17.11 Screenshots of "Game 6"

17.2.7 Tasks—Mini-Game 7

Mini-Game 7 consists of 26 tasks displayed in a random order in consecutive panels on the screen.

Setting and aim: To identify the corresponding emotion by asking a related question. All questions start with "In which picture..." The participant has to choose an answer in the array of four thematic pictures related to different emotions. Every emotion is named twice and has two corresponding thematic pictures.

Example:

Instructions:

1. In which picture is the child surprised?
   The answers to choose from are:

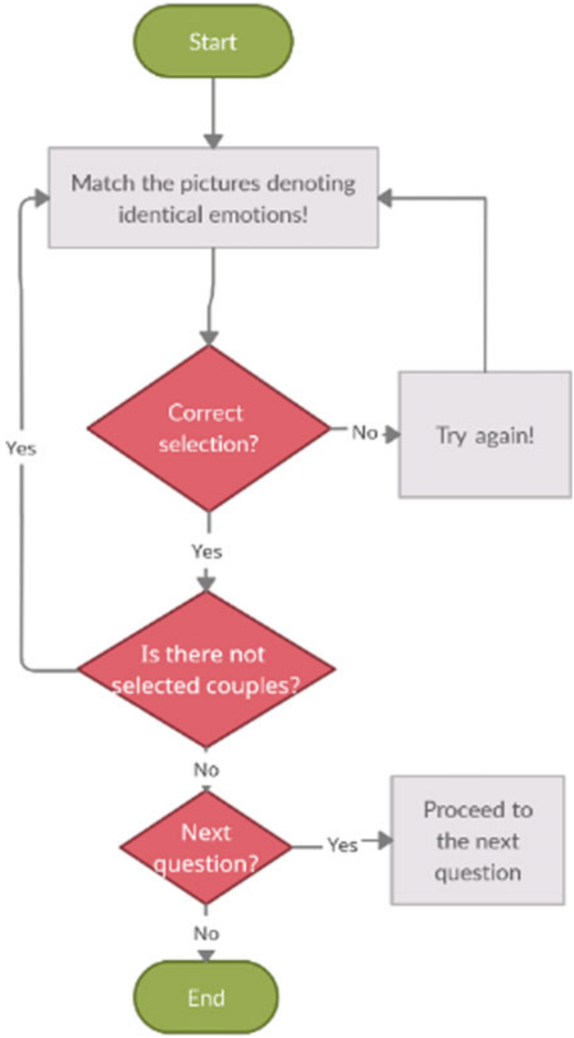


Fig. 17.12 Flowchart diagram of "Game 6"

- disgusted;
- scared;
- surprised;
- ashamed.

The correct answer is "I am surprised" (Figs. 17.13 and 17.14).

Here are some sample questions of Mini-Game 7:

2. In which picture is the child surprised? Possible answers: I am angry; I am in difficulty; I am surprised; I love you.
3. In which picture is the child sad? Possible answers: I am happy; I am sad; I am scared; I am in difficulty;

Fig. 17.13 Screenshot of Game 7

4. In which picture is the child happy? Possible answers: I am ashamed; I am proud (of); I am surprised; I am happy;
5. In which picture is the child angry? Possible answers: I am scared; I am in difficulty; I am angry; I am having fun;
6. In which picture is the child scared? Possible answers: I am angry; I am in pain; I am happy; I am scared;
7. In which picture is the child disgusted? Possible answers: I am scared; I am angry; I am sad; I am disgusted;
8. In which picture does the child feel proud? Possible answers: I love you; I am ashamed; I am proud (of); I am surprised;
9. In which picture is the child in difficulty? Possible answers: I am angry; I am in difficulty; I am disgusted; I am ashamed;

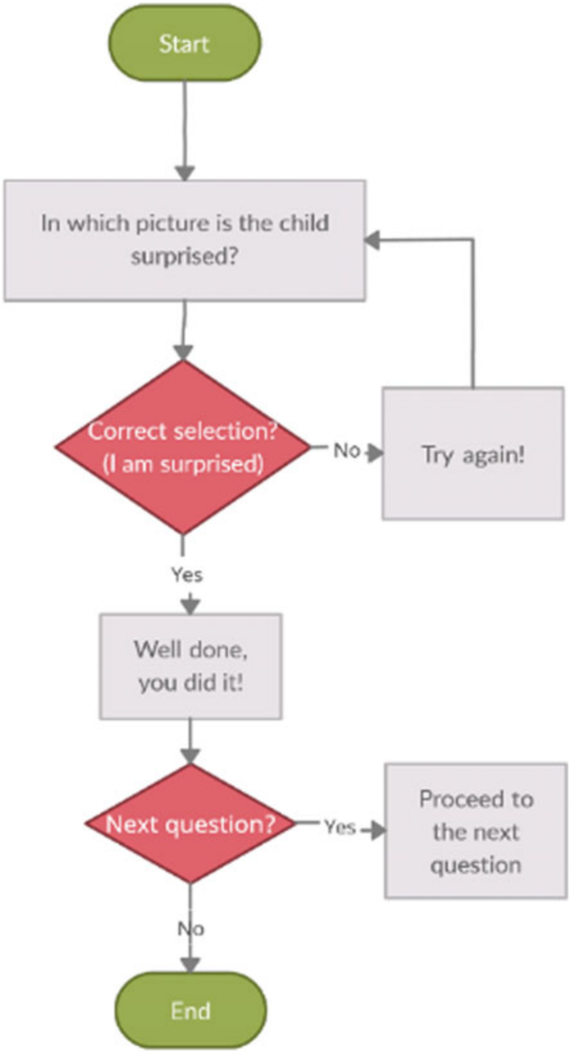


Fig. 17.14 Flowchart diagram of Game 7

10. In which picture is the child ashamed? Possible answers: I am in pain; I am ashamed; I am proud (of); I am sad;
11. In which picture is the child having fun? Possible answers: I am scared; I love you; I am having fun; I am surprised;
12. In which picture is the child loving somebody? Possible answers: I am scared; I am ashamed; I am happy; I love you.

17.3 Game Development

For the efficient implementation of the online game application, we used a specialized web-based platform called Moodle, which provides the opportunity to implement specific interactive activities suitable for use on desktops as well as on mobile devices (cell phones and/or tablets).

Moodle is a learning platform used to augment and move existing learning environments online. It is a virtual learning environment and can be used in education, training, and development, as well as in business settings. The software platform enables the development and design of new courses or programs from scratch by stacking modular media, text, and interactive blocks. The access to the platform is secured by an initially generated username and password so that we can control access, monitor the progress of the participant, and last but not least, collect statistical data for further analysis as well as for ongoing feedback and the regular coordination of the exercises.

The games were developed using Adobe Captivate (adobe.com) and exported in SCORM1.2 (Shareable Content Object Reference Model; https://scorm.com/?utm_source=google&utm_medium=natural_search). Learning objects have been integrated into the Learning Management System (LMS) Moodle. The games are based on scalable HTML5 and can be played on various devices, from a desktop computer to a tablet or smartphone. The child can access the game through the Moodle e-learning system. The introduction of games through SCORM packages allows re-use in e-learning systems that support the SCORM standard [32, 33]. This makes it possible to collect data related to the player's interaction with the individual elements of the game, such as the answers given, the length of the game, and the time between the individual interactions with the elements of the game. The games can also be used without an e-learning system, but in such cases, the child's interactions with the objects in the game cannot be traced. Each interaction is accompanied by a voice instruction for task completion, supporting or encouraging the child to choose the right answer. Each time a question is introduced, a different set of possible answers is generated. In practice, the child can progress only when he/she selects the correct picture (Fig. 17.15).

The game algorithm follows the pattern below:

Fig. 17.15 Screenshots of "Game 1"

- start of the game: user clicks the start button, which says “Start”;
- user clicks on a button, which includes the name of the object “speaker,” to repeat the instructions for a task;
- user selects an image that is a wrong answer, which includes the name of the object “wrong”;
- user moves to the next question, which includes the name of the object “next”;
- user selects an image that is the correct answer, which includes the name of the object “correct”.

An interaction marked as correct is weighted two points, and all other interactions are weighted one point (note: Adobe Captivate requires at least one point to be awarded for the interaction to be included in the report). The child progresses through the game only if he/she answers the questions correctly. This means that when the game is over, fewer interactions show a better result.

For every interaction, the SCORM package reports the time of interaction based on the server to LMS in real time. This allows us to track the speed of the participant for the current interaction.

Moodle provides the option to obtain several types of reports for all users registered in the course: basic, graph, interactions report, objectives report (Figs. 17.16 and 17.17).

The data from the SCORM package in Moodle can be exported in a.xlsx format and further analyzed (Fig. 17.18).

For example, the data in the table (Fig. 17.18) represents the number of users and some additional information. One user played the game five times, another user

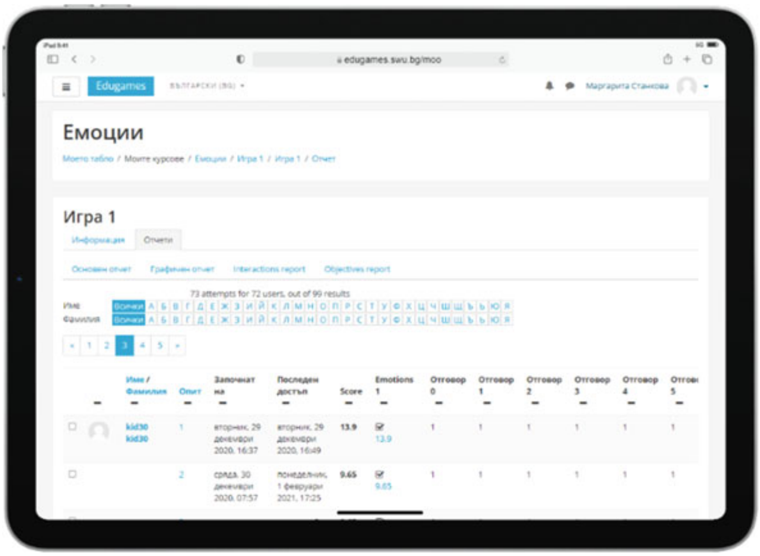


Fig. 17.16 Basic report for all participants

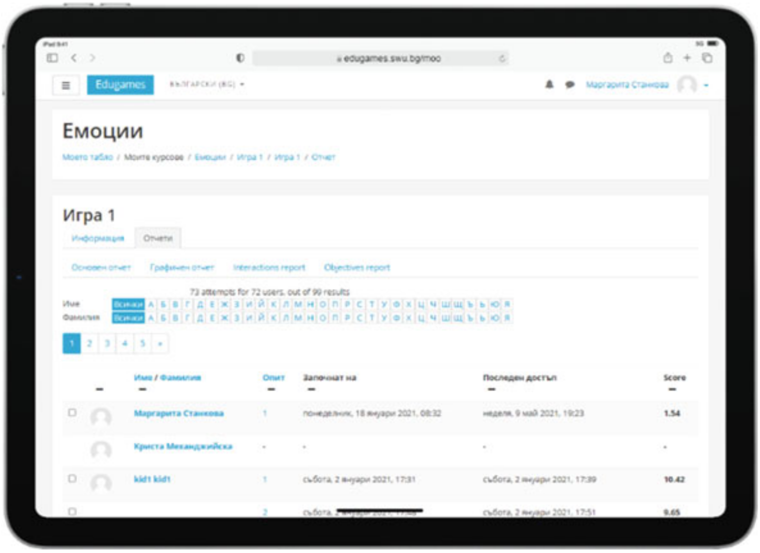


Fig. 17.17 Interaction report in Moodle

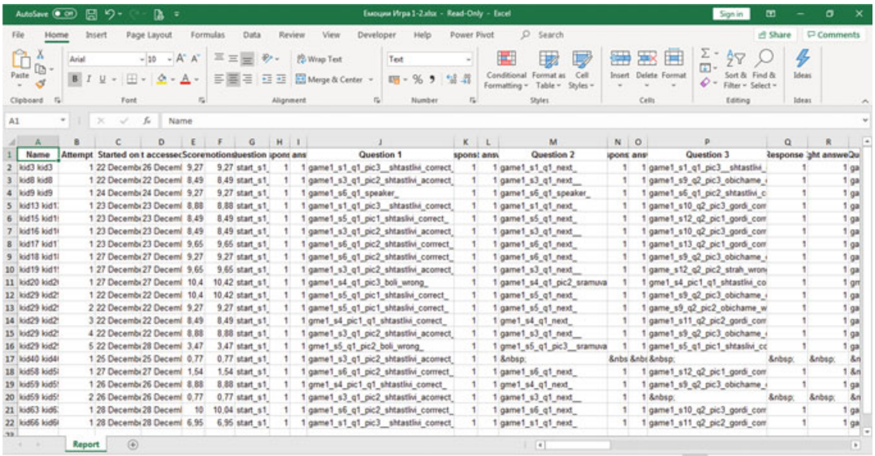


Fig. 17.18 Report exported in MS Excel (The screen was taken in the process of testing the game played by children)

played the game twice, and the rest played just once. The user "kid9" listened to the instructions for the first question twice and then clicked on the picture with the correct answer. The user "kid20" selected the wrong answer twice and in their third attempt, selected the correct one (columns J, M, and P show the answer chosen by the user. The correct picture contains the word "correct," and the wrong picture contains the word "wrong").

LMS Moodle also provides individual reports on each child's interaction with the objects in the game, which include general information about the learning object used (Fig. 17.19), detailed tracking of interactions (tracking details; Fig. 17.20), and

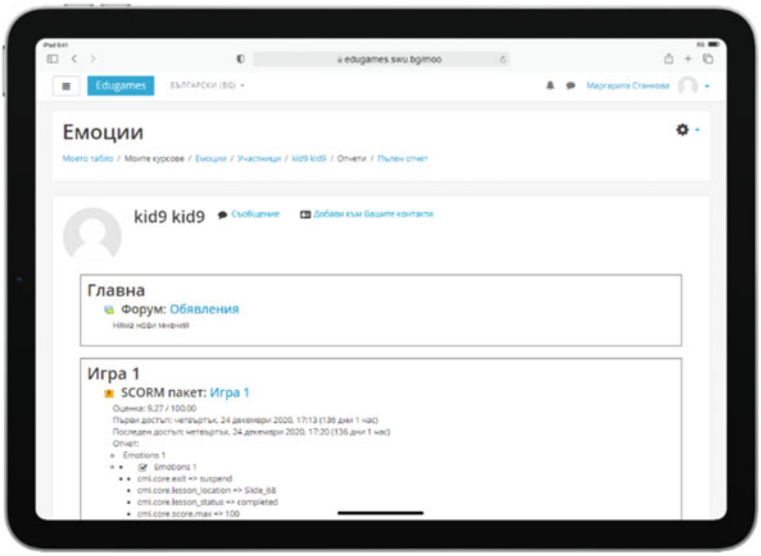


Fig. 17.19 Learning object report for user "kid9"

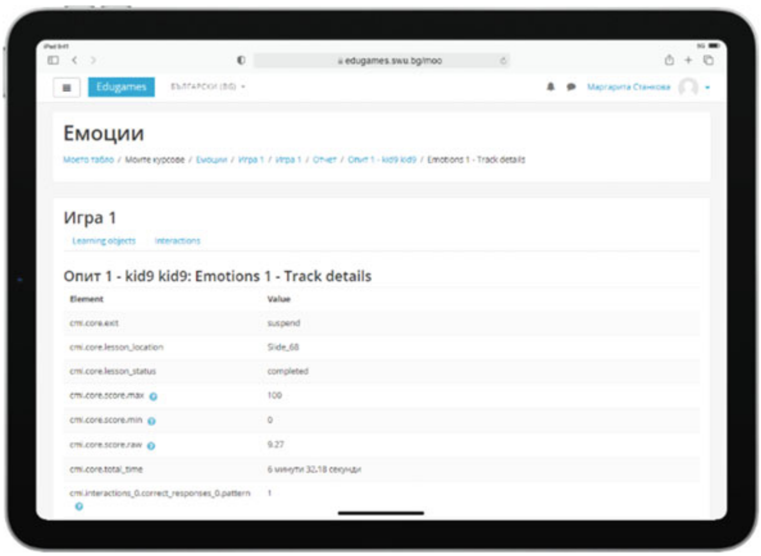


Fig. 17.20 Tracking details for user "kid9"

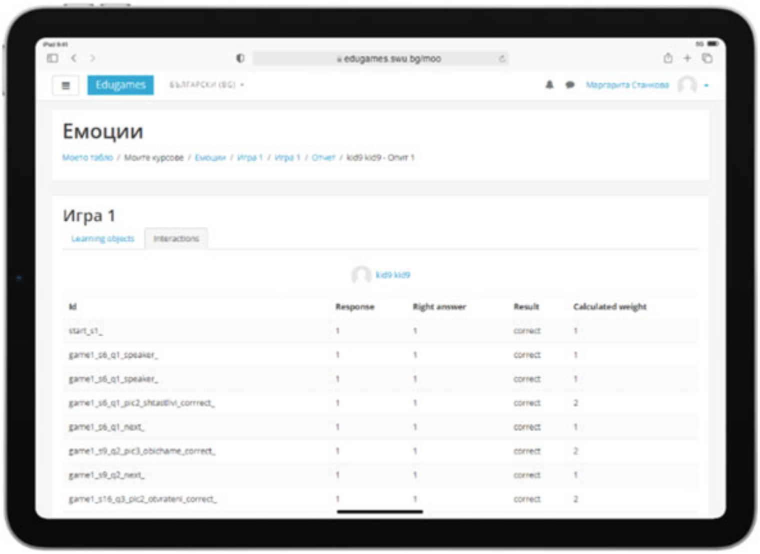


Fig. 17.21 Screenshot of interaction report for user “kid9”

information about interactions with each element included in the report of the game (Fig. 17.21). In the individual reports, the status of the learning object can be seen as well as total time, score, and link to the tracking details.

17.3.1 Pilot Testing on Two Groups of Children and Qualitative Data

The JASP statistical package (https://jasp-stats.org/) was used for statistical analysis, and a significance level of 0.05 was applied. The pilot measurement compared the results of the first and second games in control Group 1 (typically developing children) and Group 2 (children with ASD).

Mini-Game 1 was played by 13 children from Group 1 and 10 children from Group 2. Three of the children gave up at the beginning of the game and were not included in the analysis. Mini-Game 2 was played by 12 children from Group 1 and 9 children from Group 2. The majority of children in both groups played either Mini-Game 1 or Mini-Game 2. For the children who played Mini-Game 2, in Group 1, one child made two attempts, and in Group 2, four children made more than two attempts.

The descriptive statistics of the results for groups 1 and 2 for both mini-games are presented in Table 17.1.

Due to the small number of participants, we used non-parametric statistical methods for the comparison of independent samples (Mann–Whitney U test and

Table 17.1 Descriptive statistics of the wrong answers

	Group	N	Mean	SD	SE	Median	Mode
Number of wrong answers in Game 1	1	13	2.23	1.83	0.51	2	2
	2	7	5.29	5.25	1.98	4	2
Number of wrong answers in Game 2	1	13	3.00	2.77	0.77	2.5	0
	2	21	4.43	5.27	1.15	2	2

effect size estimation). The alternative hypothesis specified that the median of wrong answers in Group 1 was different from the median of wrong answers in Group 2. The effect size is given by the rank biserial correlation calculated in JASP. The data (Table 17.2) shows that we cannot reject the null hypothesis ($p > 0.05$).

Since Mini-Game 1 and Mini-Game 2 in both the control group and the ASD group were played by different children, we used the non-parametric Mann–Whitney U Test for independent samples with alternative hypotheses. Again, the median of wrong answers in Mini-Game 1 was different from the median of wrong answers in Mini-Game 2.

The data (Tables 17.3 and 17.4) shows that we cannot reject the null hypothesis for the equality of medians in both groups (control and ASD). We assume that the number of wrong answers during the playing of Mini-Game 1 is similar to the number of wrong answers during the playing of Mini-Game 2 in both groups.

Although the second game was more complicated than the first game, there was no statistically significant difference in both groups in terms of errors in the first and second game. There were no statistically significant differences between the number of errors in the control and ASD groups.

If the children from the ASD group, who played more than one game, are considered as separate cases, their progress can be highlighted. For example, kid30, who made 16 mistakes in Mini-Game 1 and listened to the questions eight times, had an average of 3.43 mistakes and four listening attempts in Mini-Game 2 and an average

Table 17.2 Independent samples Mann–Whitney U test

	W	p	Rank-Biserial Correlation
Wrong answers for Mini-Game 1	28.50	0.18	– 0.37
Wrong answers for Mini-Game 2	123.50	0.65	– 0.09

Note For the Mann–Whitney test, effect size is given by the rank biserial correlation

Table 17.3 Independent Samples Mann–Whitney U test Group 1

	W	p	Rank-Biserial Correlation
Wrong answers for Game 1	73.50	0.58	– 0.13

Note For the Mann–Whitney test, effect size is given by the rank biserial correlation

Table 17.4 Independent Samples Mann–Whitney U test Group 2

	W	p	Rank-Biserial Correlation
Wrong answers for Game 2	86.50	0.50	0.18

Note For the Mann–Whitney test, effect size is given by the rank biserial correlation

of one mistake in Mini-Game 5. We can probably assume that despite the gradual complication of the games, the child has an increasing number of correct answers and no additional listening attempts to the tasks in the games. Kid33 had an average of 11 errors and nine additional listening attempts in Mini-Game 2 and nine errors and two additional listening attempts in Mini-Game 5.

The qualitative analysis of parental feedback was done for the children in groups 1 and 2 who played at least one of the seven mini-games. Group 1 contained 26 participants aged between five and eight years who were predominantly girls (20 girls and 6 boys), and Group 2 contained 14 participants aged between five and eight years who were predominantly boys.

The questions were asked of the parents by phone. They were developed based on similar surveys [34] and were aimed at the usability of the games, the child's participation and interest in the game, entertainment, and the need for educational games. The first group of questions was focused on the parents' impression of the children's behavior during the game and the second part, on their personal impression of the game.

The parents' feedback can be summarized as follows:

Group I (Table 17.5).

Table 17.5 Group 1 parents' feedback

Feedback shared by the parents	No. of parents	%*
Child's participation		
The child enjoys the game and asks for more such examples	8	31
The child finds the game interesting	5	19
The child likes the game	7	27
The child is not interested at all	3	12
Personal opinion		
I do not find it useful	3	12
I find it instructive	2	8
I find it attractive and useful	12	46
I need more games like this	5	19

* *The percentages do not add up to a hundred, as some parents did not share a clear position or gave more than one answer*

Table 17.6 Group 2 parents' feedback

Feedback shared by the parents	No. of parents	%*
Child's participation		
The child plays the game as required but makes many mistakes	3	21
The child is not able to finish the game	6	43
The child likes the game	2	14
The child is not interested at all	3	21
Personal opinion		
I do not find it useful	1	7
I find it instructive	6	43
I find it attractive and useful	8	57
I need more games like this	6	43

* *The percentages do not add up to a hundred, as some parents did not share a clear position or gave more than one answer*

Group II (Table 17.6).

The parents in Group 2 frequently raised concerns about the flexibility in defining "emotion" and the meaning of "emoticon." Many participants commented that the instructions must be simple, and children had difficulty understanding the tasks.

17.4 Conclusions

The development of social skills and emotional intelligence can be enhanced and improved in both typically developing children and children with ASD through the application of educational computer games. A factor of basic importance in communication and the establishment of social relations is the understanding of emotions as a third component of the ability EI model. Understanding emotions through pictures is closely related to children's inclusion in social situations. This enables children to focus on the feelings of others and the situations that relate to them.

Through the use of educational computer games, the child is given the opportunity to explore a variety of visual social situations and compare various emotions in different settings to hear emotions described and seek to find their corresponding adapted images that carry related information.

The fact that children with ASD do not know the meanings of words and have difficulty naming emotions but at the same time maintain their attention on the game, means that the game can have a positive effect on the recognition and learning emotions. These exercises can help children with ASD to develop better social skills.

The skill of understanding others' emotions can be developed through multiple repetitions, providing right/wrong options, and combining visual and audio perception. There are certain implied rules that have to be observed when working with children with ASD, namely focusing on a specific educational target, combining voice instruction with audio representation, using clear and unambiguous words, short phrases, and time lapses between instructions, combining target situational pictures as well as pictures of people and adapted ones. All these rules have been carefully taken into consideration and observed in the development of the games. Thus, we believe that this type of educational game can be used successfully in improving the understanding of emotions in children with difficulties to develop their social functioning.

Acknowledgements This study was supported by a grant from the Bulgarian National Scientific Fund - Contract N DN-05/10, 2016, "Pedagogical and Technological Issues of Educational Computer Games".

References

1. C. Lord, M. Elsabbagh, G. Baird, J. Veenstra-Vanderweele, Autism spectrum disorder. Lancet (London, England) **392**(10146), 508–520 (2018). https://doi.org/10.1016/S0140-6736(18)31129-22
2. C. Lord, T.S. Brugha, T. Charman et al., Autism spectrum disorder. Nat Rev Dis Primers **6**, 5 (2020). https://doi.org/10.1038/s41572-019-0138-4
3. American Psychiatric Association, 5th edn. Arlington: Diagnostic and Statistical Manual of Mental Disorders (2013)
4. I. Chaidi, A. Drigas, Autism, expression, and understanding of emotions: literature review. Int J Online Eng (iJOE). **16**, 94–111 (2020). https://doi.org/10.3991/ijoe.v16i02.11991
5. R.P. Hobson, J. Ouston, A. Lee, What's in a face? The case of autism. British J. Psychol. (London, England: 1953) **79**(Pt4), 441–453 (1988). https://doi.org/10.1111/j.2044-8295.1988.tb02745.x
6. R. Di Lorenzo, N.M. Munsters, E.K. Ward, M. de Jonge, C. Kemner, C. van den Boomen, Is it fear? Similar brain responses to fearful and neutral faces in infants with a heightened likelihood for autism spectrum disorder. J. Autism Dev. Disord. **51**(3), 961–972 (2021). https://doi.org/10.1007/s10803-020-04560-x
7. R.J. Luyster, J. Bick, A. Westerlund, C.A. Nelson 3rd., Testing the effects of expression, intensity and age on emotional face processing in ASD. Neuropsychologia **126**, 128–137 (2019). https://doi.org/10.1016/j.neuropsychologia.2017.06.023
8. E. Malaia, D. Cockerham, K. Rublein, Visual integration of fear and anger emotional cues by children on the autism spectrum and neurotypical peers: an EEG study. Neuropsychologia **126**, 138–146 (2019). https://doi.org/10.1016/j.neuropsychologia.2017.06.014
9. G. Dawson, SJ Webb, L. Carver, H. Panagiotides, J. McPartland, Young children with autism show atypical brain responses to fearful versus neutral facial expressions of emotion. Dev Sci. Jun. **7**(3), 340–59 (2004). https://doi.org/10.1111/j.1467-7687.2004.00352.x. PMID: 15595374
10. N.J. Sasson, A.E. Pinkham, L.P. Weittenhiller, D.J. Faso, C. Simpson, Context effects on facial affect recognition in schizophrenia and autism: behavioral and eye-tracking evidence. Schizophr. Bull. **42**(3), 675–683 (2016). https://doi.org/10.1093/schbul/sbv176
11. C. Samaey, S. Van der Donck, R. van Winkel, B. Boets, Facial expression processing across the autism-psychosis spectra: a review of neural findings and associations with adverse childhood events. Front. Psych. **11**, 592937 (2020). https://doi.org/10.3389/fpsyt.2020.592937

12. L. Bayet, H.F. Behrendt, J.K. Cataldo, A. Westerlund, C.A. Nelson, Recognition of facial emotions of varying intensities by three-year-olds. Dev. Psychol. **54**(12), 2240–2247 (2018). https://doi.org/10.1037/dev0000588
13. O. Golan, S. Baron-Cohen, J. Hill, Y. Golan, The "Reading the Mind in Films" task: complex emotion recognition in adults with and without autism spectrum conditions. Soc. Neurosci. **1**, 111–123 (2006). https://doi.org/10.1080/17470910600980986
14. S. Bölte, O. Golan, M. Goodwin, L. Zwaigenbaum, What can innovative technologies do for autism spectrum disorders? Autism: Int. J. Res. Practic. **14**, 155–159 (2010). https://doi.org/10.1177/1362361310365028
15. DiGennaro Reed, Florence & Jenkins, Sarah, Hirst, J., Applications of technology to teach social skills to children with autism. Res. Autism Spectrum Disord. **5**, 1003–1010 (2011). https://doi.org/10.1016/j.rasd.2011.01.022
16. M. Goodwin, Enhancing and accelerating the pace of autism research and treatment the promise of developing innovative technology. Focus Autism Other Develop. Disab. - Focus Autism Dev Disabil. 23 (2008). https://doi.org/10.1177/1088357608316678
17. P.G. Lacava, O. Golan, S. Baron-Cohen, B. Smith Myles, Using assistive technology to teach emotion recognition to students with Asperger syndrome: a pilot study. Remedial Spec. Educ. **28**(3), 174–181 (2007). https://doi.org/10.1177/07419325070280030601
18. M. Stankova, V. Ivanova, T. Kamenski, Use of educational computer games in the initial assessment and therapy of children with special educational needs in Bulgaria. TEM J. **7**, 488–494 (2018). https://doi.org/10.18421/TEM73-03
19. D. Tuparova, M. Stankova, T. Kamenski, E. Todorova, G. Tuparov, Attitudes towards the use of educational computer games in the initial assessment and therapy of children with special educational needs. Pedagogy **91**(5), 725–735 (2019)
20. M. Tobin, K. Drager, L. Richardson, A systematic review of social participation for adults with autism spectrum disorders: support, social functioning, and quality of life. Res Autism Spect. Disord. **8**, 214–229 (2014). https://doi.org/10.1016/j.rasd.2013.12.002
21. N.A. Farb, H.A. Chapman, A.K. Anderson, Emotions: form follows function. Curr. Opin. Neurobiol. **23**(3), 393–398 (2013). https://doi.org/10.1016/j.conb.2013.01.015
22. P. Salovey, J.D. Mayer, Emotional intelligence. Imagin. Cogn. Pers. **9**(3), 185–211 (1990). https://doi.org/10.2190/DUGG-P24E-52WK-6CDG
23. J.D. Mayer, P. Salovey, The intelligence of emotional intelligence. Intelligence **17**(4), 433–442 (1993). https://doi.org/10.1016/0160-2896(93)90010-3
24. J. Mayer, R. Roberts, S. Barsade, Human abilities: emotional intelligence. Annu. Rev. Psychol. **59**, 507–536 (2008). https://doi.org/10.1146/annurev.psych.59.103006.093646
25. J.D. Mayer, D.R. Caruso, P. Salovey, The ability model of emotional intelligence: principles and updates. Emot. Rev. **8**(4), 290–300 (2016). https://doi.org/10.1177/1754073916639667
26. J.D. Mayer, P. Salovey, D.R. Caruso, Emotional intelligence: new ability or eclectic traits? Am. Psychol. **63**(6), 503–517 (2008). https://doi.org/10.1037/0003-066X.63.6.503
27. J.D. Mayer, What is emotional intelligence? in *UNH Personality Lab,* vol 8 (2004). https://scholars.unh.edu/personality_lab/8
28. R.S. Rubin, D.C. Munz, W.H. Bommer, Leading from within: the effects of emotion recognition and personality on transformational leadership behavior. Acad. Manag. J. **48**(5), 845–858 (2005). https://doi.org/10.2307/20159701
29. G. Lewis, C. Lefevre, A. Young, Functional architecture of visual emotion recognition ability: a latent variable approach. J. Exper. Psychol. General. **145** (2016). https://doi.org/10.1037/xge0000160
30. J. Mayer, P. Salovey, D. Caruso, G. Sitarenios, *Measuring Emotional Intelligence with the MSCEIT V2.0*. Emotion (Washington, D.C.). 3. 97–105 (2003). https://doi.org/10.1037/1528-3542.3.1.97
31. M.A. Brackett, M. Bertoli, N. Elbertson, E. Bausseron, R. Castillo, P. Salovey, Emotional intelligence: Reconceptualizing the cognition-emotion link, in *Handbook of Cognition and Emotion.* ed. by M.D. Robinson, E. Watkins, E. Harmon-Jones (The Guilford Press, 2013), pp. 365–379

32. G. Tuparov, D. Tuparova, Approaches for integration of educational computer games in e-learning environments 0772–0776 (2018). https://doi.org/10.23919/MIPRO.2018.8400143
33. G. Tuparov, D. Keremedchiev, D. Tuparova, M. Stoyanova, Gamification and educational computer games in open source learning management systems as a part of assessment 1–5 (2018). https://doi.org/10.1109/ITHET.2018.8424768
34. J. Keebler, Validation of the GUESS-18: A Short Version of the Game User Experience Satisfaction Scale (GUESS) (2020)