Digital Twins and Artificial Intelligence as Pillars of Personalized Learning Models

Published Version:
Marco Furini, O.G. (2022). Digital Twins and Artificial Intelligence as Pillars of Personalized Learning Models. COMMUNICATIONS OF THE ACM, 65(4), 98-104 [10.1145/3478281].

Availability:
This version is available at: https://hdl.handle.net/11585/879245 since: 2022-03-22

Published:
DOI: http://doi.org/10.1145/3478281

Digital Twin and Artificial Intelligence as Pillars of Personalized Learning Models

Marco Furini [1]*

University of Modena and Reggio Emilia, Italy, marco.furini@unimore.it

Ombretta Gaggi

University of Padua, Italy, ombretta.gaggi@unipd.it

Silvia Mirri

University of Bologna, Italy, silvia.mirri@unibo.it

Manuela Montangero

University of Modena and Reggio Emilia, Italy, manuela.montangero@unimore.it

Elvira Pelle

University of Modena and Reggio Emilia, Italy, elvira.pelle@unimore.it

Francesco Poggi

University of Modena and Reggio Emilia, Italy, francesco.poggi@unimore.it

Catia Prandi

University of Bologna, Italy, catia.prandi2@unibo.it

When AI enters a sector, it doesn't change it, it revolutionizes it. Thanks to the analysis of digital twins, which are digital replicas of physical entities, AI algorithms know the music we like, predict TV series that will excite us, understand our weaknesses and our passions. They are transforming cities in their smart version, they are preparing the Industry 4.0 revolutions, they are improving health services, but they have been rarely used in the learning process. We are convinced that time has come to revolutionize current educational systems, which are too rigid and are unable to adequately support students with work commitments, family obligations, financial constraints, physical impairments. In this paper, we show that current scientific knowledge and technological tools can be used to build personalized, inclusive and accessible learning models. It is not a purely technological issue, because these models will have a tremendous social, cultural, and economic impact. Not to mention that their use will make it possible to meet some sustainable development goals set by the United Nations General Assembly.

CCS CONCEPTS • Applied computing • Computing methodologies • Human-centered computing

Additional Keywords and Phrases: Education Technology, E-inclusion, Human-Centered Design, Data Analysis Techniques, Internet of Things, Digital Twin.

[1]* Place the footnote text for the author (if applicable) here.

1 Introduction

The CoVid-19 Pandemic has highlighted that current educational systems are not well suited to support today's students as they never really evolved to meet the needs of modern students [22]. No wonder, the percentage of dropouts from university studies is quite high (40% in US and 10% in Europe [7,10]). Students' profile has changed over the years: while yesterday's students were mainly full-time, today's students face challenges such as work commitments, family obligations, financial constraints, physical impairments and, with no doubts, current learning models are not completely adequate in engaging students or in helping them understand core concepts [11]. One might think that this issue concerns only those who fail to complete their studies, but this is a shortsighted view as today's deficiency of educational systems will affect tomorrow's society welfare.

To improve current learning models, academic institutions around the world agree that time has come to improve the world of education, moving from a traditional approach where learning is standardized and confined to those with access to educational buildings to a new one able to personalize the students' educational pathway, so that learners might progress at their own pace [18, 22]. Future learning models need to address key questions such as how to reduce the dropout rate, how to support students with psycho-physical impairments, how to integrate on-site and online students, how to personalize the learning experience.

Digital twins, which are digital replicas of students, and artificial intelligence are going to be the pillars of future innovative, accessible, and personalized learning models [18]. The good news is that we can build these models today: artificial intelligence algorithms have made great strides in recent years as well as the use of technology in education has increased enormously in the last few months.

Indeed, if, on the one side, the COVID pandemic has strongly penalized the learning process of many people around the world, on the other hand, it has given a huge push towards the use of technology within classrooms (e.g., recording and streaming facilities) and within generic university spaces like libraries, study lounges, hallways (e.g., thermographic camera and IoT sensors to monitor indoor occupancy and people flows).

But why are current systems struggling to support today's students? Attending classes should be the simplest thing in the world, and for most students it is, but for some of them, this activity poses serious problems. Let us introduce Bob, a part-time student with a job that does not allow him to attend all on-site lectures, and Alice, a student with psycho-physical impairments whose conditions force her to miss some on-site lectures. As freshmen, they are motivated, but soon they realize that the educational system is too standardized: the teaching pace does not match their own learning pace. As a result, they stop attending lectures, they procrastinate exams, and, sooner or later, they will drop out from their university degree. What Alice and Bob need is an accessible, personalized, and inclusive learning model able to assist their learning activities by giving them suggestions on the educational material they need to study in order to learn at their own pace. For instance, suppose that each on-site lecture is also delivered live through streaming technologies, and then it is transformed into an engaging educational material (e.g., video pills, handouts) and released soon enough before the next lecture. Bob could keep up with the teaching pace by accessing this material when and where he finds it best to. Similarly, Alice could watch the lectures she missed and could deepen topics using the engaging educational material. In both cases, they are able to keep up with the lectures and they might attend on-site lessons whenever they want or can. Needless to say, any other student would benefit from a personalized approach as well. However, online lessons are not enough, and here it comes the use of digital twins.

A digital twin is a digital replica of a physical entity and it is created combining pieces of data coming from various sources. For instance, Bob's digital twin might be created with data related to Bob's academic background and studying activities (e.g., past exams, high-school grades, study time), Bob's behavior on campus (e.g., library activities, classroom time), Bob's digital educational material consumption (e.g., number and/or time spent watching sources like video lectures, handouts, slideshows, books, etc.). A smart analysis of digital twins might produce important suggestions and predictions for their physical entities [1]. Indeed, it might identify knowledge and gaps and could suggest educational material to fill these gaps.

Digital twins and artificial intelligence are essential to build a personalized learning model. Indeed, they will end up knowing Bob better than Bob himself and their suggestions/predictions might change the world of education. For instance, suppose that Bob has four months to study for the "Video communication" module and suppose he wants an excellent grade. Thanks to the analysis of his digital twin, algorithms based on machine learning techniques might suggest Bob to increase the attendance of on-site lessons, which handouts to study, which video lectures to watch, which topics to deepen, how much time to devote to study, to avoid sitting in the back rows of the classroom. Moreover, it will be possible to predict Bob's grade for the exam, it will be possible to notify him if he is at risk of not passing the exam or even of dropping out from University.

This example might sound like science fiction, but personalization based on digital twins and artificial intelligence is already present in many other environments [5] and there is no real reason not to use personalization in education systems as well.

In particular, personalized learning models might be built acting on the infrastructure, data and presentation layers shown in Figure 1: the infrastructure level has to include multimedia and IoT hardware to record activities within universities spaces; the data layer has to embed intelligent strategies to create the student's digital twin (using on-site, online and offline activities such as study time on handouts, watching time on video lectures, library and classroom time, past exams evaluation), smart approaches to produce enriched digital educational material starting from on-site lessons and intelligent algorithms to analyze digital twins and to personalize learning experiences; the presentation layer has to include accessible and personalized interfaces and services.

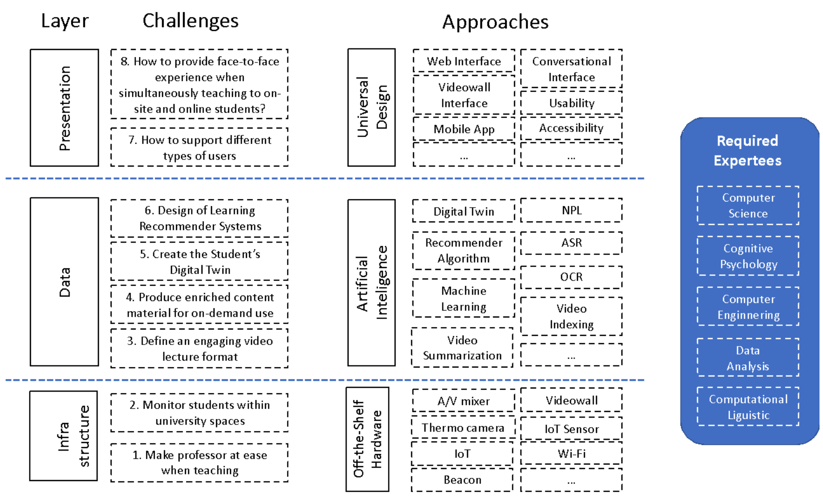

Figure 1. Personalized learning models might be built acting on the infrastructure, data and presentation layers. Each layer presents challenges that can be addressed with different approaches and with the cooperation of researchers with different backgrounds.

2 MULTIMEDIA AND IOT INFRASTRUCTURES

The multimedia and IoT infrastructure has to record activities performed within university spaces, has to use off-the-shelf technologies to keep costs under control (i.e., cost-effectiveness), has to allow possible expansions without requiring a complete redesign (i.e., scalability), and has to meet privacy regulations. Furthermore, it has to address two main challenges.

2.1 CHALLENGE #1: infrastructure to make teachers at ease

Once there was chalk and blackboard. Today the teacher's work is subject to multiple technological constraints ranging from microphone (wired or wireless), projector (VGA or HDMI), computer (personal or classroom-based), cameras (static or dynamic). The first challenge to face while building a personalized learning model that integrates on-site and online students is the use of off-the-shelf technologies to make teachers at ease. Indeed, educators should be free to use slideshow, touchscreen or the good old white/blackboard to lecture; the integration between on-site and online students should be as transparent as possible: the pace of the lesson should not be affected by the time necessary for the microphone to reach on-site students (i.e., online students can hear on-site students only if these latter use a microphone). Not to mention that sharing a microphone is against CoVid-19 containment rules, and that other possible problems, like a missing microphone or the presence of a short-length wired microphone, might arise in nowadays classrooms.

This challenge is quite easy to address. Indeed, in addition to the popularity achieved within the MOOC scenario, in recent years, video lectures have been considered a means of delivering knowledge and improving the learning process [12, 19] and during the CoVid-19 pandemic they have been the only means to keep in touch with students who were forced to stay at home. As a result, many universities around the world already have classrooms equipped to produce video lectures. In the unfortunate event that a classroom is not equipped with recording technology, off-the-shelf equipments are sufficient to build a multimedia infrastructure (e.g., a camera pointed at the teacher, a projector and a white screen to show the slides, a microphone for the teacher and an audio/video mixer to mix the different signals). If the lesson has to be broadcast live, streaming services are available in the market for a limited amount of money, if not for free.

The CoVid-19 pandemic has not only widened the use of video lectures but it has also highlighted the difficulties of dealing with on-site and online students simultaneously. Indeed, a poor oral and visual interaction among the teacher, on-site students, and online students might penalize the learning experience [8] and the lecture effectiveness. Again, off-the-shelf technologies can be of great help to us. Figure 2 summarizes how a hypothetical classroom should be: a videowall (right part of Figure 2) to display students connected from remote sites would improve the face-to-face learning experience, and ceiling environmental microphones would avoid the teacher to repeat questions at her microphone or to share the microphone among on-site students.

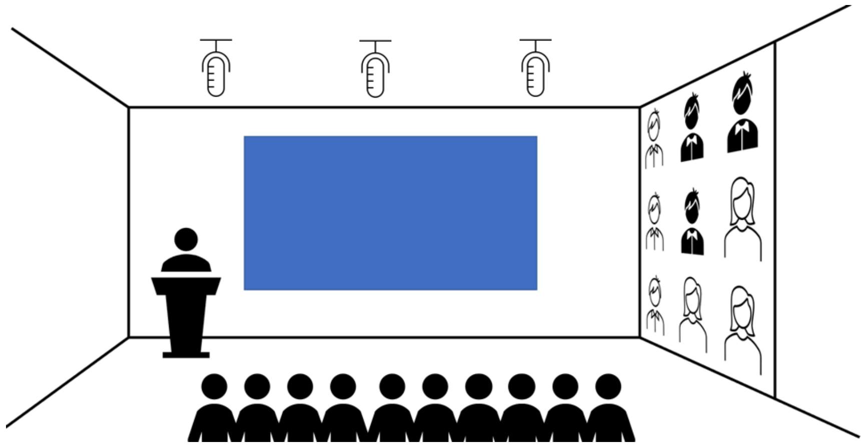

Figure 2. A hypothetical classroom with a videowall to improve the face-to-face learning experience and ceiling environmental microphones to ceiling microphones to allow on-site students to interact with the teacher and with online students.

2.2 CHALLENGE #2: infrastructure to monitor students within university spaces

To monitor and understand students' behaviors while they are conducting their educational activities within the university spaces (e.g., attending on-site lectures in classrooms and exercises in labs, consulting books at the library, study time in the lounge with some friends, or just relaxing in the campus cafeteria), it is necessary to exploit possible existing infrastructures (e.g., from any smart building facilities to Wi-Fi networks, from surveillance to thermographic cameras recently installed in some universities to monitor the CoVid-19 pandemic), and/or to install some off-the-shelf smart technologies.

For instance, the University of Bologna is already using IoT devices and tinyML strategies in the Cesena campus to monitor classrooms occupancy and to provide accessible indoor paths and orientation services to students with disabilities [15]. Similarly, specific hardware to monitor the CoVid-19 pandemic has been installed in many university spaces around the world (e.g., classroom, study lounges, libraries, hallways) to check body temperature or to measure social distance and people flows (e.g., surveillance and thermographic cameras) [16]. Adopting a frugal approach, these pieces of data might be transformed into precious information about the student's behavior [2]. For instance, indoor position and localization techniques and related devices (i.e., triangulation, BLE sensors, thermographic cameras) might provide information about Bob's presence within the classroom, understand if he is sitting in the back rows of the classroom during the math module lessons; thermographic cameras might be useful to get information about classroom occupancy and distances among the occupants; Wi-fi passive tracking and BLE sensors might be exploited to collect information about how long Alice has been working on the assignments with her group project mates in the study lounge.

3 Algorithms to produce enriched educational material

Video lectures are often produced with a fixed camera pointed at the teacher's face or with a simple recording of the slideshow. If you have ever watched such unedited video lectures produced by simply recording a classroom lesson, you will surely have noticed how long and boring they are: Bob would surely fall asleep watching such video lectures in the evening after a full work day. Indeed, movie theory teaches us that a long fixed shot (i.e., more than 20 seconds) is not pleasant to watch and that it is necessary to keep changing the framing of the movie to keep the viewer's attention high [1].

3.1 Challenge #3: Define an engaging video lecture format

Assume there is a camera pointed at the teacher and suppose the teacher is using a slideshow for her lecture. What video feed should online students see? Is it sufficient to split the screen to show both the teacher and the slideshow? Is the slideshow more important than the teacher? Or is ~~it~~ the teacher more important than the slideshow? Or do we have to present them with different sizes? We need to address these questions as the graphical layout greatly affects the learning experience. Likely, the video lecture should be produced as if there were a dedicated director, with change of framing, zoom in and zoom out between the teacher and the slides. For budget reasons, it is not thinkable to devote a human direction to each single produced video lecture; therefore, research efforts should be devoted to the design of algorithms and interfaces to produce and show educational contents in an automatic way. The final goal is to engage Bob, Alice (and all other students) into exploiting and consulting educational material derived from video lectures on a regular basis, without the teacher spending time or thoughts on such material production.

3.2 Challenge #4. Produce enriched content material for on-demand use

Suppose Bob realizes he needs to review some specific topics to prepare for an exam or to follow the upcoming lessons. He browses entire video lectures through VCR-like controls (play, fast-forward, rewind and pause) and feels like he is looking for a needle in a haystack. Suppose Alice is hearing-impaired: to her, video lectures are quite useless, on the contrary she would appreciate subtitles and textual handouts of the lectures. Moreover, they both would be happy to have a summary version of the video lecture as their personal commitments force them to watch several lectures after dinner.

We cannot ask teachers to produce such contents from scratch. Therefore research efforts should be devoted to the automatic production of such contents starting from the recorder video lectures [13, 20]. For instance, ad-hoc algorithms based on video summarization, automatic speech recognition, video indexing and text-analysis should produce video lecture summaries, audio/video material with contents aimed at people with hearing or visual disabilities (e.g., subtitles, audio version, zoomed contents), video pills focused on specific topics, handouts in textual formats.

4 Personalized learning experience

Assume now that Bob is in trouble with his learning activities. He stopped attending class lessons because he didn't understand what was being taught. He tried to fill in his gaps using the video lectures and the textbook, but it did not work. He is very disheartened, and he is thinking of giving up his study career when his fitness app reminds him to do 15 push-ups and a 10-minute jog to be able to lose the 2 kg in the next month. Looking at the app message, he thinks about how great an app telling you what and when to study would be. An app capable of providing highly personalized suggestions and predictions like "Bob, you should watch the following lectures", "Bob, you should attend to…", "Bob, you should study these handouts before watching this lesson" and might get predictions like "Bob, be careful, your study time is too short to pass the exam".

What happened to Bob happens to many students because current learning models do not consider the individual needs of students that might complicate the learning process: personal constraints, previous knowledge, psycho-sensorial-motion impairments. For instance, nearly 54% of US students who dropped out of college indicated they were unable to balance work and school [7].

Personalization of the learning process is currently considered the most promising approach that will impact and revolutionize the world of education [4, 6]. Therefore, research efforts should be devoted to personalizing the learning experience, a pathway that involves digital twins and artificial intelligence. Needless to say, all research efforts must consider privacy regulations.

4.1 Challenge #5. Create the Student's Digital Twin

A digital replica of a student might be created using data related to the student's behavior on campus, student's academic background and studying activities, student's consumption of digital educational materials (Figure 3). These types of data represents an important part of the students' digital twins [3] and should be either automatically collected by technologies (e.g., which lessons she attended, for how long, where she sat, how much time she spent in the library, time spent watching online lectures, type of digital material used, etc.) or manually entered by the student for the offline activities (e.g., academic background, possible disabilities, study time on books, study time on notes, etc.).

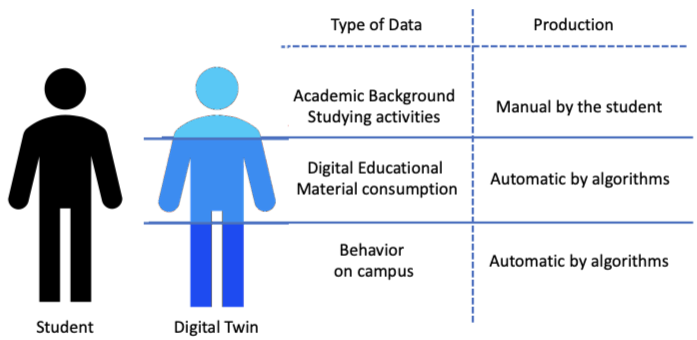

Figure 3. The student's digital twin might be created using data related to the student's behavior on campus, academic background and studying activities, use of digital educational materials.

4.2 Challenge #6. Design Recommender Algorithms to Personalize Learning

To transform the student's digital twin into highly personalized suggestions and predictions, research efforts should be devoted to the design of recommendations algorithms using classic big data analytics and artificial intelligence techniques such as classification, clustering, neural networks and deep learning. It would be like having a virtual assistant being able to help and stimulate the student's learning process. Other areas have been using users' digital twins and recommendation algorithms for a long time now, and have achieved very interesting results: music streaming services know which music we like, video streaming services know our TV preferences and suggest us which TV series to watch, fitness apps know our body better than ourselves and suggest us tailored physical exercises.

5 Design of Accessible and Personalized Interfaces and Services

A personalized learning experience should have an accessible and usable interface designed to take into account the needs of the individual user. The Universal Design approach [17] is the most promising candidate to develop such interfaces, as it puts users at the center of the design activities, allowing an early identification of their needs. Although not novel, the Universal Design concept has been rarely applied for both cultural and cost reasons, but it can bring benefits to students, in terms of better results and greater satisfaction, and to teachers and universities that offer these services.

Research efforts should focus on the design of the interfaces to support different types of students and to support teachers when a lesson is simultaneously given to on-site and online students and should meet the requirements of current privacy regulations (e.g., EU GDPR).

5.1 Challenge #7: how to support different types of users?

To understand the students' needs and to define the most suitable functionalities and interactions, the Universal Design approach suggests using individual interviews and focus groups. This task must necessarily be multidisciplinary and must require the involvement of computer scientists, cognitive psychologists, and statisticians to define the topics of the interviews and of the focus groups, and to analyze the results. The obtained knowledge should be used to build the interfaces. Note that this process should not be limited to visual interfaces, but it should be used to develop conversational interfaces as well to expand the number of supported students (e.g., sight-impaired users who might have difficulties in reading textual information unless using special assistive technology). Needless to say, the developed interfaces should be able to present educational contents in an engaging way and should motivate students to fill their educational profile with information related to the academic background and to studying activities (e.g., study time on books or on personal notes). Likely, studies on gamification and incentive mechanisms might give interesting insights on how to engage and motivate students to enter their data [14].

5.2 CHALLENGE #8. How to support teachers when the lesson is attended simultaneously by on-site and online students?

The simultaneous presence of on-site and online students is likely to become the new normality in the coming years and therefore it is necessary to mimic the face-to-face experience also from the teacher's point of view. Needless to say, this is not a trivial challenge as the high number of online students does not allow to simply use a computer screen monitor. A videowall is necessary, but not sufficient. Indeed, research efforts have to be devoted to understanding effective ways to display online students within the videowall and effective ways to allow interactions (e.g., how and when online students are allowed to intervene to ask questions or to answer a question posed by the teacher). Again, this is a multidisciplinary research that requires computer scientists to work with cognitive psychologists.

6 What will be the benefits of personalized learning?

Personalized learning models will have a deep social impact, as they will reduce the students' dropout, they will increase the percentage of successful students, they will integrate online and on-site students, they will support teachers in the mixed teaching modality, they will better support and integrate students with disabilities. In a few words, they will improve the overall quality of the learning process as well as the overall quality of the teaching process.

At the same time, personalized learning models will be able to meet Sustainable Development Goals (SDGs) set by the United Nations General Assembly [21]. In particular, it meets SDG 4 - Quality education (ensure inclusive and equitable quality education and promote university learning opportunities for all), SDG 10 - Reduced inequality (reduce inequalities among on-site and online students, limit digital barriers to students with disabilities).

Finally, personalized learning models will have a deep economic impact, as the progress of a country is strongly related to the level of the education of its citizens. By limiting students' dropout and equipping them with knowledge devoted to improving their success in university studies, personalized learning models will provide economic benefits not only to the individual, but also to the whole community, increasing its global educational and cultural level and enhancing the quality and the quantity of professionals.

In conclusion, one might argue that personalized learning is still a vision as it requires a considerable upfront investment, but that would be a very sight-short vision and an excuse to maintain the status quo. Indeed, without considering the social cost of dropouts, the average yearly lost tuition revenue from students that drop out US universities reaches the figure of $16.5 billion [7]. Moreover, the infrastructure is not disposable as the acquired multimedia and IoT technologies will last many years. It is therefore time to push on the innovation accelerator, as the industry is doing with the Industry 4.0 plan, because social and economic benefits of personalized learning models are enormous.

REFERENCES

[1] Adams B., Dorai C., Venkatesh S. (2002) Formulating Film Tempo. In: Dorai C., Venkatesh S. (eds) Media Computing. The Springer International Series in Video Computing, vol 4. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-1119-9_4

[2] Aldowah, H., Al-Samarraie, H., & Fauzy, W. M. (2019). Educational data mining and learning analytics for 21st century higher education: A review and synthesis. Telematics and Informatics, 37, 13-49.

[3] B. R. Barricelli, E. Casiraghi, J. Gliozzo, A. Petrini and S. Valtolina, "Human Digital Twin for Fitness Management," in IEEE Access, vol. 8, pp. 26637-26664, 2020, doi: 10.1109/ACCESS.2020.2971576.

[4] Andi Besse Firdausiah Mansur, Norazah Yusof, Ahmad Hoirul Basori, "Personalized Learning Model based on Deep Learning Algorithm for Student Behaviour Analytic" Procedia Computer Science, 2019, ISSN 1877-0509, https://doi.org/10.1016/j.procs.2019.12.094.

[5] Bleier A., De Keyser A., Verleye K. (2018) Customer Engagement Through Personalization and Customization. In Customer Engagement Marketing. Palgrave Macmillan, Cham. Springer. https://doi.org/10.1007/978-3-319-61985-9_4

[6] Christopher Alan Bonfield, Marie Salter, Alan Longmuir, Matthew Benson & Chie Adachi (2020) Transformation or evolution?: Education 4.0, teaching and learning in the digital age, Higher Education Pedagogies, 5:1, 223-246, DOI: 10.1080/23752696.2020.1816847

[7] Jaleesa Bustamante, "College Dropout Rates", EducationData.org, June 2019. Available at: https://educationdata.org/college-dropout-rates

[8] Delnevo, G., Mambelli, G., Rubano, V., Prandi, C. and Mirri, S. (2020). Almawhere 2.0: a pervasive system to facilitate indoor wayfinding. In *2020 IEEE 17th Annual Consumer Communications & Networking Conference (CCNC)* (pp. 1-4). IEEE.

[9] A. El Saddik, "Digital Twins: The Convergence of Multimedia Technologies", IEEE MultiMedia, 25(2), June 2018. Doi: 10.1109/MMUL.2018.023121167

[10] Eurostat Data, "Early leavers from education and training", May 2020. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Early_leavers_from_education_and_training#Overview

[11] Carol L. Fletcher, Jayce R. Warner, "CAPE: A Framework for Assessing Equity throughout the Computer Science Education Ecosystem", Communications of the ACM, February 2021, 10.1145/3442373

[12] M. Furini, G. Galli, M.C. Martini "An Online Education System to Produce and Distribute Video Lectures", Mobile Networks and Applications, June 2020. Vol. 25. No. 3. ISSN: 1572-8153. Springer US. DOI: doi.org/10.1007/s11036-019-01236-4

[13] M. Furini, F. Geraci, M. Montangero, M. Pellegrini, "STIMO: STIll and MOving Video Storyboard for the Web Scenario", Multimedia Tools and Applications Journal, Vol. 46, No. 1, pp. 47-69, January 2010. Springer Netherlands Editor. ISSN: 1380-7501 DOI: 10.1007/s11042-009-0307-7

[14] Keusch, F., & Zhang, C. (2017). A review of issues in gamified surveys. Social Science Computer Review, 35(2), 147-166.

[15] S.D. Kristiansen, T. Burner, B.H. Johnsen, G. Yates, "Face-to-face promotive interaction leading to successful cooperative learning: A review study", Cogent Education, October 2019. DOI: 10.1080/2331186X.2019.1674067

[16] Longo, E., Redondi, A.E., Bianchini, M., Bolzan, P. and Maffei, S., 2020, September. Smart Gate: a Modular System for Occupancy and Environmental Monitoring of Spaces. In *2020 5th International Conference on Smart and Sustainable Technologies (SpliTech)* (pp. 1-6). IEEE.

[17] Rose, D. H., & Meyer, A. (2002). Teaching every student in the digital age: Universal design for learning

[18] R. Saracco, "What would education be like in 2050? Digital Twins", IEEE Future Directions, February 2018. Available at: https://cmte.ieee.org/futuredirections/2018/02/21/what-would-education-be-like-in-2050-digital-twins/

[19] Scagnoli, N.I., Choo, J. and Tian, J. (2019), Students' insights on the use of video lectures in online classes. Br J Educ Technol, 50: 399-414. https://doi.org/10.1111/bjet.12572

[20] Hijung Valentina Shin, Floraine Berthouzoz, Wilmot Li, and Frédo Durand. 2015. Visual transcripts: lecture notes from blackboard-style lecture videos. ACM Trans. Graph. 34, 6, Article 240 (November 2015), 10 pages. DOI:https://doi.org/10.1145/2816795.2818123

[21] United Nations, "17 Goals to Transform Our World", 2015. Available at: https://www.un.org/sustainabledevelopment/

[22] World Economic Forum Report, "Schools of the Future", January 2020. Available at: https://www.weforum.org/reports/schools-of-the-future-defining-new-models-of-education-for-the-fourth-industrial-revolution