Smart Pedagogy for Smart Learning

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

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

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1 Concepts for Building an Epistemology

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

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

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

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

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

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

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

1.1 Learning Space: Building a Concept from Different Disciplines

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

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

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

cognition, and interaction strategies by shaping learning spaces and the activities that are organized in them. Researchers such as Franz Boas and Margaret Mead started a brand-new discipline to study customs and communities.

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

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

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

1.2 Classroom Space: Evolution of Active Learning

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

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

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

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

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

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

1.3 Expanding Knowledge: Evolution of School Technology

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

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

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

2 Learning Process: Toward Smart Learning

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

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

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

2.1 Learning Process in Virtual Learning Places

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

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

The introduction of word processors to classrooms in schools and universities had a major effect on written assignments. They generated a first meaningful mental change in teachers' understanding of knowledge, correction, and assessment in digital spaces, especially when applied to foreign language learning (Lee, 2000).

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

2.2 Computer-Assisted Learning Spaces: A New Learning Process

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

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

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

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

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

2.3 Building a New Knowledge Concept: Distance Learning Evolution

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

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

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

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

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

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

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

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

2.4 Smart Learning Environments: Personal Networks for Smart Learning

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

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

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

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

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

3 Education Models in Smart Learning Spaces

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

3.1 Educational Technology: Acquisition Models

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.3 Building Digital Skills for Developing Collective Responsibility

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

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

Inner Strength

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

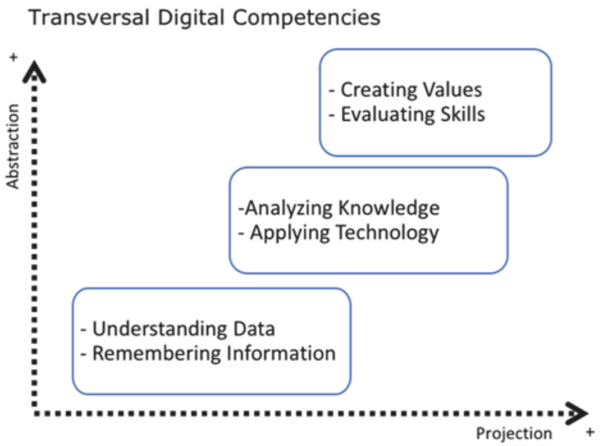

Fig. 1 Associating Bloom's taxonomy with UNESCO digital skills. (Chart by the authors)

Interactive Action

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

Transformational Knowledge

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

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

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

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

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

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

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

4 Information 4.0: Toward a Smart Learning Epistemology

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

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

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

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

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

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

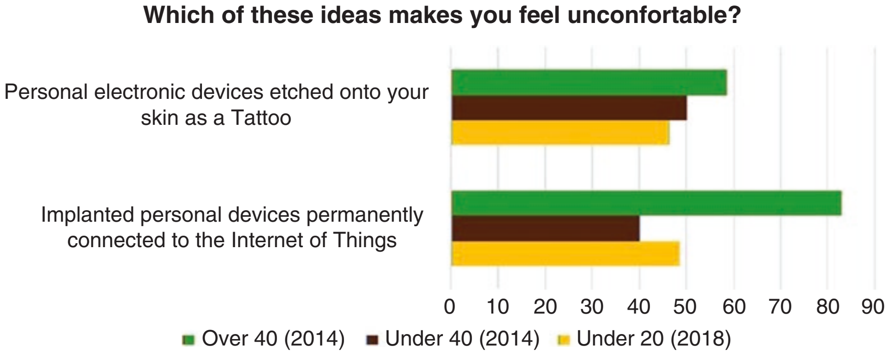

Fig. 2 Comparative levels of discomfort, by age group, with different types of bionic device. (Research by the authors)

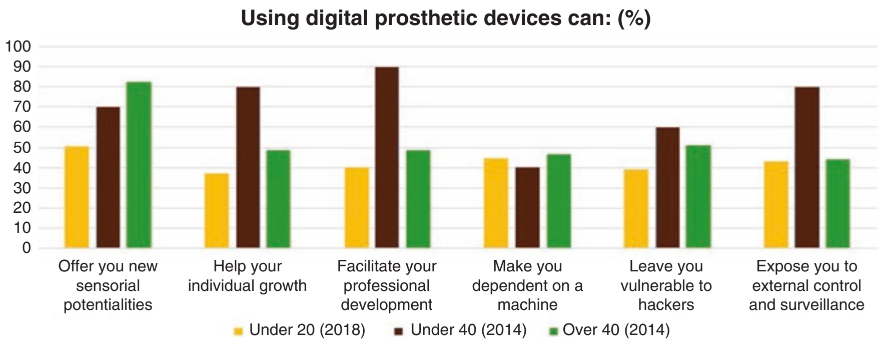

Fig. 3 Comparison, by age group, of perceptions about digital prosthetic devices. (Research by the authors)

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

4.1 A New Agent: Smart Conversational Learning Systems

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5 Conclusions

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

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

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

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

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