Conceptualising of smart education

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Smart education, a concept that describes learning in digital age, has gained increased attention. Broadly defined, smart learning environments represent a new wave of educational systems, involving an effective and efficient interplay of pedagogy, technology and their fusion towards the betterment of learning processes. Smart learning environments involve context-awareness that can combine a physical classroom with many virtual learning environments. The development of new technologies enables learners to learn more effectively, efficiently, flexibly and comfortably. Learners utilize smart devices to access digital resources through wireless network and to immerse in both personalised and seamless learning. This paper discusses the main characteristics of smart education and smart learning environments and sustains the relevance of taking the participation of future users into account during the design process to increase knowledge of the design and the implementation of new pedagogical approaches in smart learning environments.

Концептуално моделиране на интелигентни образователни системи (Елена Шойкова, Румен Николов, Евгения Ковачева). *Интелигентното образование, концепция, която описва ученето в дигиталната ера, придобива все по-голямо внимание. Широко дефинирани, умните учебни среди представляват нова вълна в образователните системи, включваща ефективно и ефикасно взаимодействие на педагогиката, технологиите и техния синтез с цел подобряване на учебните процеси. Приложението на новите технологии в синергия с иновативните образователни подходи позволява на учащите се да учат по-ефективно, ефикасно, гъвкаво и комфортно. Те използват интелигентни устройства за достъп до цифрови ресурси чрез безжични мрежи за осъществяване на персонализирано и безпрепятствено обучение. Настоящата статия, обсъжда концептуалната основа и основните характеристики на системите за интелигентно образование въз основа на богат анализ на постиженията в тази област.*

Introduction

With the exponential technological advances, anything could be instrumented, interconnected, and infused with intelligent design, so is education. Smart education has gained significance attention in recent years. Educational projects focused on smart education have been performed globally in recent years [1], [2], [3], [4], [5], [6]. In 1997, Malaysia first carried out a smart education project, Malaysian Smart School Implementation Plan. Smart schools, which are supported by government, aim to improve the educational system in order to achieve the National Philosophy of Education and to prepare work force that meets the challenges of the 21st century. Singapore has implemented the Intelligent Nation (iN2015) Master plan since 2006, in which technology-supported education is an important part. In the plan, eight Future Schools that focus on creating diverse learning environments are established. Australia collaborated with IBM and designed a smart, multi-disciplinary student-centric education system. Their system links schools, tertiary institutions and workforce training. South Korea had the SMART education project, the major tasks of which are reforming the educational system and improving educational infrastructures. New York' Smart School program emphasizes the role of technology integrated into the classroom. They focus on enhancing student achievement and prepare students to participate in 21st century economy. Finland also realized a smart education project that is on-going systemic learning solutions (SysTech) in 2011. The project aims at promoting 21st century learning with user-driven and

motivational learning solutions. UAE began to invest a smart learning program in 2012, which aims to shape new learning environment and culture in their national schools through the launch of smart classes. Overall, the smart education focus and developments has become a new trend in the global educational field.

Change and innovation in teaching and learning

Modern and sophisticated smart devices, smart systems, and smart technologies create unique and unprecedented opportunities for academic and training organizations in terms of new approaches to education, learning and teaching strategies, services to on-campus and remote/online students, set-up of modern classrooms and labs.

The coming together of several historical factors highlights the urgent need to engage in a step-change in education by developing new paradigms for learning and supporting these in a systematic way. The first, most widely acknowledged factor is the significant level of change occurring in the world, including: the shift from industrial to information-based knowledge economies; the globalisation of products, markets and companies; changing patterns of life, including greater life expectancy; significant advances in technologies requiring new kinds of literacy. The second factor is the changing nature of work. The shift towards technology-rich smart workplace environments requires multidisciplinary teamwork and greater levels of innovation and creativity. Manual labour and routine skills are increasingly being automated or sent offshore. The development of successful learners, confident and creative individuals, and active and informed citizens requires the deployment of new learning paradigms. Featuring innovative learning environments designed to support students' development of 21st century capabilities, the new learning paradigm builds capacity to: adapt to a rapidly changing world; operate successfully in changing work environments; work towards solving difficult, ill-defined problems/develop a proactive approach to solving ill-defined problems; be creative and innovative; learn and work collaboratively; develop local and global citizenship responsibilities; create and publish content. The adoption of new pedagogies to transform practice at scale requires connections between pedagogy and technology, underpinned by knowledge of how to bring about change.

Improved learning outcomes from high quality learning environments

Although there is evidence of significant integration of digital technologies in education, they are still regarded as optional in many cases. Better articulation of how digital technologies can support improved learning outcomes is required. Improved learning outcomes require high quality learning environments. There are three general principles about high quality learning environments, all of which can be enhanced through the good use of digital technologies.

Principle 1. There is a direct relationship between what students learn and how they learn. Students are more likely to achieve high quality learning outcomes when they have the opportunity to learn content within a meaningful context.

Principle 2. Developments in personalising learning make it possible for every student to learn. Personalising learning has been explained as every student should, within their university, have excellent teaching that suits them; building on what they know, fitting them for what they aspire to, and helping them reach their full potential. Thus every student can learn.

Principle 3. All learning should be student centred. Digital technologies make it possible for learners to engage in learning that is tailored to their particular situation.

Conceptual framework for opportunity to leverage the technology base

A strategic framework that both fits within existing educational systems and curricula and provides a roadmap for achieving significant innovative and lasting change is the Education Innovation Grid [7]. The Grid outlines four kinds of change: improving schools; supplementing schools; reinventing schools; and new paradigms. Achieving each change depends on re-thinking the way formal education engages with the world outside school to provide relevance, engagement and motivation (Fig. 1) [7].

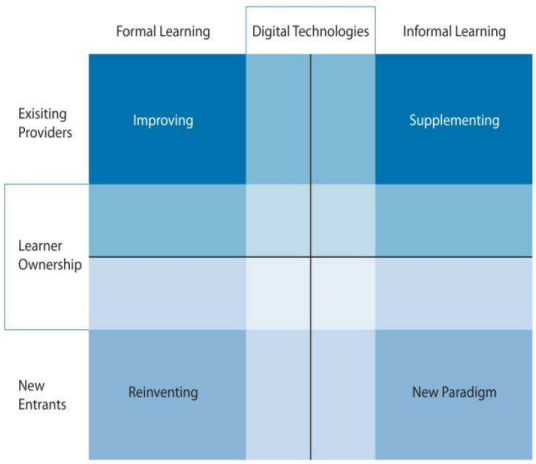

Fig.1. The Education Innovation Grid.

This framework acknowledges that learning no longer takes place solely within formal learning environments such as schools, but increasingly occurs within the home, community and other informal learning environments. Access to digital technologies has accelerated this shift, providing opportunities to connect the learning that takes place in informal settings, to learning within existing formal school settings. The most meaningful impact on learning occurs at the intersection of the two axes of the Grid: that is, where learners are deeply engaged with, and actively building, their knowledge from traditional and non-traditional sources using digital technologies to bridge their learning in formal and informal settings. Digital technologies have the biggest impact on teaching and learning when they combine formal and informal learning structures and result in improvements in, and supplements to, learning. Learning is also reinvented and new paradigms created when these technologies are used in partnership with new providers. Learning in such environments is more relevant, engaging and motivating.

There is a need to create and sustain knowledge-building environments where the focus is on the support of students' skills development. When used in support of contemporary, knowledge-building strategies, new and emergent technologies such as Internet of things, personal learning environments and augmented reality, mobile devices, will realise the meaningful impact on learning needed to equip students for the future and thereby support innovation in learning. One such group of strategies is referred to collectively as inquiry-based learning and includes project-based learning, problem-based learning, and design-based learning. These strategies engage students in completion of authentic tasks, investigation of meaningful problems, and the design or creation of a product respectively. Students work on these tasks and problems collaboratively in small groups, making it an even more powerful learning experience. It demonstrates significant learning benefits for: (1) student learning outcomes in terms of deeper learning and enhanced performance on complex tasks when engaged in such authentic learning, and significantly higher achievement on intellectually challenging tasks; (2) all students working on collaborative learning activities benefit; (3) students from low-income backgrounds and ethnic minorities, who benefit more than those from high-income, non-minority backgrounds. Design thinking as a more sophisticated approach where designing is seen as playing the key role in innovation (described as 'about finding creative solutions to problems') is increasingly being extolled by industry and educational institutions alike. The value of design thinking approach is in promoting abstract thinking and problem solving. These new approaches requires the development of new forms of assessment to support future planning (formative assessment for learning) and reporting against students' developmental progressions of these knowledge-building strategies.

Evolution of "smart classroom systems"

The concept of smart classroom was introduced several years ago and it is in permanent evolution and improvement since that time. Smart classroom represents a focus on reorienting our educational structures and business process around individual students and their learning needs. It is a transformative strategy to transition from traditional to a digital way of working that is meaningful, engaging and connected. The performed research clearly shows that smart education market, in general, and market of software and hardware for smart classrooms and smart universities, in particular, will exponentially grow in upcoming years [8].

The first (2001-2007) generations of smart classroom systems implementations were primarily focused on synchronous delivery of learning content to local and remote/online students as well as synchronous teacher-students and local student-to-remote student communications.

The second (2008-current) generation of smart classroom systems implementations is mainly based on active use of Internet of things, mobile technology, user/student/learner mobile devices and automatic communications between them and smart environment. Combining the Internet of things technology with social and behavioral analysis, an ordinary educational environment can be transform into a smart environment that actively listens and analyses voices, conversations, movements, behavior, etc., in order to reach a conclusion about the lecturers' presentation and listeners' satisfaction. For example, the Samsung Smart School solution [9] has three core components: (1) the interactive management solution, (2) the learning management system, and (3) the student information system (Fig. 2) [9].

Its multiple unique features and functions are targeted at smart school impact on education and benefits, including (1) increased interactivity, (2) personalized learning, (3) efficient classroom management, and (4) better student monitoring. We believe that the next generation of smart educational systems should significantly emphasize the smart features and functionality of smart systems (Table 1).

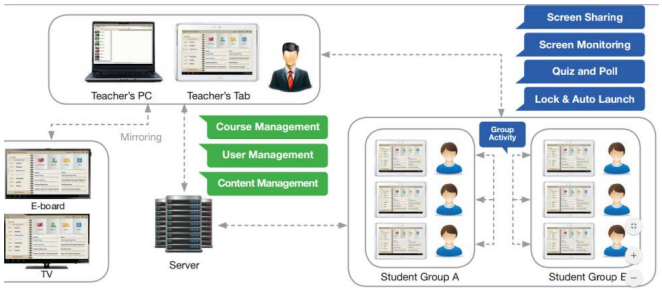

Fig.2. Samsung Smart School solution structure.

Table 1

Smartness levels

Smartness levels (i.e. ability to)	**Details**
Adapt	Ability to modify physical or behavioral characteristics to fit the environment or better survive in it.
Sense	Ability to identify, recognize, understand and/or become aware of phenomenon, event, object, impact, etc.
Infer	Ability to make logical conclusion(s) on the basis of raw data, processed information, observations, evidence, assumptions, rules and logic reasoning.
Learn	Ability to acquire new or modify existing knowledge, experience, behavior to improve performance, effectiveness, skills, etc.
Anticipate	Ability of thinking or reasoning to predict what is going to happen or what to do next.
Self-organize	Ability of a system to change its internal structure (components), self-regenerate and self-sustain in purposeful (non-random) manner under appropriate conditions but without an external agent/entity.

Therefore, next generation of smart classrooms should pay more attention to implementation of smartness maturity levels or intelligence levels, and abilities of various smart technologies [10]. The performed analysis shows it is expected that in near future (in upcoming 5….10 years) smart classroom concept and hardware/software solutions will have a significant role and be actively deployed by leading academic institutions – smart universities – in the world.

Smart education framework

There's no better time to start building a smarter education system – a student-centric, digital, collaborative approach to education that prepares the next generation to participate in the digital economy. Enterprise architecture of a smart city presents how the ICT would break 'silos' between different industry sectors including education system. (Fig.3).

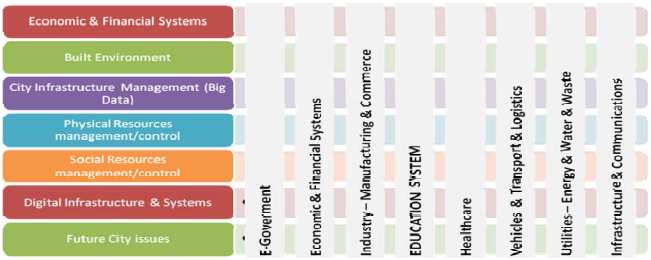

Fig.3. An enterprise architecture view of smart city.

Schools and universities can't do the hard work of educating students on their own. We must reach outside the traditional boundaries of our educational institutions and form learning networks with the businesses that will employ our future workforce. We need to move towards student-centred learning, where school data is provided in real time to teachers to guide, improve and individualise instruction and resources. Currently, the challenge ahead is to design learning ecosystems that integrate smart learning to personalise and self-regulate learning. According to Zhu, et al. [11], "the objective of smart education is to improve learners' quality of lifelong learning. It focuses on contextual, personalised and seamless learning to promote learners' emerging intelligence and facilitate their problem-solving ability in smart environments". Similarly, Kim, [12] consider that smart education is a learner-centric and service-oriented educational paradigm. In [13] Middleton also believes that smart education must be developed based on learner-centric aspects. In MESTRK [14] the features of smart learning defined as self-directed, motivated, adaptive, resource-enriched and technology-embedded are presented, while Lee, [15] proposed that the features of smart learning include formal and informal learning, social and collaborative learning, personalised and situated learning, and application and content focus. According to Gros [16], the smart learning is founded on two different types of technology: smart devices and intelligent technologies.

Smart devices refer to artefacts that exhibit some properties of ubiquitous computing, including artificial intelligence. The use of intelligent technologies, such as the Internet of things, wearable technology in the form of an accessory such as glasses, a backpack, or even clothing, cloud computing, Big data analytics (learning analytics) focuses on how data can be captured, analysed and directed towards improving learning and teaching

[17],[18],[19]. While the Internet of things is about collecting data and turning it into information, augmented reality is about providing people doing the work with that information in a form that allows them to do more with it. Augmented reality services enable a wide swath of users to see real-time, contextual information about their smart, connected products [20].

Despite the distinction between smart devices and intelligent technologies, the two are in fact related, because neither type of technology is independent. For instance, the Internet of things and most wearable technology require big data to generate personal information and provide the user with feedback.

Besides the technical characteristics, it is useful to analyse the characteristics that outline smart education. Along these lines, Zhu [11] describes ten key features that define smart education:

- Location-aware: in smart learning the location in real time is important data that the systems need in order to adapt the content and situation to the learner;
- Context-aware: exploring different activity scenarios and information;
- Socially-aware: sensing social relationships;
- Interoperable: setting standards for different resources, services and platforms;
- Seamless connection: providing continuous service when any device connects;
- Adaptable: pushing learning resources according to access, preference and demand;
- Ubiquitous: predicting learner demands until clearly expressed, providing visual and transparent access to learning resources and services;
- Whole record: recording learning path data to mine and analyse in depth, then providing reasonable assessment, suggestions and pushing on-demand service;
- Natural interaction: transferring the senses of multimodal interaction, including position and facial expression recognition;
- High engagement: immersion in multidirectional interactive learning experiences in technology-enriched environments.

In summary, in smart learning, location in real time can be important to adapt the content and situation to the learner. However, location is not always a necessary condition in smart learning. The most important characteristic is that the system will be able to advise and predict learner needs. Smart learning is a learning system that provides advising learners to learn in the real world. The goal of a smart learning environment is to provide self-learning, self-motivated and personalised services.

According to Spector [21], it is also highly desirable for the design of smart learning environments to provide motivation for a variety of learners, recognising learners' competencies, learning styles and interests. Moreover, the learning environment must provide personalised assignments and/or formative feedback, and should include pedagogical strategies that support:

- Conversation: the learning environment can engage the learner in a dialogue or facilitate a group dialogue on a relevant topic or problem;
- Reflection: the learning environment can generate self-assessment based on student progress and performance, preferably suggesting activities and attributes in the learning environment that can be adjusted to improve overall effectiveness;
- Innovation: the learning environment uses new and emerging technologies and leverages innovative technologies in creative ways to support learning and instruction;
- Self-organisation: the learning environment can rearrange resources and control mechanisms to improve its performance over time based on data that are automatically collected and used to refine how the environment interacts with learners in various circumstances.

According to Hwang [22], a smart learning environment must:

- Detect and take into account the real-world contexts.
- Situate learners in real-world scenarios.
- Adapt learning interfaces for individual learners.
- Adapt learning tasks for individual learners.
- Provide personalised feedback or guidance.
- Provide learning guidance or support across disciplines.
- Provide learning guidance or support across contexts.
- Recommend learning tools or strategies.
- Consider learners' online learning status.
- Consider learners' real-world learning status.
- Facilitate both formal and informal learning.
- Take multiple personal and environmental factors into account.
- Interact with users via multiple channels.
- Provide learners with support in advance, across real and virtual contexts.

Smart pedagogies must take into account the knowledge creation metaphor of learning that

highlights competencies in producing knowledge. "The knowledge-pull approach to learning is based on providing learners with access to a plethora of tacit/explicit knowledge nodes and handing over control to them to select and aggregate the nodes in the way they deem fit, to enrich their personal knowledge networks"[23]. These skills are increasingly related to the use of digital technology which provides a flexible way to support modelling, sketching, testing and social interactions.

The ubiquity of technology calls for a shift away from low-level use of technology, such as drilling, practice and looking up information. Rather, smart education encourages a 'high-level' use of technology, utilising it as a 'mind tool' or 'intellectual partner' for creativity, collaboration and multimedia productivity. Technology must enable and accelerate learning relationships between teachers and students and between students and other learning partners, such as peers, mentors and others with similar learning interests.

Deep learning tasks re-structure learning activities from a singular focus on content mastery to the explicit development of students' capacities to learn, create and proactively implement their learning. In their most effective instances, deep learning tasks are guided by clear and appropriately challenging learning goals, which ideally incorporate both curricular content and students' interests or aspirations; include specific and precise success criteria that help both teacher and student know how well the goals are being achieved; and, incorporate feedback and formative evaluation cycles into the learning and doing processes, building students' self-confidence and proactive dispositions.

The development of smart learning technologies provides great potential for the enhancement of automated assessments. According to Kopainsky [24] learning analytics systems can be used to balance evidence-based, real-time assessment (especially self-assessment) with intelligent digital systems designed to foster critical thinking and problem solving. Data from tracking and managing learning activities can inform learning design by providing evidence to support the choice of media and sequence of activities. Such analytical feedback for students can be continuous during a course and enable learners to focus on areas of weakness.

Besides the use of technology, new pedagogies emphasise the active engagement of students in their own learning, learner responsibility, metacognitive skills and a dialogical, collaborative model of teaching and learning. For this reason, self-assessment and peer-assessment are also very important. Andrade [25] provides a helpful definition of self-assessment that focuses on the formative learning that it can promote: "Self-assessment is a process of formative assessment during which students reflect on and evaluate the quality of their work and their learning, judge the degree to which they reflect explicitly stated goals or criteria, identify strengths and weaknesses in their work, and revise accordingly".

Peer assessment involves students taking responsibility for assessing the work of their peers. They can therefore be engaged in providing feedback for their peers. It is a powerful way for students to gain a better understanding of assessment criteria and can also transfer some ownership of the assessment process to them, thereby potentially increasing their motivation and engagement.

Some considerations about the design of smart learning environments

The International Association for Smart Learning Environments [26] embraces a broad interpretation of what constitutes a smart learning environment: A learning environment can be considered smart when it makes use of adaptive technologies or when it is designed to include innovative features and capabilities that improve understanding and performance. In a general sense, a smart learning environment is one that is effective, efficient and engaging. Broadly defined, smart learning environments represent a new wave of educational systems, involving an effective and efficient interplay of pedagogy, technology and their fusion towards the betterment of learning processes (Fig. 4) [26].

Fig.4. Smart learning environments - an effective and efficient interplay of pedagogy, technology and their fusion towards.

There are two key issues that must be taken into account when designing smart learning environments: a) user participation in the design, and, b) the provision of useful support to offer users appropriate feedback.

Participatory design. The potential for smart learning depends on the design of the learning environment and it is important to design the ecosystems of learning using participatory processes. Smart learning must emphasise the idea of

transparently immersive experiences - transparency between people, businesses and devices - ever more adaptable, contextual and unimpeded at work, at university and at home, interacting with business and other people (Fig. 5).

Fig. 5. The user experience in a hyper connected world.

The field of learning experience design has developed in recent years and now offers a set of methods, tools, systems and models [27] that can empower educators in the design of scenarios that provide richer learning experiences (Fig.6).

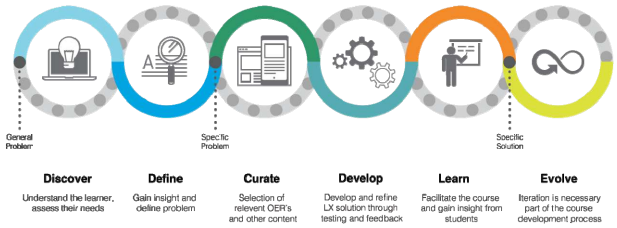

Fig.6. Design-thinking principles drive "learner experience design (LX)."(Adopted from iDesign/LX).

The design should articulate and orchestrate the disciplinary content, pedagogical theory, experience based on practice and the use of increasingly diverse and sophisticated technological resources. Design is, by nature, iterative and collaborative. It requires discussion, reflection, critique and implementation. Designing for complex assemblages of humans and things requires an epistemic fluency that is rare, indeed sometimes frowned upon, in educational practice. In the design of smart learning environments, it is necessary to take into account that the user will interact with heterogeneous devices that must be successfully integrated and interconnected. According to Pons [28], "it is unlikely that developers can come up with systems capable of discovering the user's contextual preferences with a high degree of accuracy in all cases without any input from users themselves. The user's preferences should therefore form the key knowledge to be identified during the initial stages of the configuration."

Participatory design is being used to increase the knowledge of smart device design. For instance, Pons et al. [28] applied participatory methodologies to design a visual language and tool to be used when creating future tangible tabletop-based editors for personalising smart environments. The design has served to identify the characteristics of visualisation, taking into account differences in the learners' knowledge. Durall [29] applied participatory design to develop Feeler, a prototype created to help people develop an awareness of how different habits and mental states have an impact on their learning. Thus, Feeler aims to foster an awareness of and reflection on study activity. Feeler's design is based on the assumption that learning technology built on monitoring physiological data should aim to empower students by helping them understand the different aspects that have an impact on their learning performance. Therefore, Feeler explores several strategies for supporting reflection in the prototype design such as the creation of time, asking reflective questions and leaving some aspects incomplete in order to encourage users to enquire into the meaning.

Visualisation of data. Feedback has been considered a key tool for helping students to improve performance. Traditional feedback usually relates to learners' mechanisms of communication with their teachers and colleagues. As mentioned in the previous section, the use of technology adds new possibilities for tracking learners' activity and offers them more immediate feedback about their learning performance. However, most efforts to use learning analytics focus on providing information for instructors in order to refine their pedagogical strategies [30]. Very rarely are students considered the main receivers of learning analytics data or given the opportunity to use the information to reflect on their learning activity and self-regulate their learning more efficiently. Learning analytics could actually disempower learners by making them reliant on institutional feedback [31]. Most analytics studies have drawn on historical data to identify patterns in students' learning behaviour which are then related to academic performance and/or retention. Essentially there is a knowledge gap for teachers attempting to bridge the divide between the information provided by learning analytics and the types of pedagogical actions designed by teachers to support learning. In response to the use of learning analytics as a tool at the service of the institution, a growing number of scholars have begun to advocate student-centred analytics [32]. In line with these authors, we consider that learning analytics can and should be used as a tool for reflection and metacognition to support selfregulated learning [33].

It is vital to identify the main challenges in the design of learning environments that make use of learning analytics to foster reflection. The most urgent challenges to be faced fall into two categories: data and visualisation. What sort of data is most meaningful for learners? What types of visualisation can foster reflection most successfully? Transforming data into knowledge is a cognitive process that can be supported by the way in which data is made available. Information visualisation has been recognised as a tool for sense-making, since it helps synthesise complex information and facilitates comparisons and inferences [34]. Therefore, in order to truly use analytics to help students become autonomous learners, it is necessary to adopt a student-centred approach. There is a need to rethink how learning indicators are selected and to what extent they contribute to conceiving learning as a process instead of in terms of outcomes. In this regard, allowing students to decide what aspects they are going to monitor and analyse could help make learning analytics a tool for reflection on smart learning environments.

Conclusion

Learning anytime anywhere is not a novel concept. However, where such processes are considered a common activity during life, it is important to explicitly design and intentionally support them. As mentioned above, smart learning environments must integrate formal and informal learning in order to create autonomous adaptive learning environments to support individual learners. These environments need to use big data and learning analytics techniques to integrate real-time information about learners' location and historical data to identify meaningful learning patterns. Smart learning environments involve context-awareness that can combine a physical classroom with many virtual learning environments. A new concept of 'Education as a Service' is emerging as an approach to deal with the challenges of global and open markets. Educational resources in this approach are made easily accessible to global learners by delivering them as a service. From this perspective, we can expect traditional education organisational structures and teaching processes to undergo great changes. For example, lectures may be separated from the course itself. Some of the lectures may be given by a teacher other than the teacher responsible for the course. Assessments may be separated too, where a third party may conduct the tests instead of the course teacher. Services must consider the learners' viewpoint and learning experience. In a smart learning environment, learners would have different service choices at different learning stages, where these services are provided by different educational facilities, either online or physically. Knowing more about students' learning performance and perceptions is vital for researchers to be able to develop more effective smart learning environments. An evaluation can be conducted using various aspects, such as learning achievement, problem-solving ability, self-efficacy and self-regulation. In the meantime, it is worth investigating the effects of smart learning environments on the learning performance and perceptions of students with different learning styles, cognitive styles, or other personal characteristics. Having an in-depth understanding of learners' behaviours and learning patterns will be very important to researchers and educators in developing more effective learning tools and strategies.

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