Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 219 (2023) 1057–1066

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022

A Reference Model for Artificial Intelligence Techniques in Stimulating Reasoning, and Cognitive and Motor Development

Vitor Santos[a,*], Henrique Mamede[b], Clara Silveira[c], Leonilde Reis[d]

[a]*NOVAIMS da Universidade Nova de Lisboa, Portugal.*
[b]*INESC TEC, Departamento de Ciências e Tecnologia, Universidade Aberta, Lisboa, Portugal.*
[c]*Escola Superior de Tecnologia e Gestão, Instituto Politécnico da Guarda, Guarda, Portugal.*
[d]*Escola Superior de Ciências Empresariais, Instituto Politécnico de Setúbal, Setúbal, Portugal.*

Abstract

Artificial Intelligence is increasingly being discussed as something essential and pressing in all aspects and areas of society. Its potential use in education is no exception. Artificial Intelligence, in particular, and technologies, in general, are unavoidable elements to be considered in the teaching-learning process at all levels of education and training.
There are many initiatives, essentially exploratory in nature, for the application of Artificial Intelligence in this process. Therefore, it is imperative to understand how they can be used for this purpose and how they relate to pedagogical methods.
In the present study, and within this context, we address how Artificial Intelligence can be used in software to support cognitive and motor development and stimulate reasoning. We propose a reference model for techniques for this purpose. Concrete cases of existing applications are presented to better illustrate the potential of Artificial Intelligence in education.

Peer-review under responsibility of the scientific committee of the CENTERIS – International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022

Keywords: Artificial Intelligence, Teaching, Cognitive Development, Motor Development.

* Corresponding author.
E-mail address: vsantos@novaims.unl.pt

Peer-review under responsibility of the scientific committee of the CENTERIS – International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2022
10.1016/j.procs.2023.01.384

1. Introduction

Artificial Intelligence (AI) based technologies for teaching are spreading and being used more and more because of their advantages. [2,16,33]. The establishment of the Beijing Consensus [29], which is the first AI and education document adopted by UNESCO member states, has brought to the attention of education leaders and policymakers worldwide the recognition of the urgency to discuss and define the future of education. As a result, AI in Education (AIED) - the intersection of the AI and education domains - has become a strategic priority in many countries [30].

However, there are barriers to its effective and widespread use. For example, Wang and Cheng (2021) identify barriers in secondary schools in Hong Kong, findings that can be generalized in the sense that they are not culturally dependent.

If we look at the actual situation in most of the various schools and training centers spread throughout Portugal, we see that its use is not yet as widespread as one would expect. In this paper, we refer, in particular, to what concerns the use of Artificial Intelligence techniques to support the cognitive and motor development of children and adolescents and stimulate their reasoning.

There are different strategies for building Artificial Intelligence, and it is possible to use each one or a combination of them to address different specific problems. In solving some types of problems, only a few strategies are possible. In other problems, there are several alternative paths.

Artificial Intelligence is a vast area of computer science composed of different specialty subfields. These domains include Automatic programming, Planning; Learning; Reasoning; Natural language; Problem-solving, Search, Genetics and Evolution, Knowledge representation, Vision, Simulation and social modeling, Speech, Affective computation, Demonstration of theorems; Artificial life, among others. Regardless of the area or subarea, it is possible to identify three base approaches for building intelligent systems: the computational or symbolic, the connectionist, and the biological [9].

The Symbolic or Computational approach is based on a computational metaphor, in which intelligence is defined by the sum of processes that simulate reasoning and computational structures. In the so-called connectionist approach, intelligence is considered an emergent property of the interactions of a large number of elementary processing units, usually neurons or artificial lymphocytes, that simplistically replicate the functioning of their biological counterparts. The biological approach is based on the computer simulation of Darwin's theory of natural selection of species. The "intelligence" emerges from the evolution and learning of a species of artificial individuals in each context.

Physical and motor development can be understood as the development of a child's or adolescent's motor skills. In children, everything referring to the act of crawling, walking, running, grasping objects, sucking, eating, drinking, etc. In adolescents, it is the biological part of the body that transforms throughout life [11]. Regarding cognitive development, in the context of this text, we refer essentially to Jean Piaget's theory of cognition development [18], i.e., the set of brain/mental capacities necessary to obtain knowledge about the world that involves thinking, reasoning, abstraction, language, memory, attention, creativity, and problem-solving skills, among other functions.

Activities that stimulate reasoning are understood as all activities that directly or indirectly encourage and promote the development of reasoning [25]. Good examples are games (chess, checkers, go, ...), hobbies (crossword puzzles, sudoku, ...), puzzles (Cluedo, ...), curiosities (history, science, ...), and challenges (competitions, self-overcoming, ...).

We seek to answer whether technologies based on Artificial Intelligence can help in physical and motor development and stimulate reasoning. It is known that, with respect to physical and motor development, they have an enormous potential to complement the work of a teacher/tutor, for example, obtained by participating in games that require increasing motor coordination, agility, and speed. Regarding the stimulus to reasoning, for example, by making games more "intelligent," hobbies and puzzles more dynamic and challenging, they contribute relevantly to the learner's facing increasing difficulties and thus receiving an evolving stimulus adjusted to the learner's evolution [3].

This paper presents a proposed reference model for using AI techniques to stimulate reasoning and cognitive and motor development. We better illustrate the potential of AI in education by presenting some cases in which, using the application of Artificial Intelligence in well-known contexts, platforms are obtained that enhance physical and motor development.

2. Methodology

We used the Design Science Research (DSR) methodology for this work. DSR is an approach with growing relevance in information systems research based on the construction of an artifact (in this case, a reference model) that aims to ensure answers to the questions posed by the study problem [19]. Since we intend to design and implement an artifact, we consider this to be the most appropriate methodology for its elaboration, implementation, and critical analysis of the results. The artifact is the central element of the Design Science Research (DSR) and must be well tested, understood and documented to ensure its pragmatic validity. The evaluation is a central phase of the process, in which the usefulness, quality and effectiveness of the artifact are demonstrated, using well-executed evaluation methods. The sequence of steps provided in the methodology is illustrated in Fig. 1.

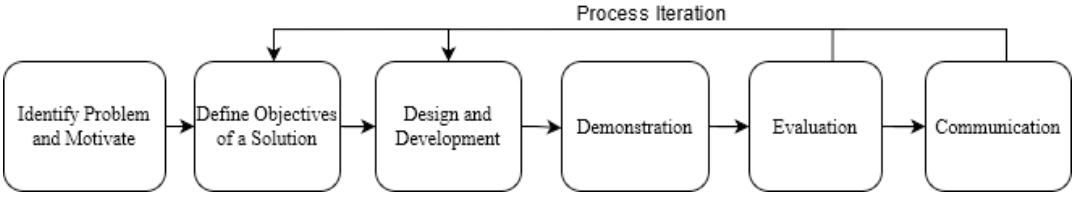

Fig. 1. DSR sequential activities [19].

In the form of a reference model, the artifact to be proposed will be materialized by the collection and analysis of AI application cases in stimulating reasoning and cognitive and motor development. After this phase, we will validate it through interviews with experts. With this collected data, we will process it, incorporate the identified improvements, and conclude.

3. Artificial Intelligence technologies in teaching

It is always tricky to predict the future. However, it is possible that technologies currently in use will see their use expanded and that technologies of growing importance, such as Artificial Intelligence and Virtual Reality, will be progressively integrated into schools.

There are countless cases of Artificial Intelligence being applied to support teaching and education, allowing teachers novel ways of teaching-learning and increasing the efficiency of the whole process [28].

The Internet has enabled a large proportion of children to access quality teaching platforms and content. These collaborative platforms and teaching aid applications allow access to school material and communication; and support knowledge sharing between school institutions in all areas and different languages [8]. They can be used on all computer operating systems, mobile devices, and the Internet [4]. An example of context for the use of AI techniques is known as MOOC (Massive Open Online Courses). This system allows several students to have access to numerous courses, making it possible, for example, for a teenage boy from Bangladesh to attend a digital circuits course remotely and learn other subjects that do not exist in schools in his/her country. Another technology related to mobile devices is E-books (electronic books). All material is available 24 hours a day, there is a text search functionality, and the portability of texts is an advantage [6].

Furthermore, the availability of specialized periodicals and scientific and literary texts, libraries, music, films online, despite the controversy related to copyright and intellectual property and the consequent impact and challenges posed to the sustainability of markets, will definitely contribute to broadening and disseminating knowledge [23]. Besides the existence of virtual libraries, museums, and countless sites for sharing music, videos, films, or series, there are multiple thematic sites and ad hoc offers focused on authors, geographies, and even works.

Artificial Intelligence will increasingly have a decisive say. Noteworthy are automatic translation systems, which are already fundamental in breaking down language barriers, the support systems for the development and stimulation of reasoning in children and teenagers (intelligent tutors, games, ...), and the support systems for motor development. In this last case, a good example is the Nintendo Wii, which through movement sensors, helps improve the motor

activities of students, namely those with Autism and Down Syndrome. Another instance is the game Wii Fit, which can help individuals with difficulties in movement and balance through a platform because it offers instant feedback on the movements performed on the platform. In addition, technologies for automatic translation from sign language to spoken language and from spoken language to sign language will remove traditional accessibility barriers for mute and/or deaf students.

4. Artificial Intelligence use cases in teaching

4.1 Physical and motor development

There are many examples of the use of AI, in association with other types of technologies, to support physical and motor development. It is easy to find illustrative cases in the education of children and young people, in sports, and the support of people with special needs, from dexterity support (fine motor skills), to training and preparation of high competition athletes or intelligent software with self-adaptation of interfaces for special users [21,22]. Usually, AI techniques appear together with other important technologies. In particular with the so-called Virtual Reality and IoT (Internet of Things) technologies [7, 27].

The first is a rapidly expanding and already relatively advanced technology that allows the simulation of real-life or fictitious environments. It has already been consolidated in applications in several areas, such as education, health, and entertainment. There are several types of Virtual environments: The "fully immersive" ones where everything is virtual objects; the "Augmented Reality" ones where immersion in the real world is affected by the addition of virtual elements; and the "non-immersive" ones where the virtual environments are seen through windows (the screens).

The second, IoT, constitutes a set of emerging technologies that can be defined as a network connecting various technologies through the Internet and allowing communication and the exchange of information between different devices and systems. With the spread of Artificial Intelligence techniques, the progressive introduction of IoT-based intelligent systems can be expected [14]. However, it cannot be said that the education sector is at the forefront of adopting smart IoT technologies. A school that uses smart devices promotes a more advanced level of personalized learning [20]. These devices that use Wi-Fi to receive instructions and send data can help students utilize key school resources, create more innovative lesson plans, secure campuses, and improve access to information. Several examples and application cases can be considered. One example is wearable technology on students in a school that automatically counts students as being present, late (they are on school premises but not in their class), or absent (they are not on school premises) when the bell rings. With that information, the system will determine the information for the parents and provide links to the elements of the subject matter that the student missed. These same wearable devices can also help determine when the class is too tired or becomes inattentive and in need of a break, and the smart boards will record all the notes taken in a class. The inclusion of smart microphones in this solution will even allow it to recognize when a teacher mentions that there is a homework assignment due and update the students' calendars accordingly.

An excellent example of using IoT to support students' physical and motor development is the use of performance monitoring sensors in physical education (see example in Fig. 2). These sensors collect data that can be analyzed by AI systems and teachers and be translated into adaptive practices, such as changing the pace of practice and training for better energy management and increased performance.

Fig. 2. Shoe-based wearable sensors.

These types of applications can also be considered game-changers, as they provide a large number of educational games that provide exciting features and possibilities in teaching and learning and thereby aid cognitive development.

4.2 Reasoning stimulus

Also, with regard to stimulating reasoning, there are multiple examples of the use of Artificial Intelligence, either, for example, by applying 3D systems or by applying natural language processing [10,13]. Next, we analyze three relevant cases that we consider significant insofar as they allow the use of AI in stimulating reasoning.

Chess

In recent years, technological advances have made it possible to investigate better which factors are related between chess and human cognitive abilities. The first to study and relate chess with human intelligence was the French psychologist Alfred Binet, who is considered the father of intelligence tests. In 1894, he conducted studies where he asked chess players to describe how they reasoned during a chess match [5].

Play helps develop skills considered relevant to cognitive development. These skills include logical thinking, concentration, strategy, patience, memory, mental and physical control, and the perspective of future scenarios, which are useful for decision making.

Artificial Intelligence techniques in chess games date to the 60s/70s. Even then, using techniques from Game Theory and "Alpha-Beta pruning" search tricks, computers managed to rank among the top 100 in the world at the tournament level. In 1982 the Belle Chess Computer, which included special circuits for motion generation and evaluation, achieved a score of 2250, with beginners having about 1000 and the world champion at 2750. In 1987 Hitech System's system, capable of evaluating 10 million positions per move, defeated the world champion. In 1990 Deep Thought 2, with a capacity to evaluate 500 million positions per move, was among the top 100 globally. In 1995 Deep Blue (1024 specialized parallel chips) could analyze one billion positions per second. Today, an advanced Artificial Intelligence system, such as Google's Alpha Go Zero, can learn and master the game of chess in 24 hours to the point of defeating world champions [12,32].

Cluedo

Cluedo (also known as Clue) is a mystery game for three to six players created by Anthony E. Pratt of Birmingham, England. The game was first manufactured in 1949 in the United Kingdom. The game's objective is to determine who murdered the game's victim (Dr. Black), the location of the crime, and what weapon was used. Each player assumes the role of one of the six suspects and tries to deduce the correct answer by strategically moving around a game board representing the rooms of a mansion (see Fig. 3) and collecting clues about the circumstances of the murder from the other players. It is possible to establish deductive reasoning starting from the clues, which can be reproduced by an AI system, leading to discovering the culprit. For example:

Assumptions: P=Killer, Q1= Lounge, Q2=Room, Q3=Kitchen, R1=Hammer, R2=Knife, R3=Scissors, S1= Green Robe, S2=Red R., S3=Blue R., T1= Lightweight, U1=Man, U2=Woman, V1 = Used Hammer, V2=U. Knife, V3=U. Scissors.

Deductive System

1. $(P \leftrightarrow (Q1 \wedge (V1 \vee V3) \wedge S2))$
2. $(R1 \wedge (U1 \vee (U2 \wedge \neg T1))) \Leftrightarrow V1$
3. $U2 \rightarrow \neg U1$,
4. $U1 \rightarrow \neg U2$
5. $(R2 \wedge Q3) \Leftrightarrow V2$
6. $(R3 \wedge Q2) \Leftrightarrow V3$
7. $A \rightarrow U2 \wedge T1 \wedge Q1 \wedge R1 \wedge S2 \wedge \neg R3 \wedge \neg R2$

$(\{\ldots,A\}, \neg(A \rightarrow P))$

Fig. 3. - Cluedo game board

Similar work was presented and discussed by Aartun in 2016 in his dissertation, demonstrating how Cluedo knowledge actions can be formalized in dynamic epistemological logic, in this case, implemented in Prolog [1].

4.3 Artificial Life and evolutionary computer games

The study of artificial life (A-Life) focuses on creating and evolving organisms and systems like living systems. The material from which artificial life is produced is inorganic, and its essence is information. Computers are test tubes in which new organisms are produced [24].

When the primary purpose of a game is to teach/train, the players should have increasing challenges that allow them to evolve. So it is expected that when they mature in their way of playing, their "opponent" will do the same. On the other hand, each player has a different "game strategy," meaning that the "opponent" must follow a different strategy for each case. For this purpose, Artificial Life techniques can be a good idea [15,26]. Let us imagine, for example, an aim training game where it is intended that the player, by trying to shoot a given type of duck (e.g.,), can improve his intelligence, strength, and agility via the game (see Fig. 4).

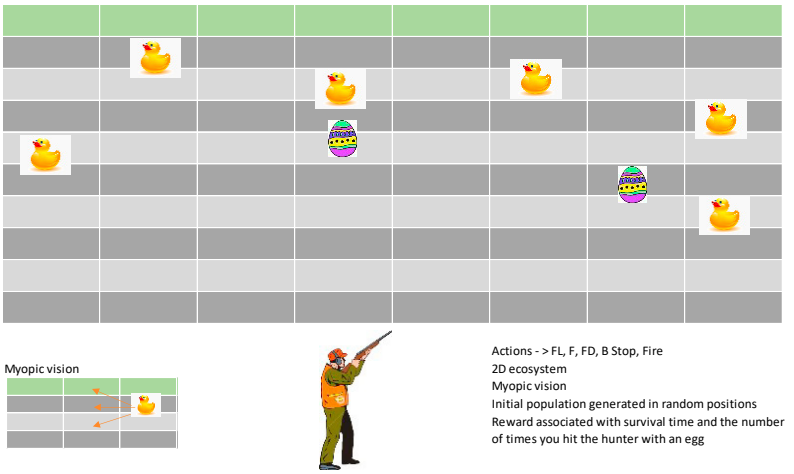

Fig. 4. - QuaQua (Duck Hunt) game.

5. Reference Model for using Artificial Intelligence techniques to stimulate reasoning and cognitive and motor development

Based on the literature review and the cases described, it was possible to ascertain two critical elements. One is to realize the multiplicity and dispersion of techniques and areas, and the other is the lack of aggregation and the usefulness of having a reference model for the use of AI techniques in the teaching context. With the analysis of the cases, elements were possible to build a reference model for this purpose.

This circumstance highlights the need for a reference model, as shown in Table 1.

Table 1. AI techniques reference model in stimulating reasoning and cognitive and motor development

		Reasoning stimulus	**Cognitive development**	**Motor development**
Application Areas of Artificial Intelligence	**Games**	Games of intellect (chess, Cluedo, Go,)	Strategy gaming, gamification	Action games (e.g., Duck Hunt)
	IoT (*Internet of Things*)		Monitoring and feedback systems (e.g., Image acquisition)	Monitoring and feedback systems (e.g., Image acquisition)
	MOOCS		Smart Tutors, Affective Computing, Assessment	
	e-Learning	Intelligent Tutors	Intelligent Tutors, Affective Computing	
	Virtual Reality	Spatial Reasoning development systems	Simulators	Simulators, Avatars
	Learning Analytics	Intelligent Data Analytics (*Data Mining*, *Deep Learning*,…)	I Intelligent Data Analytics (Data Mining, Deep Learning,...)	Intelligent Data Analytics (*Data Mining*, *Deep Learning*,...)

The reference model crosses different areas of artificial intelligence application techniques (table rows) with the areas of the teaching-learning process under study (table columns). The crossing of the rows and columns of the table corresponds to the identification of the types of technologies that, according to what has been studied, can be used in each situation.

Teachers and tutors can use the reference model to select the tools that best fit their teaching strategies

6. Validation

As shown in Table 2, a questionnaire was created based on the analysis vectors and questions to evaluate this reference model.

Table 2 – Questions to validate the proposed reference model.

#	Vector Analysis	Question
Q1	Relevance	How relevant and/or essential do you consider the existence of the now proposed reference model?
Q2	Usefulness	In your opinion, will the proposed reference model be useful for educators, teachers, trainers, trainers, ...?
Q3	Completeness	In terms of completeness, how do you rate the reference model?
Q4	Use	Do you consider the proposed reference model simple to use?
Q5	Improvements	What recommendations/suggestions would you indicate to be able to improve the reference model?
Q6	(Generic)	Do you have any other comments you can provide on the proposed reference model?

Interviews were conducted with three professionals in the education field, covering secondary education, higher education, and vocational training. Table 3 summarizes the answers obtained to each of the six questions

Table 3 – Answers to the reference model validation questions.

#	Answers
Q1	It seems useful to me. One talks about AI but does not know how to apply it. This also helps in the decision to build tools.
	The reference model may make sense for beginners, but it would need to be further developed for those who are teachers or trainers.
	I find it pertinent as it organizes/systematizes the use of AI in various application areas.
Q2	Very useful. It works like a map, where I quickly find what I'm looking for. It adapts to the current supply.
	It will be useful only as general guidelines for approaching AI in education/training.
	In my opinion, it is useful because it facilitates the choice of the most appropriate tools according to the objectives to be achieved.
Q3	I think more areas and ideas could be added.
	I think the reference model needs to be further developed and deepened; there are areas that overlap (e-learning and MOOCs) and others that are not there (Augmented Reality, for example).
	I can't think of any important elements that are missing in the reference model.
Q4	Yes, it is useful.
	Yes, it seems simple in a purely informative approach.
	I find it accessible, although some of the terms used are not familiar to all teachers.
Q5	In MOOCs, you can put intelligent tutors in the reasoning part, for example, when the MOOCs have exercises to detect a sequence of wrong answers from the student/trainee.
	As improvements, there should be more comprehensiveness in the application areas and more objectivity in the educational options.
	Explanation of some of the terms used (e.g., Affective Computing).
Q6	-
	Maybe it is better to use other matrices as a basis and adapt them.
	Perhaps give examples of tools that fit each case.

An analysis of the answers obtained determines that the proposed reference model is pertinent, although it needs to be developed further in some particular situations. We, therefore, understand the need to provide more detail, particularly explanatory, about it. It is also verified that the reference model is useful and unanimously recognized. Regarding completeness, there is flexibility to include other tools, and it is indicated that there is room for development in this area for future work. At the same time, the reference model is simple to use, although it includes some terms with which not all potential reference model users will be familiar. Thus, several suggestions for improvement were made, and ways of introducing them into the proposed reference model were indicated.

7. Conclusions

As Niemi (2021) mentioned, AI has the ability to change the landscape of learning while recognizing the need to specify the application scenarios of AI in education further, particularly in stimulating reasoning and cognitive and motor development [17].

This paper sought to discuss how Artificial Intelligence can be used in systems to support cognitive and motor development, stimulate reasoning and suggest concrete ways to implement these strategies. Tangible examples were presented in which the application of Artificial Intelligence promotes physical and motor development and stimulates reasoning. Based on the study and rigorous analysis of these examples, a proposal for a reference model for the use of Artificial Intelligence techniques in stimulating reasoning and cognitive and motor development was presented.

Although there is still a long way to go, it is already clear today that Artificial Intelligence can play a vital role in systems that support cognitive and motor development and stimulate reasoning. However, we realize that the link between pedagogy and technology is often absent from the debate about AI-driven teaching tools.

It is, therefore, possible to foresee that, in the future, this role may become more relevant and that new forms and even more ambitious projects will be born.

Regarding future work, we can mention two distinct areas. On the one hand, the application of the proposed reference model and the observation of the results obtained through this application. On the other hand, throughout the texts we used as references for this work, we can see, either implicitly or explicitly, that there is a growing popular belief that AI will one day surpass human intelligence. Although it is not part of this work's objectives, we believe it is pertinent to mention the importance of examining whether this common belief translates into negative psychological and behavioral consequences when individuals evaluate that AI performs better than them in cognitive and intellectual tasks. This effort would be to continue the existing clues in the work of [31].

References

[1] Aartun, V. I. (2016). Reasoning about Knowledge and Action in Cluedo using Prolog (Master's thesis, The University of Bergen).

[2 Alexander, B., Ashford-Rowe, K., Barajas-Murph, N., Dobbin, G., Knott, J., McCormack, M., ... & Weber, N. (2019). EDUCAUSE Horizon Report 2019 Higher Education Edition (pp. 3-41). EDU19.

[3] Appleton, L., & Mackie, J. (2019). Using Digital Organism Evolutionary Software in the Classroom. The American Biology Teacher, 81(1), 12-17.

[4] Bhattacharya, S., & Nath, S. (2016). Intelligent e-learning systems: An educational paradigm shift. International Journal of Interactive Multimedia & Artificial Intelligence, 4(2).

[5] Binet, A. (1966). Mnemonic virtuosity: A study of chess players.[Trans. ML Simmel & SB Barron.]. Genetic psychology monographs.

[6] Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial Intelligence trends in education: a narrative overview. Procedia Computer Science, 136, 16-24.

[7] Ciolacu, M. I., Svasta, P., Hartl, D., & Görzen, S. (2020, November). Education 4.0: Smart Blended Learning Assisted by Artificial Intelligence, Biofeedback and Sensors. In 2020 International Symposium on Electronics and Telecommunications (ISETC) (pp. 1-4). IEEE.

[8] Coelho, S.; Santos, V; (2019) – Referencial de utilização das Tecnologias de Informação para a melhoria da Qualidade de Vida nas Smart Cities", revista Proelium, vol 2, Issue VIII, ISSN 1645-8826, Janeiro

[9] Ernesto Costa e Anabela Simões (2008), Inteligência Artificial: fundamentos e aplicações (3ª Edição), FCA.

[10] Fuertes, W., Pilaluisa, F., Zambrano, M., Villacís, C., Aules, H., & Toulkeridis, T. (2017, July). Intelligent agents, voice and facial recognition applied in videogames in order to stimulate cognitive development of children—A case study of Tictactoe in 3D. In 2017 Computing Conference (pp. 1152-1159). IEEE.

[11] Hadders-Algra, M. (2010). Variation and variability: key words in human motor development. Physical therapy, 90(12), 1823-1837.

[12] Hassabis, D. (2017). Artificial intelligence: Chess match of the century. Nature, 544 (7651), 413.

[13] Kim, N. Y. (2019). A study on the use of artificial intelligence chatbots for improving English grammar skills. Journal of Digital Convergence, 17(8), 37-46.

[14] Kravčík, M., Ullrich, C., & Igel, C. (2018). The Potential of the Internet of Things for Supporting Learning and Training in the Digital Age. In Positive Learning in the Age of Information (pp. 399-412). Springer VS, Wiesbaden.

[15] J., Lin, G. T., Li, C., & Hsi, P. H. (2017). The Development of Artificial Life and Its Relationship with Artificial Intelligence.

[16] Luckin, R.; Holmes, Wayne; Griffiths, Mark and Forcier, Laurie B. (2016). Intelligence Unleashed: An argument for AI in Education. Pearson 6Education, London

[17] Niemi, H. (2021). AI in learning: Preparing grounds for future learning. Journal of Pacific Rim Psychology, 15, 18344909211038105.

[18] Piaget, J. (1976). Piaget's theory. In Piaget and his school (pp. 11-23). Springer, Berlin, Heidelberg.

[19] Peffers, K; .Tuunanen, T.; Rothenberger, M. A., Chatterjee, S., (2007) "A Design Science Research Methodology for Information Systems Research," J. Manag. Inf. Syst., vol. 24, no. 3, pp. 45–77, Dec.

[20] Ravindra, S. (2018). Role of IoT in Education. Retrieved, 5(11), 2019.

[21] Sandini, G., Metta, G., & Konczak, J. (1997, November). Human sensori-motor development and artificial systems. In International Symposium on Artificial Intelligence, Robotics, and Intellectual Human Activity Support for Nuclear Applications (AIR&IHAS 97), Japan.

[22] Santos, O. C. (2015). Education Still Needs Artificial Intelligence to Support Personalized Motor Skill Learning: Aikido as a Case Study. In AIED Workshops.

[23] Santos, V. (2016) As Tecnologias da Informação e a Democratização Cultural, Faculdade de Letras da Universidade de Lisboa, Julho.

[24] Sayag, T., & Strauss, S. (2005). Teaching and artificial life. In Perspectives on Language and Language Development (pp. 159-171). Springer, Boston, MA.

[25] Sternberg, R. J. (1986). Toward a unified theory of human reasoning. Intelligence, 10(4), 281-314.

[26] Stone, R., et al. (2009). The Virtual Scylla: an exploration of 'serious games', artificial life and simulation complexity. Virtual Reality, 13(1), 13–25.

[27] Šumak, B., Brdnik, S., & Pušnik, M. (2022). Sensors and Artificial Intelligence Methods and Algorithms for Human–Computer Intelligent Interaction: A Systematic Mapping Study. Sensors, 22(1), 20.

[28] Timms, M. J. (2016). Letting artificial intelligence in education out of the box: educational cobots and smart classrooms. International Journal of Artificial Intelligence in Education, 26(2), 701-712.

[29] UNESCO. (2019). Beijing Consensus on Artificial Intelligence and Education.

[30] Wang, T., & Cheng, E. C. K. (2021). An investigation of barriers to Hong Kong K-12 schools incorporating Artificial Intelligence in education. Computers and Education: Artificial Intelligence, 2, 100031.

[31] Webb, M. E., Fluck, A., Magenheim, J., Malyn-Smith, J., Waters, J., Deschênes, M., & Zagami, J. (2021). Machine learning for human learners: opportunities, issues, tensions and threats. Educational Technology Research and Development, 69(4), 2109-2130.

[32] Wimmer, P. (2019). AlphaGo Zero & AlphaZero Mastering Go, Chess and Shogi wihtout human knowledge. Seminar Report: Artificial Intelligence for Games SS19.

[33] Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators?. International Journal of Educational Technology in Higher Education, 16(1), 39.