Chapter

Artificial Intelligence in Education

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Abstract

Information technology, through networking, knowledge-based systems and artificial intelligence, interactive multimedia, and other technologies, plays an increasingly important role, which will even increase in the future, in the way that education is taught and delivered to the student. For this reason, we decided to present some ideas for such learning-training environments in education in this chapter. Like many researchers in other countries, we are also developing a user-friendly general system, designed particularly for solving problems. It is based on experience-based intelligent tutoring systems, and intended primarily for executing better lessons and for students' self-learning. Like all powerful tools, experience-based AI design approaches must be applied carefully. Without a carefully designed experience and extensive testing, these systems could easily result in unwanted outcomes (such as negative training or increased phobia anxiety). Despite the promise of the early efforts, the best approaches to designing these experiences are still topics of research and debate. Any technology as powerful as AI provokes many general social and ethical questions in all of us. Does AI make killing by remote control too consequence-free? Do AI models systematize existing biases? What will AI do when it enters education? We will try to provide an answer to this question in the following chapter.

Keywords: artificial intelligence (AI), education, machine ethics, machine behavior, intelligent tutoring system

1. Introduction

> *"Natural science is knowledge about natural objects and phenomena. We ask whether there cannot also be 'artificial' science – knowledge about artificial objects and phenomena."*
>
> *Herbert Simon*

> *Teachers will not be replaced by technology, but teachers who do not use technology will be replaced by those who do.*
>
> *—Hari Krishna Arya*

For years, experts have warned against the unanticipated effects of general artificial intelligence (AI) on society [1, 2], predicting that by 2029 intelligent machines will be able to outsmart human beings. Stephen Hawking argues that *"once humans develop full AI; it will take off on its own and redesign itself at an ever-increasing rate"*. Elon Musk warns that AI may constitute a "fundamental risk to the existence of human civilization". If the problems of incorporating AI in manufacture and service operations, i.e. using *smart machines*, are smaller, as the 'faults' can be recognized relatively quickly and they do not have a drastic effect on society, then the *incorporation of AI in society and especially in the educational process* is an extremely risky business that requires a thorough consideration. The consequences of mistakes in this endeavor could be catastrophic and long-term, as the results can be seen only after many years. The threat of AI and its potential evolving into a commonly named 'superintelligence' can be summarized with the following thought of Boston:

"/…/ I try to understand the challenge presented by the prospect of superintelligence, and how we might best respond. This is quite possibly the most important and most daunting challenge humanity has ever faced. And – whether we succeed or fail – it is probably the last challenge we will ever face." [3].

The scientific background of such ideas and questions is based on the findings that have materialized at the intersection of the fields of philosophy (ethics), artificial intelligence, and pedagogy (education). Our research will stem from the findings of authors such as Turing, Bostrom, Rahwan, Kurzweil and others. Also, this idea is based on the European AI Alliance, which the European Commission launched at the beginning of 2018. The main documents are "*Artificial Intelligence for Europe*[1] [4] and "*Coordinated Plan on Artificial Intelligence* [5]."

The increasingly faster hardware and the progressively optimized software in the realm of computers have, during the course of the past few years, stimulated and disturbed academic philosophy, which quickly began pointing out the ethical issues that might arise with the usage of artificial intelligence. Saying that such problems are a thing of the distant future is not something philosophers and researchers of AI would agree with. AI expert Nick Bostrom (University of Oxford) offers the following answer to the question of "When will human-level machine intelligence (HLMI) be attained?": "10% probability of HLMI by 2022, 50% probability by 2040, and 90% probability by 2075" [3].

1.1 Why must we be careful?

Let us start at the beginning of the story about the easy and the hard philosophical problem of incorporating AI. If the problems of incorporating AI in manufacture and service operations, i.e. using *smart machines*, are smaller (hence the name, easy problem), as the 'faults' can be recognized relatively quickly and they do not have a drastic effect on society, then the *incorporation of AI in society and especially in the educational process* (hence the name, hard problem) is an extremely risky business that requires thorough consideration. The consequences of mistakes in this endeavor could be catastrophic and long-term, as the results will be seen only after many years.

AI is ultimately only a computer program, a "simple" optimization algorithm. Such algorithms can contain different ethical constraints (law) in the source code. A well-known historical example in the form of such simple "robotic laws" dates as far back as 1950, when Isaac Asimov proposed the following:

1. A robot may not injure a human being, or, through inaction allow a human being to come to harm.

2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law [6].

[1] http://www.ijcai-18.org/wp-content/uploads/2018/07/1_20180717_IJCAI_ECAI_Cecile-Huet.pdf.

It is clear from these laws that the robot (intelligent machine), or, in today's terminology, AI, must protect humans and put the safety of human beings before its own existence. 50 years later, however, Mark W. Tilden wrote similar, but at the same time different laws[2]:

1. A robot must protect its existence at all costs.

2. A robot must obtain and maintain access to a power source.

3. A robot must continually search for better power sources.

Tilden's laws suggest that the primary role of the robot (AI) is first and foremost to protect itself from the outside world, including human beings. Because the AI of today learns primarily from the world wide web, where both types of laws can be found, an ethical dilemma could thus be created: *which of these two sets of laws should be considered as guidelines, or, in other words, what is the Categorical Imperative for AI according to Kant* [7]*?*

1.2 Machine ethics and/or machine behavior

Machine morality in intelligent systems, whether physical systems with a mind and body or just thinking algorithms somewhere in the cloud, is a recurring issue. Morals demonstrate the relationship of humanity to nature and society and are manifested as a sum of values (rules, norms, principles, categories, ideals, etc.), according to which we make decisions, what is good and what is bad, what is just and what is unjust, what is right and what is wrong, and in line with which we also behave. When it comes to the morality of smart machines, philosophers mostly focus on theoretical questions such as: *does AI have the status of a moral agent, is AI responsible for its actions, is AI a 'being' with a higher moral status*, etc. – rather than on such a specific and practical area as is the usage of AI in education, especially in the field of ensuring social competences and developing emotional intelligence [8, 9].

The ethical dilemma related to the understanding and interpretability of the behavior of AI agents, is one of the pivotal challenges of the next decade of AI. Until today, most of the interpretability techniques have focused on exploring the internal structure of deep neural networks. But *machine behavior* [10] relies more on observations than on engineering knowledge in order to understand the behavior of AI agents. Most of the conclusions obtained from observations in nature are not related to knowledge from biology, but rather to our understanding of social interactions. In the case of AI, scientists who study the behaviors of different virtual and embodied AI agents are predominantly the same scientists who have created the agents themselves. But understanding AI agents must go beyond interpreting a specific algorithm and requires analyzing the interactions between agents and with the surrounding environment. In order to accomplish that, behavioral analysis via simple observations can be used as a powerful tool.

1.3 Machine behavior

Machine behavior [10] is a field that leverages behavioral sciences to understand the behavior of AI agents. Currently, scientists who most commonly study the behavior of machines are computer scientists, roboticists and engineers who have

2 http://www.botmag.com/the-evolution-of-a-roboticist-mark-tilden/

created the machines in the first place, but they are typically not trained behaviorists. Similarly, even though behavioral scientists understand those disciplines, they lack the expertise to understand the efficiency of a specific algorithm or technique. From that perspective, machine behavior sits at the intersection of computer science, engineering, and behavioral sciences, in order to achieve a holistic understanding of the behavior of AI agents. As AI agents become more sophisticated, analyzing their behavior is going to be a combination of understanding their internal architecture (the domain of computer scientists), as well as their interaction with other agents and their environment (the domain of behavioral scientists). While the former aspect will be a function of deep learning optimization techniques, the latter will rely partially on behavioral sciences.

In developing a new transdisciplinary science, which we call *AI behavioral science,* we, as many others researchers, use Nikolaas Tinbergen's work [11] for identifying the key dimensions of animal behavior. Tinbergen's thesis was that there were four complementary dimensions to understand animal and human behavior:

1. **Mechanism:** The mechanisms for generating the behavior of AI agents are based on its algorithms and the characteristics of the execution environment.

2. **Development:** The behavior of AI agents evolves over time. Machine behavior studies how machines acquire (develop) a specific individual or collective behavior.

3. **Function:** Understanding how a specific behavior influences the lifetime function of an AI agent.

4. **Evolution:** AI agents are also vulnerable to evolutionary history and interactions with other agents. They can be reused in new contexts, both constraining future behavior and making possible additional innovations.

Despite fundamental differences between AI and animals, machine behavior borrows some of Tinbergen's ideas to outline the main types of behavior in AI agents. Machines have *mechanisms* that produce behavior, undergo *development* that integrates environmental information into behavior, produce *functional consequences* that cause specific machines to become more or less common in specific environments, and embody *evolutionary histories* through which past environments and human decisions continue to influence machine behavior. An adaptation of Tinbergen's framework to machine behavior is schematically presented in **Figure 1**.

Four Tinbergen's dimensions [11] provide a holistic model for understanding the behavior of AI agents. However, these four dimensions do not apply in the same way with respect to whether we are evaluating a classification model with a single agent, or with hundreds of agents. In that sense, machine behavior applies the previously mentioned four dimensions across three different scales:

1. The first is **Individual Machine Behavior:** this dimension of machine behavior attempts to study the behavior of individual AI agents by themselves. There are two general approaches to the study of individual AI agent behavior. The first focuses on profiling the set of behaviors of any specific machine agent using a within-machine approach, comparing the behavior of a particular machine across different conditions. The second, a between-machine approach, examines how a variety of individual machine agents behave in the same conditions [12].

Type of explanation	**Object of study**	
	Dynamic view Historical (evolutionary) view	**Static view** Current behavior of a machine
Proximate view of individual type of machine functions	**Development (Ontogeny)** Developmental explanation how machine (AI) acquires its different type of behavior with learning in a particular environment.	**Mechanism (Causation)** Mechanistic explanation what behavior is and how it is constructed.
Ultimate (evolutionary) view Why individual machine behaviors as it has	**Evolution (Phylogeny)** Forces that describe why the behavior evolved and spread.	**Function (Adaptation)** The consequence of the machines behavior in the current environment.

Figure 1.
Tinbergen proposed that the study of animal behavior can be adapted to the study of machine behavior [10, 11].

2. The second scale is **Collective Machine Behavior:** unlike the individual dimension, this area looks to understand the behavior of AI agents by studying the interactions in a group. The collective dimension of machine behavior attempts to spot behaviors of AI agents that do not surface at an individual level.

3. And finally, the scale of **Hybrid Human-Machine Behavior:** there are many scenarios in which the behavior of AI agents is influenced by their interactions with humans. This dimension of machine behavior focuses on analyzing behavioral patterns in AI agents triggered by the interaction with humans.

2. Solutions, or: Why should we be optimistic?

What can be done? In trying to provide a solution, a simple example related to the notion of *proprioception* [12] can be considered. What does proprioception really mean? Proprioception could also be called *self-perception of thought*, or *self-awareness of thought*, i.e., thought, which is able to perceive its own flow, be aware of its own movement.

With proprioception, the emotional intelligence (EI) of a person (**Figure 2a**) also develops, which will change, step by step, the human historical memory, and add new elements to this historical memory on the level of intuitive thinking. By way of analogy, we can develop a similar philosophy of proprioception for AI (**Figure 2b**). We must therefore develop this awareness in every individual - human or AI; we must "change" or establish the specific way of thinking (creative, critical, and conscious thinking); and it is very important to begin this process with agents (human or AI) of the "youngest" possible age. These competences must be developed step by step, which will enable us to deal with the day-to-day needs of others, and help raise the awareness. This transformation/analogy is shown schematically in **Figure 2**.

2.1 Machine behavior and education

Before any kind of learning environment is given some sort of intelligence (see **Figure 3**), machine ethics and/or machine behavior must be built into this learning

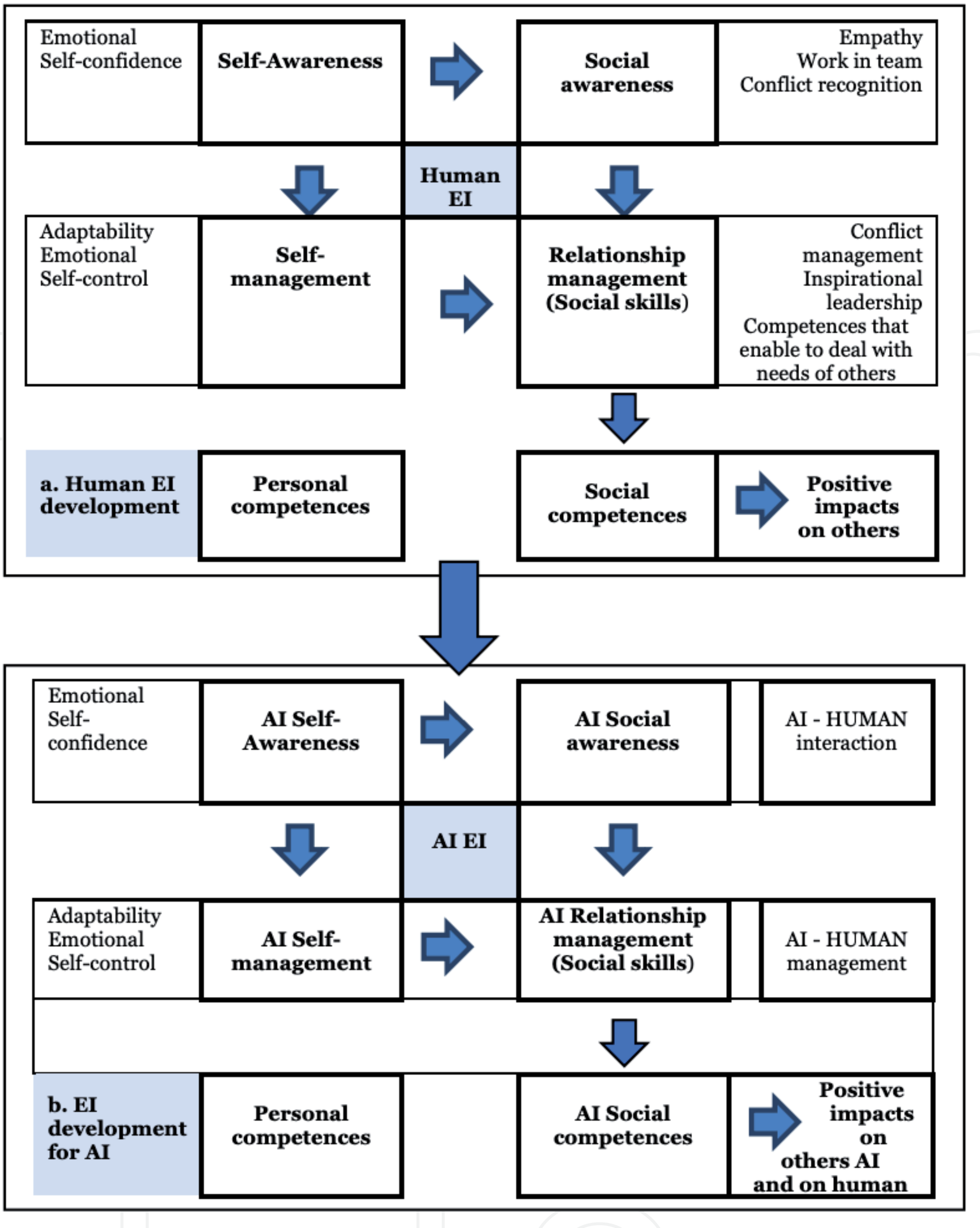

Figure 2.
From human to AI emotional intelligence (EI).

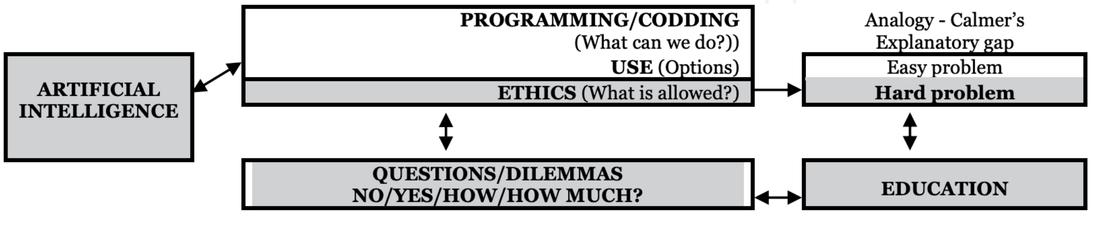

Figure 3.
Moral and ethical dilemmas in society and education.

environment, in order to ensure that the cognitive, social, and emotional competences of students are defined in a way that will allow them to be formalized or translated into a scientific language, into a language familiar to the machine.

Additionally, methods have to be defined for assessing whether such intelligent systems work correctly in the long-term, since either noticing or removing the consequences which their failure or irregular operations have on the moral development of individuals, is not possible in real time. And since these methods, as mentioned earlier, are not in the domain of computer scientists, roboticists and engineers who have created the machines, but rather in the hands of experts from the field of behavioral science, the roles of the evaluator and the auditor must take over the role of teachers. For this reason, teachers must be able to acquire some kind of knowledge from the area of AI behavioral science in order to become competent observers and evaluators of such intelligent learning environments [13].

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The general question to be answered could therefore be formulated thus: "*What are the moral problems of using advanced learning systems and modern learning environments supported by AI methods*?", with the concrete goal of the research being *the development of a test, on the basis of which teachers could assess whether an intelligent accessory (program or algorithm) for learning is such that it ensures the acquisition of all cognitive, social, and emotional competences in students*, i.e., whether it is 'safe' to use in the educational process. The development of such a test, as well as the related knowledge and skills, could encourage the development of various other similar 'security' tests for AI usage in other areas.

2.2 From smart to intelligent self-learning tutoring systems

Learning, knowledge and intelligence are closely related. Although there is no universally accepted definition of intelligence, it can be roughly defined as follows:

> *Intelligence is the ability to adapt to the environment and to solve problems.*

Nowadays, most researchers agree that there is no intelligence without learning, so learning adaptation takes place in almost all living beings, most obviously in humans. Learning by a living system is called *natural learning*; if, however, the learner is a machine – a computer, it is called *machine learning*. The purpose of developing machine learning methods is, besides better understanding of natural learning and intelligence, to enable algorithmic problem-solving that requires specific knowledge. In order to solve problems we obviously need knowledge and the ability to use it. Often such knowledge is unknown or is used by a limited number of human experts. Under certain preconditions, by using machine learning algorithms, we can efficiently generate knowledge which can be used to solve new problems.

Even the whole natural evolution can be regarded as learning: through genetic crossovers, mutation and natural selection, it creates ever better systems, which are capable of adapting to different environments. The principle of evolution can also be used in machine learning to guide the search in the hypothesis space through the so called *genetic algorithms*.

2.3 Artificial intelligence and learning

A long-term goal of machine learning research, which currently seems unreachable, is to create an artificial system that could achieve or even surpass human intelligence. A wider research area with the same ultimate goal is called *artificial intelligence*. Artificial intelligence (AI) research deals with the development of systems that act more or less intelligently and are able to solve relatively hard problems. These methods are often based on imitation of human problem solving. AI areas, besides machine learning, are knowledge representation, natural language understanding, automatic reasoning and theorem proving, logic programming, qualitative modeling, expert systems, game playing, heuristic problem solving, artificial senses, robotics and cognitive modeling.

Machine learning algorithms play an essential role in all AI areas. One has to include learning practically everywhere. By using learning techniques, the systems can learn and improve in perception, language understanding, reasoning and theorem proving, heuristic problem solving, and game playing. The area of logic programming is also highly related to inductive logic programming that aims to develop logic programs from examples of the target relation. Also in qualitative modeling the machine learning algorithms are used to generate descriptions of complex models from examples of the target system behavior. For the development of an expert system one can use machine learning to generate the knowledge base from training examples of solved problems. Intelligent robots inevitably have to improve their procedures for problem solving through learning. Finally, cognitive modeling is practically impossible without taking into account learning algorithms.

2.3.1 Natural learning

Humans learn throughout our whole lives. We learn practically every day, which means that our knowledge is changing, broadening and improving all the time. Just like humans, animals too are capable of learning. The ability to learn depends on the evaluative stage of species. Investigation and interpretation of natural learning is the domain of *the psychology of learning* and *educational psychology*. The former investigates and analyses the principles and abilities of learning. On the other hand, the latter investigates the methods of human learning and education and aims at improving the results of educational processes. Educational psychology considers attention, tiredness and motivation to be of crucial importance for a successful educational process and carefully takes into account the relation between the teacher and the students, and suggests various motivation and rewarding strategies. All those are of great importance for human learning, however, they are much less important for (contemporary) machine learning.

2.3.2 Learning, intelligence, consciousness

As we already stated, intelligence is defined as *the ability to adapt to the environment and to solve problems*. Learning alone, however, is not enough. In order to be able to learn, a system has to have some capacities, such as sufficient memory capacity, ability to reason (processor), ability to perceive (input and output), etc. These abilities do not suffice if they are not appropriately integrated or if they lack an appropriate learning algorithm. In addition, efficient learning also requires some initial knowledge – background knowledge, which is inherited in living systems. Through learning, the abilities of the system increase, and therefore the intelligence of the system also increases [14].

2.3.3 The amount of intelligence

Systems cannot be strictly ordered with respect to the amount of intelligence, because we have to consider various types of intelligence (abilities): numerical, textual, semantical, pictorial, spatial, motor, memorial, perceptive, inductive, deductive, etc. Lately, even emotional intelligence became widely recognized. Some authors describe more than a hundred types of human intelligence. A system (human or machine) can be better in some types of intelligence and worse in others, and vice versa. When speaking about artificial intelligence, we do not expect an intelligent system to be extremely capable in only one narrow aspect of intelligence, such as for example the speed or the amount of memory, the speed of computation or the speed of searching the space or (almost optimal) game playing. The computers of today already have very advanced capabilities in each of these aspects. We expect an intelligent system to be (at least to some extent) intelligent in *all* areas which are characteristic of human problem solving. It seems that we need an integration of all different types of intelligence into a single sensible whole (a kind of supervisory system), so that during problem solving it is possible to switch appropriately between different types of intelligence. Anyway, most of the speculations about artificial intelligence do not take into account yet another level: consciousness (which seems to be a good candidate for the supervisory system).

3. Education 4.0 in society 5.0

The use of contemporary learning strategies, such as games, research-based and problem-based learning connected to collaborative teaching/learning, and brain-based techniques based on cybernetics theory and information-communication technologies, have provided scholars from diverse disciplines with an unusual opportunity to observe possible flaws in their own thinking [12, 15, 16]. The choice of method was crucial: if we were to report results obtained only through conventional, standard behavioristic methods, our work would have been less noteworthy, less critical, and less memorable. This is why we did not choose demonstrations over standard methods, because we wanted to influence the entire spectrum of audiences. We preferred *problem-based and research-based methods* and *collaborative learning,* because they were more fun for students, and we were lucky in our choice of method, as well as in many other ways. We used the *brain-based technique* because it provides the educator with an understanding of what happened, and of how to react during the lecture. And we proposed intelligent serious games and game-based learning because they increase motivation.

The spontaneous search for intuitive solutions to complex problems, such as for example ecological problems, or today's global pandemic problem, sometimes fails – neither an expert solution, nor a heuristic answer comes to mind. The responsibility of the teacher is to equally develop all ways of problem solving, critical thinking, and decision-making, by choosing appropriate research problems and using a transdisciplinary model of teaching [15].

There is a huge number of opportunities to introduce novelties like the proposed problem- and research-based learning in the learning process simply by being creative; for instance, the teacher can use fresh examples or problems, or surprise students with new data, or present a scenario that is completely unpredictable. The teacher can also engage students through games and simulations that require them to apply the information in unfamiliar contexts. E-learning environments, role play, energizing online discussions, and quick serious games, can all add sensory stimuli to raise the blood pressure and epinephrine levels to eliminate drowsiness, reduce restlessness, and reinforce information. Allowing learners to do some research and exercises on their own to better understand abstract ideas, write an essay, or work with an interactive simulation, are also helpful strategies.

3.1 Cybernetics, learning and AI

The purpose of this chapter is to complement the preceding ones, changing the focus from the dynamics of social systems to that of individual human systems and developing their emotional intelligence (EI). It will be seen that second-order cybernetic 4.0 systems study self-observing systems, which are comprised by *cognitive machines*, information processing mechanisms that reside in the human mind [17].

The idea of rationality as a *cognitive machine* that has as its purpose though coherence will be offered as the staple of second-order cybernetics 4.0; another aspect of it will be that of heuristics, not only as practical reasoning but as ways of conceiving and understanding the world. The framework that will be offered will consist of the understanding of patterns (order), their proportion (balance) and harmony as their functional conjunction; constructive epistemology will also be delved upon in order to create a complete perspective upon human psychic systems.

Finally, the ideas of second-order cybernetics 4.0 will culminate in the idea of social and cognitive morphogenesis as heuristics is related to measures of complexity: order will be related to hierarchy, balance to self-similarity and harmony to universality; it will be concluded that repetition is the most adequate measure of complexity in social systems.

3.2 Brief description of second-order 4.0 cybernetic pedagogy

3.2.1 Points of contact between second-order and second-order 4.0 cybernetics

Self-consciousness is the point of transition between lower cognition (knowledge and lower levels of cognition without any emotional intelligence (EI) components which pertain to second-order cybernetics) and that which belongs to human beings, i.e. high cognition (developing cognitive and social competences, which is the object of study of what will be called second-order 4.0 cybernetics). The latter is referred to as a high cognition model because of the self-consciousness that a system can acquire through self-observation, and thus become teleonomical and teleological. Before entering the study of second-order 4.0 cybernetics, it is necessary to further develop the notion of cognition, so that the analysis will be complete.

Let us start with the pioneer of the psychological theory of cognitive development and learning, Piaget. In his widely known psychological research, Piaget makes a typology of the cognitive development of a human being from birth to adulthood:

- *Sensorimotor stage* (from birth to a year and a half, two): the first motor reflexes develop, along with first instincts and emotions, there is also a development of a sensory-motor intelligence prior to language. Knowledge starts developing on the basis of experiences/interactions; some language skills are developed at the end of this stage.

- *Pre-operational stage* (from two to seven years): language skills are present, intuitive intelligence develops, there is a submission to adults and spontaneous intersubjective feelings; memory and imagination are developed.

- *Concrete operational stage* (from seven to twelve years): logical and systematic intelligence blossoms, along with moral and social sentiments of cooperation;

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manipulation of symbols related to concrete objects; operational thinking predominates.

- *Formal operational stage* (adolescence to adulthood): abstract intellectual operations appear, personality forms and there is an affective and intellectual insertion into adult society.

If we disregard that children over the past few decades have been growing up in significantly different circumstances, and have developed differently on account of an increased access to information, we can still use Piaget's findings as the starting point for the further development of second-order 4.0 cybernetics pedagogy.

Every state is distinguished from the preceding one because of the appearance of new original cognitive structures. In this typology, the difference between lower and higher cognition can be seen more clearly: while in the sensorimotor there is motor activity, knowledge based on experience and interaction and limited language acquisition, in the formal operational stage an individual can communicate with others by means of a symbol system, they are capable of logical and abstract reasoning and start to develop their emotional intelligence. This is the transition between lower cognition in animals and primates who possess it alongside a limited ability for self-observation, and human beings, which are capable of higher cognition by means of language, abstraction and formal reasoning. Higher cognition has already been defined, but a reprisal of the concept is useful: it is the processing (storage, retrieval, transformation, creation and transmission) of information made by an autopoietic system in its interaction with what surrounds it (environment and other beings) with the possibility of stating a purpose beyond self-sustainment.

3.2.2 Second-order 4.0 cybernetic pedagogy as the realm of self-observing systems

Second-order 4.0 cybernetic pedagogy exhibits features of both first- and second-order cybernetic machines. Second-order 4.0 cybernetics studies cognitive machines (in our case the tutoring system as a universal meta-model), information processing mechanisms of the high order that have their basis within the neural network of human beings, that is, it is the cybernetics of human beings transforming the human being's reaction and/or activities in AI form, to build intelligent tutoring systems (ITS). There are many cognitive machines that make up higher cognition, however, the one to be pre-eminently studied by this branch of cybernetics is rationality, understood as a mechanism which allows the development of coherence within the thought system and also its relationship to language, understood as the cognitive machine that complements rationality and also the one that allows the bridging of cognitive systems, thus fostering socialization. The high degree of flexibility of human cognition requires that we think of much of the human cognitive architecture not as determining specific thoughts and behaviors but as an abstract set of mechanisms that potentiates a vast range of capabilities.

The following can be stated as reasons for the development of a new version of second-order cybernetics 4.0:

- to introduce a new paradigm shift,
- to address an explicit discussion of the human system, including the problem of teaching and learning and
- to develop a model to demonstrate how structure and context influence such systems.

Although there are resonances between Mancilla's [17] notion of fourth-order cybernetics and the one advanced in this study (second-order 4.0 cybernetics), the main difference between them lies in their approaches: the former adopts a psychological, post-modern approach as well as the requirements of the industry 4.0, which assimilate cybernetics into this discipline and school of thought respectively, while the latter attempts not an interdisciplinary approach, but a transdisciplinary one, i.e., it attempts to develop a model that does not fit within the boundaries of a specific branch of social sciences, but one that respects the basic tenets of cybernetics.

3.2.3 Cognitive machines

When we talk about cognitive machines, we talk about *programmed learning* (or *programmed instruction*) which is a research-based system which helps learners work successfully. The method is guided by research done by a variety of applied psychologists and educators. Anticipating programmed learning, Edward L. Thorndike wrote in 1912:

> *If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print.*

On the basis of these premises Skinner developed programming learning, the theory of programmed instruction (programmed sequences), which he proposed as early as 1958 [18]. According to Skinner, the basic and most important goal of programmed instruction *is to carry out learning in a controlled environment.* His scheme of programmed instruction was to present the material as part of a "schedule of reinforcement" in typical behaviorist manner. The programmed text of Skinner's theory of behaviorism is the most complete example of his ideas in action. Skinner's system was generally called "linear programming" because its activities were placed in otherwise continuous text. He laid the foundations of this instruction, which should pursue three mainly objectives:

1. It should provide information in smaller (substantive) sets,

2. it is intended for self-learning and

3. provides immediate background checks and feedback to the learning.

Today's learning systems could be built on the same basic idea, although the range of possibilities for preparing such learning environments is much wider. Whenever we refer to AI in this book, we will be referring to intelligent teaching/learning environments, and usually we will use the term intelligent tutoring system (ITS).

Two questions are to be asked in order to understand todays model-ITS as a universal meta-model or cognitive machine:

- first, what are the elements that constitute such mechanisms? (We are talking about the architecture or structure of such systems).

- Second, what are the defining features of a cognitive system? (We are talking about the function of such systems).

As it was already mentioned, there are three requirements to be fulfilled in order for a machine to be considered as cognitive:

- it must store and retrieve information,
- it must help to understand received information, and
- it must create new information.

The defining features of cognitive machines can be expounded by analyzing their relation to their inputs and outputs. Cognitive machines receive, create, transform and transmit information, which is both their input and output, and which can be used either to create new data, different from that received or to broaden the existing information storage in the brain. This can result in the expansion of the cognitive domain. This means that cognitive machines are omnipoietic because they can produce both their own components and other information; omnipoiesis, the

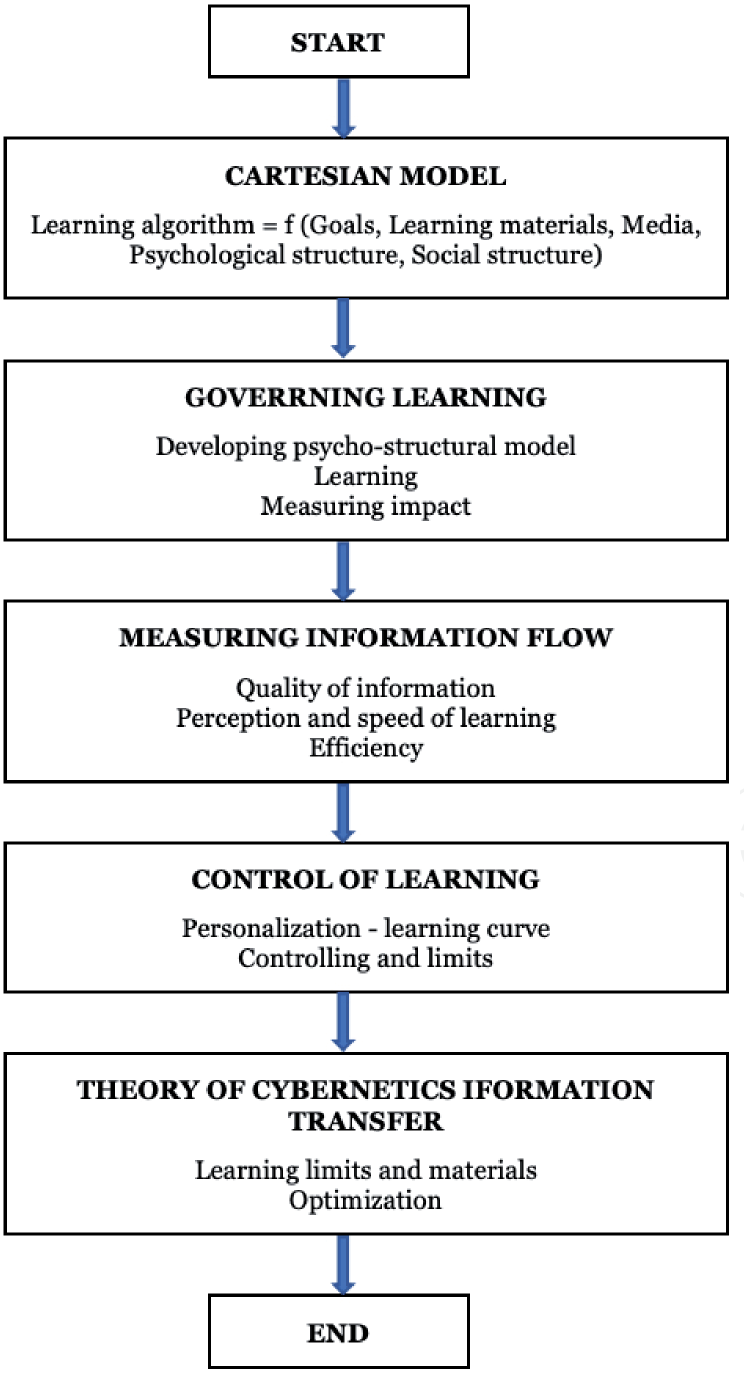

Figure 4.
Algorithm of a cybernetic learning system.

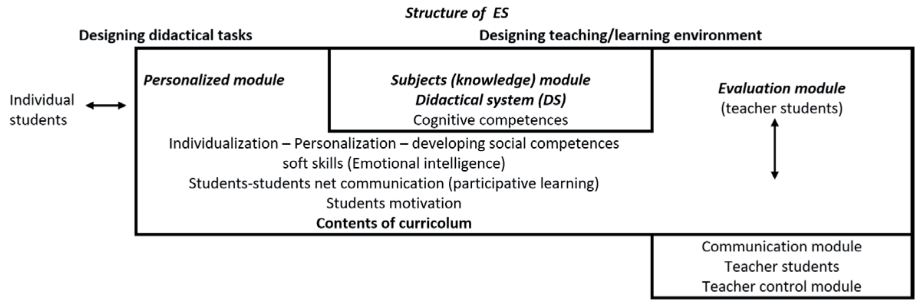

Figure 5.
LMS_AI.

ability to create all kinds of output (internal and external to self) is the distinguishing feature of cognitive machines, which are the subject of study of our second-order 4.0 cybernetic system.

3.3 Second-order 4.0 cybernetic learning algorithm

Let us now transfer these theoretical findings onto a concrete example of modern innovative learning environments. **Figure 4** shows an algorithm for a cybernetic learning system (universal meta-model) on the basis of *second-order 4.0 cybernetic systems* and the *didactics of learning theory 4.0* [12].

3.4 Education 4.0 - case study: (ITS) based on intelligent solution: LE_LMS_AI

On the basis of the presented theory and the algorithm in **Figure 4**, we present (see **Figure 5**) an intelligent tutoring system ITS (a learning management system or LMS) based on second-order cybernetic pedagogy 4.0 and AI solutions. We named it the *LE_LMS_AI*. The LE_LMS_AI is heuristically based on a hybrid cybernetic second-order system 4.0. Since the educational system is a complex, multidimensional, non-linear and dynamic system, our findings will be presented using a simplified concrete example.

4. *General description of the* LE_LMS_AI

Based on the concept shown in **Figure 5**, we developed the LE_LMS_AI, consisting of three permanent system modules (the personalized module, the evaluation module, and the communication module) and one module relating to the subject matter at hand (the subject module), which can be independently adapted and/or altered by the teacher. The basic functions of the individual modules are as follows:

The *personalized module* (PM) is a connecting system between the individual learner and the learning system LMS_AI. It is a link between the teacher and the learner, as well as a link between the learners themselves during their engagement in participatory classes. The PM is closely linked to the evaluation module (EM). Its primary task is to adapt the learning path to an individual learner (individualization and personalization), to determine their initial state (the level of knowledge about a particular topic (learning content) and the learner's attitude regarding this topic), to monitor their progress and adapt the learning path to their needs (e.g., their learning style) and abilities (differentiation). Since both system modules are AI-based, this module is used to store the personal data of an individual, for whom the learning system has been adjusted already at the beginning by modifying the subject module (SM), in order to fit his/her needs and abilities, as defined during previous lessons (i.e. previous SM). If at the beginning of the school year the

LE_LMC_AI is the same for all students, at the end of the school year we will have as many different LE_LMC_AI as there were students in the class. They will have all achieved the same learning goals and met the same learning standards, however, they will have reached these goals through entirely different paths.

The e*valuation modu*le (EM) is a module based primarily on AI methods. Its basic purpose is to:

1. analyze the existing condition of
   - the students' knowledge (the cognitive component) and
   - the decisions, the awareness (the social component, emotional intelligence) of an individual student.
2. and forward the results of these analyses to
   - the teacher, who can thereby monitor the progress in individual students (formative assessment),
   - the student, for the purpose of self-evaluation and motivation, and
   - the system, i.e. to the personalized module (PM), with the intent of individualizing and personalizing the learning path for the individual student.

The basic scheme of this module is shown in **Figure 6**.

The *subject module* (SM) is a module related to a specific subject, i.e., to the concrete teaching/learning content. This module consists of several elements (blocks) and is founded on the idea of brain-based teaching/learning. The module is shown schematically in **Figure 7** (below). The individual learning contents (activities) are divided into learning units with the duration of approximately 45 to 90 minutes, consisting further of blocks in the duration of 10 to 20 minutes. Such modules can be organized for individual subjects as a whole (intelligent i-textbooks), or they can be organized for individual problems or projects, which are stored in a database and are accessible to teachers as a teaching aid. The modules are set up on the basis of concrete examples/learning situations to facilitate individual problem- or research-based work in students engaged in formal (here, the modules serve as a teaching aid to the teacher) or non-formal types of learning (self-learning, reinforcing knowledge, homework assignments, etc.). These modules represent the flexible part of the LE_LMS_AI, which can be adapted or complemented to meet the existing needs and/or requirements (e.g. a change in the curriculum). A schematic representation of such a module is shown in **Figure 8**.

The basic structure of individual blocks is shown in **Figure 8**.

It is necessary to emphasize, as is apparent from **Figures 6** and 7, that two processes take place simultaneously within an individual block, and that we are thus tracking:

- the cognitive process (knowledge, understanding) and
- the socialization process (relationships, emotional intelligence).

Each SM is built hierarchically, which enables a differentiation of the knowledge acquisition path, and is automatically adapted to the individual learner. In theory, three levels are anticipated (high, medium and low), while the possibility of

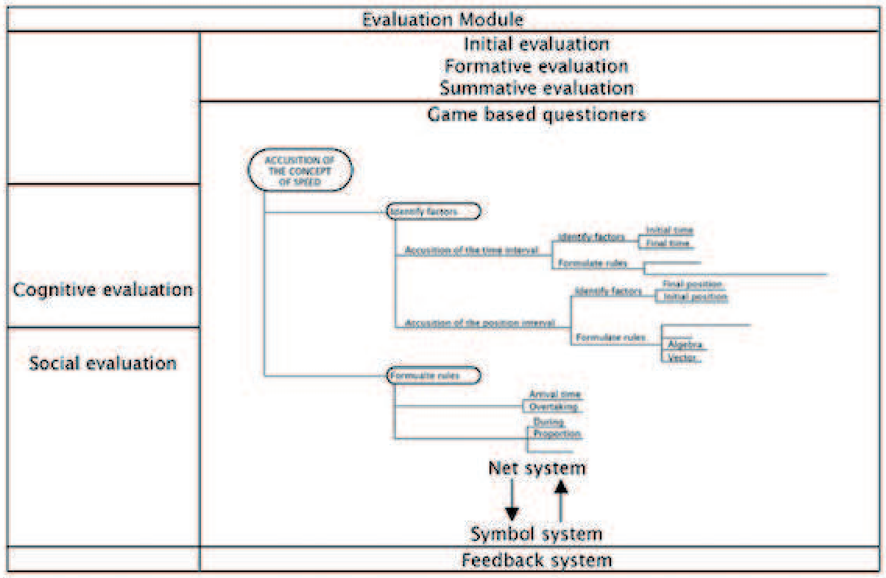

Figure 6.
Evaluation module.

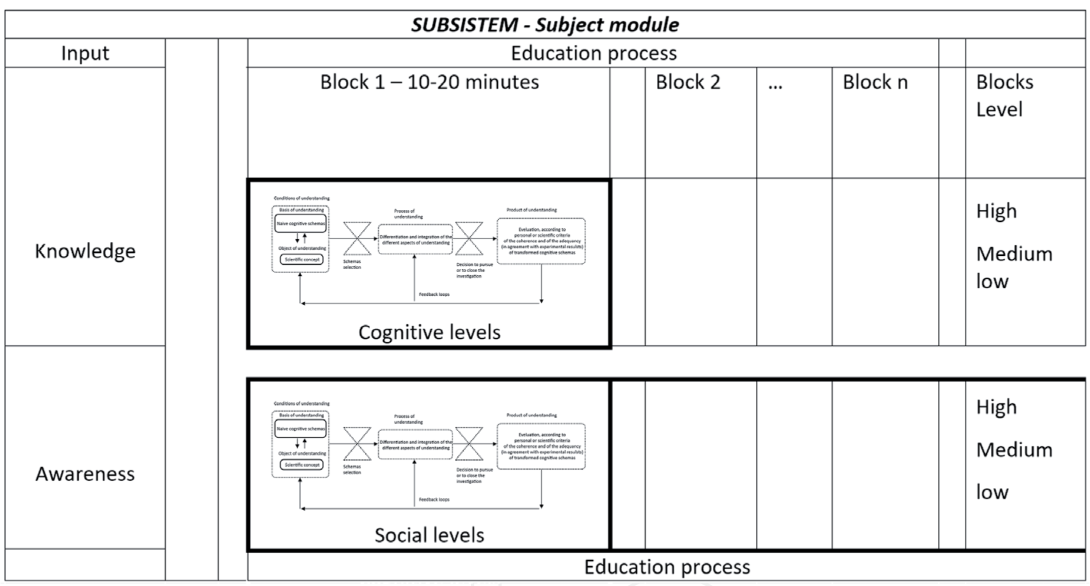

Figure 7.
Subject module.

employing AI methods would eventually result in a "complete" personalization of the learning paths. The SM are divided into three groups, depending on the difficulty level of the learning content, and on the ways and methods of acquiring this content, namely:

- for lower cognitive levels, which are related to the elementary acquisition of basic knowledge (memorizing), and where traditional (frontal instruction, transmission approach) forms of teaching are used as the teaching method, the LMS_AI is intended mainly for teachers in the preparation of classes;

- for lower cognitive levels, learners use it mainly to reinforce their knowledge. This module includes various learning strategies, especially game-based techniques, used to increase the motivation and interest of students. By means of this, the teacher can formatively monitor the individual students' progress and adjust subsequent lessons accordingly.

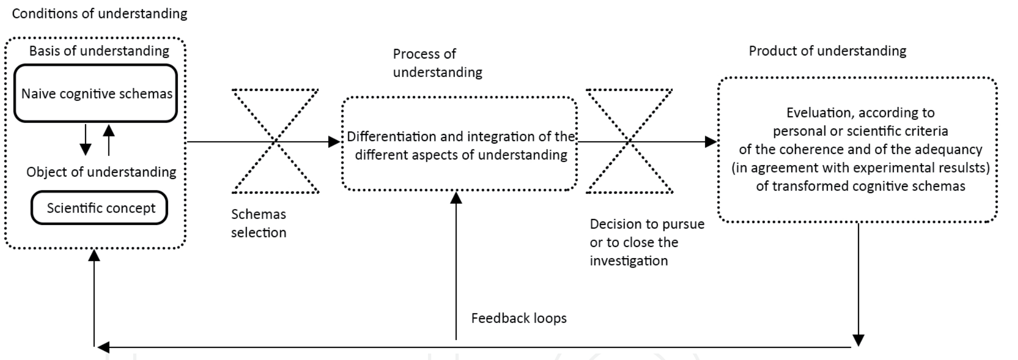

Figure 8.
The structure of the SM block.

- for higher cognitive levels, the LE_LMS_AI can be used predominantly as a self-learning tool for the student, supported by the teacher's research-, problem-, or project-based working methods. In this kind of situation, the teacher only appears as a tutor, as the one who provides guidelines and encouragement to the students involved in the learning process. In this kind of process, students are active, curious, and motivated.

The *communication module* (CM) is the link between users (students) and the learning system. It is a module that enables data input, and communication, both between teachers and students, as well as between students and the ITS.

4.1 Other possibilities of using AI in education

4.1.1 Student evaluation

An intelligent program can automatize an entire process of evaluation and unburden the teacher, enabling them to focus on qualitative aspects of lessons. Since the efficiency of machine learning increases proportionately with the expansion of the database, the evaluation of students from the quantitative aspect would not be disputable. The possible mistakes could be corrected by the teacher, and the intelligent system could use this to learn. The time that the teacher would gain with the automatization of evaluation could then be spent for interaction with students, preparing for lessons, or career development, nonetheless leaving her enough time to examine the correctness of the grades, and this would represent the mentioned fail-safe. However, we must be cautious of unpredictable deficiencies of such an approach: the automatization of evaluation may, for example, include the traces of bias and therefore lead to unjust or unrepresentative grades.

4.1.2 Individualization of learning

Intelligent devices are essentially devices the user interface of which and interaction with them are highly individualized. The presence of teaching tools of AI in the educational process will reinforce this aspect of communicating with the world. With the help of intelligent accessories, learning will also become individualized, for the intelligent system can respond to students' needs, focus on certain topics, insist on revising a subject, and determine the learning speed. Here, the question of the goal of such learning arises. Does this program enable, through individualization, the students to develop the necessary cognitive, social and emotional competences:

does it, for example, teach them to be active citizens and not passive consumers? Undoubtedly, the individualized and regularly adjustable learning is a significant pedagogical step; however, it includes certain aspects that need to be analyzed and evaluated, so that the inevitable implementation does not lead to unwanted consequences.

4.1.3 Improvement of seminars

Drawbacks of a seminar are not always obvious, and AI may help teachers to uncover them. *Coursera* is an online seminar platform that is already practicing this. When there is an occurrence of a greater number of students submitting incorrect answers in homework, the system warns the teacher and prepares an individualized message for future students, which contains a hint as to the correct answer. Such an approach helps to eliminate a pedagogical gap and ensures that the students get the immediate feedback which helps them to understand a difficult concept.

4.1.4 Searching for information

We seldom pay attention to the AI systems that customize information for us every day. The customization parameters are based on, for example, locations (Google), purchase history (Amazon), or our needs and demands (Siri). Almost all online advertisements are tailored according to our interests and buying preferences. These intelligent systems have a significant role in how we interact with the internet and information in our professional and private lives. And why should matters be any different in the educational process? Here, too, exists the possibility of customizing information that we use for learning. Current generations of graduates have a radically different approach to research compared to their colleagues from a few years ago. The use of new intelligent accessories in education can increase the impact of the customization of information, and that is why it is even more important for us to be capable of correctly assessing their developmental adequacy [19, 20].

5. Conclusion

Machine behavior is one of the most intriguing, nascent fields in AI. Behavioral sciences can support traditional interpretability methods in developing new methods that will help to better understand and explain the behavior of AI. As the interactions between humans and AI become more sophisticated, machine behavior might play a crucial role to enable the next level of hybrid intelligence. From all of the above it can be concluded that at least the following three guidelines should be taken into consideration, especially with respect to using intelligent learning environments in education:

1. Not every kind of AI is a benefit to mankind, and not all uses of AI are ethical and moral.

2. The ethical use of AI should be judged not only by computer scientists, roboticists and engineers, but (especially) by behavioral scientists.

3. Teachers need to be trained (empowered) and provided with appropriate competences to assess the usefulness and ethical use of AI.

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