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Disruptive Innovation Technology for Inclusive Education

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Key Words: *Disruptive innovation technology; cyber-physical systems; inclusive education; pedagogical rehabilitation.*

Abstract. *The emergence of disruptive innovation technologies (DITs) is influencing all aspects of life and will inevitably change the physical and organisational nature of schools. The paper presents a novel vision of the school of the future in relation to the recent and current research of the authors within a joint research project. It emphasizes the cyber-physical system (CPS) approach to inclusive education and the validation of the proposed technologies with novel smart sensors and devices for the classroom.*

1. Introduction

Disruptive Innovation Technology based schools, or DIT-based schools can be perceived as the schools of the future. Imagine schools, where children do not have to choose between the lesson and the smartphone, schools with less tests, yet with better teacher awareness of children attention distribution, schools with individualised teaching methods within however big classes, schools where children are engaged in supporting each other to acquire new knowledge instead of competing for better marks than the other children. Is such a school possible? Is the level of present day technology sufficient for the emergence of such a school?

The present paper tries to justify the concept that the DIT-based schools can provide the facilities to achieve the goal of educating children without tiring them or forcing them to memorise material they do not understand and will forget very soon, but helping them reveal their learning potential and talents, and enjoy the process of learning.

The proposed theory is based on two important scientific developments: The first one is the emerging concept of cyber-physical systems for education and pedagogical rehabilitation [5] and the second - the emerging theory of social-cognitive neuropsychology at the intersection of cognitive neuropsychology and social cognitive neuroscience [9]. Section 2 presents the current taxonomy of cyber-physical systems and the possible theoretical relation to a current taxonomy of DITs. Smart sensors and devices to be included in novel types of DIT for the classroom of the future are discussed in this context.

2. The CPS as a novel type of DIT for schools with inclusive education

The concept of Cyber-Physical Systems (CPSs) has been introduced to account for technical devices with certain adaptive, sensing and reasoning abilities with a varying degree of autonomous behaviour within networked environments with or without the human in the information and control loop [6, 12, 20].

The present day school is a complex hierarchical organisation of many functional levels; its operation is based on planned activities aimed at achieving certain goals within fixed time constraints. From a managerial point of view a school resembles an industrial enterprise – therefore it can be modelled like a cyber-physical system, designed to accomplish some production mission within a networked environment with humans in the information and control loop. And the product is the type of knowledge the children acquire – deep, dynamic, problem-solving oriented, or shallow, static, encyclopaedic, but without links to the pressing issues to be resolved in the society.

Present day sophisticated, adaptive and semi-autonomous robotic technology is a radically new stimulus for the cognitive system of the human learner from the earliest to the oldest age and deserves extensive, thorough and systematic research, based on novel frameworks for analysis, modelling, synthesis and implementation of CPSs for social applications [8].

2.1. Taxonomy of current CPSs

Seven types of CPSs are defined in the working documents of the EU [12] (first 7 rows of *table 1*). To them 3 additional, but none less important, are proposed as emerging and rapidly acquiring influence in present day society – under No 8-10 of *table 1* – in [7].

Table 1. Taxonomy of Cyber-Physical Systems (adapted from [7])

	Cyber-Physical Systems
1	Disabled People
2	Healthcare
3	Agriculture & Food Supply
4	Manufacturing
5	Energy & Critical Infrastructures
6	Transport & Logistics
7	Community Security & Safety
8	Environmental Robotics
9	Creativity, Art, Social Communication/Media and Companionship
10	Education & Pedagogical Rehabilitation

Environmental robotics includes swarm robots, robots intended to replace bees in the field, growing robots like trees, robotic fish intended to collect the underwater pollution especially in bay areas of big cities and underwater cleaning of ship corpuses. Two such robotic systems are currently being developed under the FET Proactive funding scheme of the EC – 2015-2018: FLORA ROBOTICA and subCULTron [13].

The domain of CPS for creativity, art, social communication/media and companionship deals with the entertainment industry where robotic performance is comparable to the human one – in composing music, painting, performing music or dancing and in simulating human-to-human communication in the social media [3, 22].

The education & pedagogical rehabilitation frameworks have emerged recently but have been employed widely for implementing information and robotic technology in clinics and special education [1, 2, 15, 16]. Multi-paradigm modelling approaches to CPSs have been explored within the COST Action MPM4CPS (2014-2018) [4]. Specifically for special education is the orientation of the EU MSCA Project CybSPEED: Cyber Physical Systems for Pedagogical Rehabilitation in Special Education [2017-2021] [5].

This classification of CPSs is proposed and justified by an experimental study on the process of design of novel educational technology in [7]. A staged process was implemented including eliciting teacher's scores after each stage in order to ascertain that the final design was reached by incrementally moving in the direction of better user acceptance of the new technology. In such a case the teachers perceive the new technology not as something alien to their work, but as a necessary and awaited extension of their own teaching method and style. It is possible to transfer the method to approaching the social services in order to overcome the resistance towards new technologies in social service institutions in the direction of better acceptance and higher work satisfaction of the social service providers.

2.2. Taxonomy of current DITs

"A disruptive technology is one that displaces an established technology and shakes up the industry or a ground-breaking product that creates a completely new industry" [17]. *Table 2* summarizes the most commonly assumed technologies that have disrupted a number of industries in recent years – from 1 to 8 [21].

Table 2. Taxonomy of Disruptive Innovation Technologies

	Disruptive Innovation Technologies
1	Artificial Intelligence
2	Robots
3	Drones
4	Virtual Reality
5	Augmented Reality
6	Blockchain
7	The 'Internet of Things'
8	3D printing
9	Cyber-Physical Systems Approach to Social Institutions
10	Social Cognitive Neuro-Psychology Based Human-Robot Interface

The presented in the paper vision is that the school sustaining industries can be reshaped by the concept of the school as a CPS which may bring ground-breaking innovations into schools. We propose to add to table two more – the CPS approach to social institutions under No. 9 and the emergence of the new theory for understanding the process of interaction between humans and the CPS – the social cognitive neuro-psychology – as motivating the design of novel interfaces for the school of the future – under No. 10 (*table 2*).

2.3. Intelligent classrooms of the future

In the classroom of the future the desks are intelligent and can measure a variety of indicators of the child emotional state and attentional focus – like restlessness or eye blink rate. The "internet of everything" approach to building it is based on the one hand on artificial intelligence algorithms to define the physical and emotional states of the child, and on the other – on implicit measures avoiding video recording or other explicit ways of disclosing the personality of the learner. The teacher will be able to track the states of the learner remotely or post hoc for follow-up meta-analysis of the teaching process.

Robots will play a significant role in the process as assistants to the teacher (*figure 1*). However they will not be used for recording of child's behaviour or state – in order to avoid the feeling of being observed and assessed by the child. Robots will be used to engage attention and support the learning process with more entertainment and focus on novelty in the lesson as it is well known that novelty supports memorisation [11].

Figure 1. Initiating dialogue with a humanoid robot, designed to respond in an empathic way (https://www.softbankrobotics.com/emea/en/pepper)

2.3.1. Smart sensors in the classroom

In the smart classroom of the future the desks are equipped with sensors to detect various influences. One such influence is the restlessness of the child. Tactile and temperature sensors will detect if the child is sitting still or is being nervous/impatient. It will analyse the physical behaviour and even diagnose conditions like flu or allergy, for example. All the information will be stored in a decision support system (DSS), which will be used for longitudinal analysis of the child condition and for support of the teaching strategy of the teacher.

The influence we focus here is the blink rate of the individual child [18, 19]. This indicator is essential in respect to certain moments in the lesson, dealing with introducing novel information. The blink rate suppression is an indicator that the child it interested in the provided information, which is a spontaneous reaction of the brain to novel stimuli [19]. Lack of blink rate suppression is an indication that the child is bored or the information in the lesson is not new. When the DSS system is aware of the child inattentiveness to certain new aspects in the lesson, it will be possible to generate recommendations to learn or revise certain items, but not all. This process will also help optimize the number of tests in class, which will reduce the overall level of stress of the children. Therefore, the entire framework aims at providing more positive atmosphere during learning overall.

2.3.2. Blink counting device

The device consists of 3 sub-circuits (parts) (*figures 2* and *3*). The first sub-circuit will use an ir cut beam sensor or a vibrator sensor, as well as a voltage comparator or an amplifier (part 1). This is the most difficult part of the device design, where enough experiments and adjustments will have to be done so that we have the optimal result (voltage), which will be the input of the one-shot vibrator. This is shown in the combinations made in part 1.

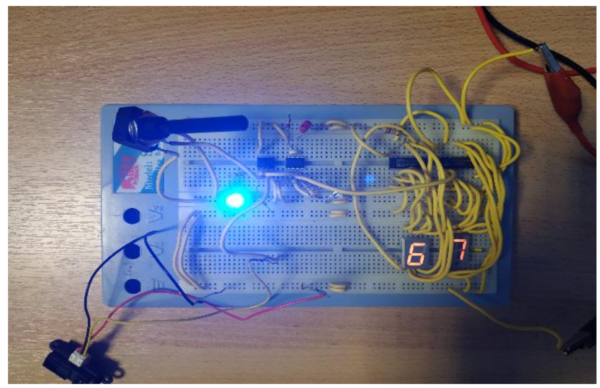

Figure 2. Blink counting device

The 2nd sub-circuit consists of a one-shot vibrator. This is a circuit that just gets the proper voltage at its input from the 1st part and produces at the output a square pulse with a positive pulse front of certain duration. This pulse is entered to the 3rd sub-circuit and specifically to the integrated circuit of the 7-segment display driver. With each such pulse that triggers its input, the driver produces a voltage at its output, which changes the state of the displays by increasing the number by one. This device can measure up to 99 blinks p/s. Of course, there is the possibility of extending it for more measurements.

The blink counting device can be integrated in the environment of the classroom – i.e. in the desk. If implemented in a DSS or a blended learning framework, it will provide data on the attentional resources of the individual learner. Based on this information the teaching style can be adapted to the individual child. Moreover, by using such implicit, indirect indicators the process of human-system interaction will be relieved from the feeling of being observed or videotaped [10, 14].

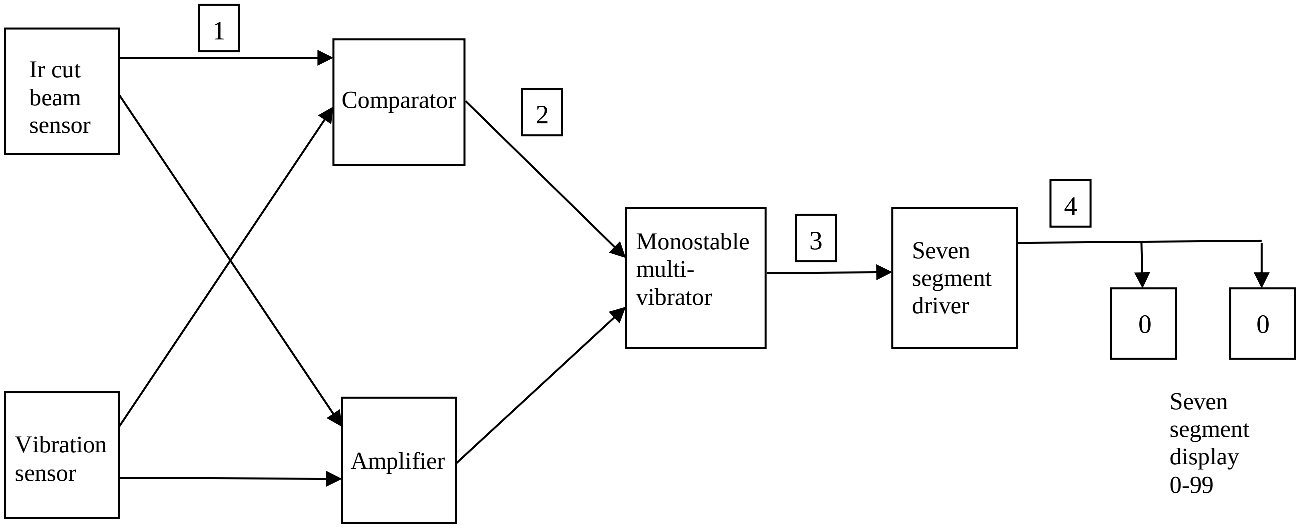

Figure 3. Block diagram of the blink counting device

Conclusion

The paper presented a novel approach to the transformation of present day schools into the school of the future by intensively introducing disruptive innovation based technologies, such as artificial intelligence, virtual reality, etc. It is argued in the paper that two novel theoretical approaches to understanding the interaction of the human with technology can play the role of disruptive innovation based technologies – the cyber-physical systems approach to social institutions on the one hand, and the approach to derive design guidelines from recent social cognitive neuro-psychology in novel human-robot interfaces for education. Future studies foresee pilot tests of the designs in realistic conditions.

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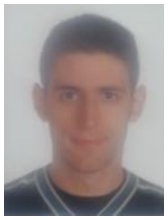

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