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INQUIRY-BASED SCIENCE LEARNING IN DIGITAL AGE: RETHINKING THE SAMR MODEL

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Abstract

The paper deals with transformations of science education inspired by integrating emerging technologies in inquiry-based educational practices. Specifically, transformations of practices associated with microcomputer-based laboratories (MBLs) are discussed. A new exposition of known SAMR (Substitution Augmentation Modification Redefinition) model is proposed for above purposes. According to the proposed approach, the sequence of the SAMR levels is considered as a progressive advancement from the traditional instrumental interpretation of technology (Substitution) to its transformational interpretation (Redefinition). Particularly, a number of innovative educational practices have been associated with the Redefinition level of MBLs. Among them: a) augmented-reality based laboratories equipped with mobile and wearable technologies; b) cloud computing based remote science laboratories; c) laboratories equipped with cyber-physical systems. It is shown that the Redefinition level reflects fundamental transformations of our society in the Digital Age. The newly proposed SAMR model demonstrates the deep interpenetration of science and technology. The authors believe that the approach will allow to determine new ways for future advancements of science education.

Keywords: Science education, inquiry-based learning, microcomputer-based laboratories, emerging technologies.

1 INTRODUCTION

Presently, various remarkable and promising emerging technologies (e.g., mobile, wearable, cloud computing, and cyber-physical systems) started their integration in science educational practices. A number of researchers associate their great expectations with the advent of these technologies in school. What is the role of the emerging technologies in science learning? Do they improve/transform science learning environments? Do they enhance students' understanding of scientific concepts and/or improves scientific practices? These questions are on the research agenda of many science educators and researchers.

A number of models were suggested to study and to assess the role of emerging technologies in science education. One of such models, so-called SAMR (Substitution Augmentation Modification Redefinition) was designed to support and to assist integrating technologies in teaching and learning [1]. According to the SAMR model, there are four levels of the integrating: 1) the substitution level corresponds to cases where technology acts as direct tool substitute, with no functional change; 2) the augmentation level corresponds to the tool substitution, which includes a certain functional improvement; 3) on the modification level, technology allows for significant task redesign; 4) on the redefinition level technology allows for the creation of new tasks, previously inconceivable. Learning activities that fall within the substitution and augmentation classifications are said to enhance learning, while learning activities that fall within the modification and redefinition classifications are said to transform learning [1].

In our paper, we propose a new exposition of the SAMR. The main idea is to consider the sequence of the SAMR levels as a progressive advancement from the traditional instrumental interpretation of technology (represented by the Substitution level) to its transformational interpretation (represented by the Redefinition level). The Redefinition is the supreme level of technology integration reflecting fundamental transformations of our society in the Digital Age [2].

The paper is organized as follows. In Section 2, the main transformations of our society in the Digital Age are presented. How emerging technologies reflect the transformations is discussed in Section 3. The new interpretation of SAMR and its exemplary implementation for study of microcomputer-based laboratories presented in Section 4.

2 TRANSFORMATIONS OF SOCIETY IN DIGITAL ARE

Global society has transitioned into the digital era; this shift represents a revolution in human history – the so-called digital revolution [2]. This revolution relates to fundamental principles of humanity. It has changed people's understanding of their place in the world, as people no longer merely consider humanity a part of the nature, but also a part of the artificial world that humans have created. The digital revolution also changed people's perception of society. Digital society is a hyper-connected one, in which people may have hundreds of acquaintances living in distant parts of the planet, with whom they exchange information. Presently, people have unlimited and ubiquitous access to desirable information, which, in turn, becomes personalized and context-aware [3]. Our world has become the world of information abundance. The society of information abundance contrasts with the previous (industrial) society of information scarcity. Therefore, the *information abundance* serves as one of the important transformations of coming digital era [4].

The digital era has led humanity to take on a new perspective on its surrounding environment. People are gaining an awareness of the fact that we live not only in a ‘real’ environment, but also in a virtual space. Such a ‘twofold reality’ is manifested by emerging technologies of augmented and mixed reality, which enable new forms of knowing the surrounding world. This phenomenon corresponds to another transformation of digital society – *a blurred distinction between reality and virtuality* [5].

Within the digital society, people have begun perceiving themselves as “informational organisms (inforgs), mutually connected and embedded in an informational environment (the infosphere)” ([2], p. 94). The concept of inforg includes not only humans but also specific informational artifacts that are able to communicate with people and even demonstrate elements of social behavior. The emerging cyber-physical systems (CPSs) comprise an example of such informational artifacts, since they are hybrid systems that can be considered neither purely artificial nor purely natural. Indeed, as advanced computer-embedded systems, CPSs demonstrate other transformation of digital society whereby the *boundaries between people, artifacts, and nature are blurring* [5].

The above transformations, which relate to very fundamental features of the human being affected a plurality of components of human culture. Among such highly transforming components of culture - the scientific inquiry in general, and inquiry-based science education specifically [6]. Naturally, the main accelerating component of the transformations is the phenomenon of emerging technologies addressed the next section.

3 EMERGING TECHNOLOGIES AS REFLECTED TRANSFORMATIONS OF DIGITAL SOCIETY

We focus on three emerging technologies: (a) mobile and wearable; (b) cyber-physical systems; and (c) cloud computing. Namely these technologies reflect the mentioned above transformations of digital society. Each of these technologies corresponds to the specific transformation.

3.1 Cloud computing

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [7]. Floridi (as cited in [8], p. 4) considers cloud computing as the first “graceful step out” of the idea that computers need humans. When compared to locally controlled computers, computing resources in the cloud are remote from their users and more independent.

Cloud computing being providing ubiquitous and easy access to data as well an ability for data exchange, reflects one of the transformations of the digital society - *reversing from information scarcity to information abundance*.

3.2 Mobile and wearable technologies

Mobile devices are currently the main example of ubiquitous technologies. Ubiquitous computing is based on the concept of an invisible computing power embedded in the environment that can act and react according to the user's needs. Ubiquitous computing is a group of technologies including context-aware computing, ubiquitous wireless networks, smart objects, location-based systems and, more recently, mobile-based technologies. This paradigm involves the most natural possible interaction between a user and a computer, with the final aim being that the user will not even realize that he is interacting with a system [9].

Emerging technologies such as mobile computing, sensors and sensor networks, and augmented reality have led to innovations in the field of wearable computing. Devices such as smartwatches and smart glasses allow users to interact with devices worn under, with, or on top of clothing. Wearable technologies being integrating observation of data both from simulations and from reality, reflect the other transformation of the digital society: *blurring the distinction between reality and virtuality*.

3.3 Cyber-physical systems

CPSs represent a specific branch of complex technical systems conferencing knowledge and technologies of computing, networking and informing, and those of physical artifacts and engineered systems towards operating and servicing in human and social contexts. In the cultural context, we consider CPSs as the artifacts owing characteristics that allow them to be inhabitants of the newly recognized infosphere is a new habitat corresponding to the digital society [10]. Humans behave as informational beings not only in cyberspace, but also (and even more) in reality. However, the reality is permanently changing by accommodating more and more other informational entities, which, in turn, may also serve as artifacts.

CPS is a bright example of objects that cannot be attributed either to nature or to the technology. They contain both natural and artificial components. Obviously, such kind of systems reflect another important transformation of the digital society, which is: *blurring the distinctions among people, nature, and artifacts.*

In the next section, we show how the above correspondence between the emerging technologies and the main transformations of the society can be studied on the base of our SAMR model.

4 ANALYSIS OF MICROCOMPUTER-BASED LABORATORIES BY USING SAMR

In this paper, we focus on the specific science learning environment - Microcomputer-Based Laboratory (MBL) and analyze it by our SAMR model. The MBL is a learning environment equipped with emerging probes and sensors, actuators, controllers, data processing and communication hard- and software. MBLs provide hands-on activities including various lab experiments in the majority of science curriculum topics [11].

The emerging of the MBL in science laboratory is converting the traditional laboratory into digital one by integrating such devices as microprocessors, digital probes and sensors. The function of these digital devices is automation of the collecting and registration of experimental data. Obviously, the MBL-based upgrading of the traditional science laboratory where the data collecting was carried out manually, was a significant step ahead. Nevertheless, this upgrading didn't change the essence and methodology of experimental research. The innovative digital means just replaced the previous tools (analog probes, sensors). Thus, the MBL transformation has to be determined as the Substitution level of integrating technology in science laboratory.

More advanced versions of MBL had provided the data processing and not only data collecting. Obviously, this feature had improved the students' experimental activities by freeing them from the traditional time-consuming calculations. The students became able to observe on-line various of visual computer representations of real processes being plotted simultaneously with the corresponding experiment. Such MBL provides students with the opportunity to analyze processes and corresponding scientific concepts. The converting MBL into a data processing tool can be defined as the Augmentation level of the integrating technology. Notice that both of the automations: the data collection and the data processing still represent just enhancing traditional science laboratory.

Nevertheless, there are technological advances in the laboratories, which should be interpreted as significant transformations of the MBL. The most remarkable example of such advances is the emergence of networked MBL, which is the MBL connected with the global network of Internet. Such connecting is performed on the base of special software developed in order to provide collaborative learning activities in a network of science laboratories [12]. The collaborative activities give born to a new style of learning experimental science – the collaborative learning style. We determine such interconnected MBL as manifesting the Modification SAMR level. Indeed, the networked MBL provides such innovative inquiry activities as collaborative data acquisition, sharing and analysis; collaborative inquiry argumentation, brainstorming, reflective writing, feedback, and interacting dialogue.

According to our SAMR model, in order to correspond with the supreme, Redefinition level, the MBL has to represent a new entity, which is not similar, even far away from the traditional laboratory. In this direction, we associate our expectations with such new educational practices as:

1). *Augmented-reality based laboratories*. Mobile and wearable technologies provide some new types of augmented-reality labs, where real phenomena are augmented with virtual objects [13]. Such kind of labs represents an example of the – blurring the distinction between reality and virtuality in digital age.

2). *Remote laboratories*. Cloud computing opens a way to remote experimentation, which enables students to carry out live science experiments over the Internet by efficiently sharing the necessary resources seamlessly [14]. Such unlimited and ubiquitous access to experimental data as well as possibility to share the resources represent an example of the information abundance.

3). *Laboratories equipped with Cyber-physical systems*. Integrating cyber-physical systems in lab learning environment changes the traditional lab where research objects or phenomena are natural. The new labs include the hybrid natural-artefact objects. Such learning environment represents a new educational entity, where the distinctions among people, nature, and artifacts are blurred (see for example [15]).

Figure 1 represents the above SAMR-based interpretation of the MBL graphically in a form of the conceptual map. In this figure, each SAMR level is represented in a form of rectangle and corresponds to a specific above-mentioned MBL forms. Furthermore, a rectangle corresponding to the Redefinition, the supreme SAMR level, is connected to rectangles of the main transformations of the digital age (left in the figure).

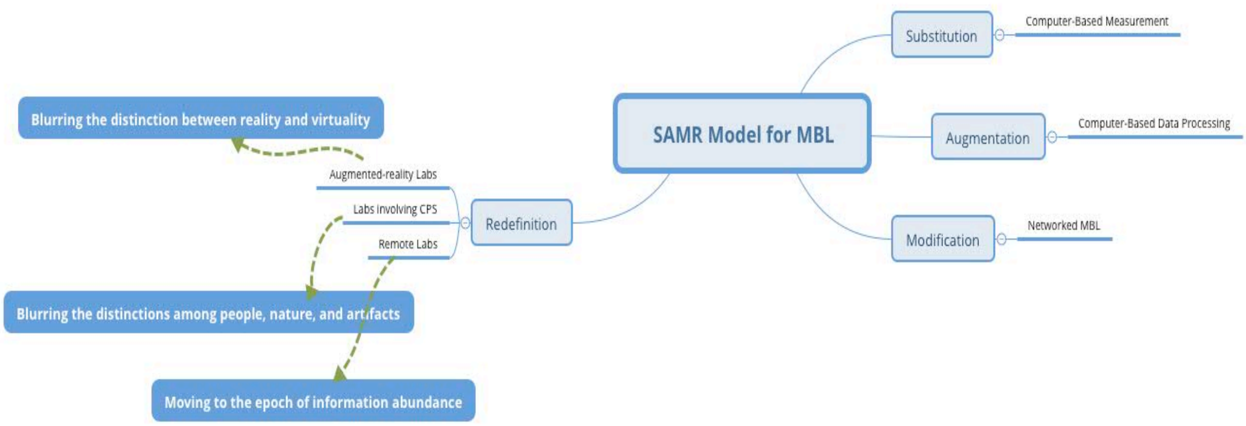

Figure 1. The conceptual map of the proposed SAMR interpretation of MBL.

5 CONCLUSIONS

Our study contributes to the existing knowledge regarding the integrating digital technologies in science education. We have introduced a new approach for studying the integration. Our approach formulates a new exposition of known SAMR model.

First of all, the roots of the proposed approach are the correspondences between advances in emerging technologies on the one hand, and the transformations of our society in digital turn - on the other hand. The SAMR Redefinition level is considered as the supreme level where the transformations are manifested.

Secondly, the approach demonstrates an important phenomenon of the deep interpenetration of science and technology. This phenomenon is illustrated by an example of integrating digital technologies in Microcomputer Based Laboratories.

We believe that the approach enables to determine ways for future advancement of science educational practices.

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