DECONSTRUCTIONISM IN EDUCATION – A PERSONAL WANDERING TOWARDS CONSTRUCTIONISM

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Abstract
This paper presents an application of constructionism in two different environments – a university level course blending Mathematics, Physics and Computer Science; and a secondary school project for Inquiry Based Learning. Discussed are the main solutions and results, their advantages and disadvantages. Then the main phases of knowledge construction are identified, while a special attention is paid on the deconstruction of knowledge, its manifestation and impact on education. The deconstructionism is defined as a new approach co-existing with constructionism. The paper discusses the deconstruction in education and concludes with deconstruction of education.

Keywords Educational Software, Mecho, weSPOT, Virtual Classroom, Deconstructionism

"Every act of creation is first an act of destruction"
Pablo Picasso

1. Constructivism and Constructionism

Constructivism in education is a philosophy that advocates the construction of knowledge through real-life or real-life-alike experiments fostering learning. The role of the teacher is not to transmit knowledge, but to guide the learner through his personal journey in learning. The earliest examples of constructivism in education are proposed by John Dewey and Maria Montessori. Dewey describes thinking as a natural act that should be supported by an encouraging environment rather different from the monotonous uniformity of classrooms and textbooks [1]. An important factor for development of creative thinking is the curiosity that leads to exploration. According to Montessori, education starts from birth and "*the child must not be considered as he is today ... He must be considered in his power of potential man*" [2]. She builds unique learning environments which are considerate of student's physiological and psychological age.

A significant contribution to the constructivism is made by Jean Piaget. He sees learning as a continuous process, where a student assimilates knowledge entities into meaningful knowledge constructs. The constructivism, as described by Piaget, is focused on the mental models of the world. This theory is further extended by Seymour Papert in a way that it applies to the practical construction. Papert calls this *constructionism* [3]. The main concept is that constructing tangible artefacts helps the construction of mental understanding of the world. Papert proposes an extensive use of IT in the classroom that supports another important aspect of constructionism. Namely, constructing real entities is public in the sense of observable by others. More importantly, the process of construction is also public [4] and this makes learning more effective and sustainable.

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2. Constructionism in Education

2.1. Constructionism at University Level

The concepts of constructionism have been applied to education and the results are promising. Several courses based on Logo have been introduced in the Faculty of Mathematics and Informatics at Sofia University. Some of them were focused on building educational software; others were addressing topics like real time computer animation [5]. The common attributes of all courses were:

- Students are taught the basics of building complex constructs out of a small set of elements.
- Students make a project on a topic of their choice but in the frame of the specific course.

One of these courses, named *Geometry of Motion* (*GM*), is a multidisciplinary course blending Mathematics, Physics and Computer Science. In this course the students get familiar with the fundamentals of Geometry, how it is used to describe motion in Kinematics and how animations in Computer Graphics represent physical motion based on mathematical properties.

A few years after the beginning of this course Logo has been used to create virtual mechanisms that recreate mathematical concepts. A collection of animations was made public [6, 7]. However, all these mechanisms were implemented as individual programs. When GM started in 2007, the CS segment in GM was merely a demonstration of how computer animation is implemented. In 2010 it was decided to make a library *Mecho* (*Mechanical Objects*) allowing the students to construct their own devices [8]. Since then new versions of Mecho are released annually, the last one being completed in March 2014. The latest versions Mecho 3.x are developed within the research project DFNI-O01/12 financially supported by a grant from the Bulgarian Science Fund of the Ministry of Education and Science. The project is addressing contemporary programming languages, environments and technologies and their application in development of software specialists.

The library followed the major elements of the constructionism, providing an elegant tool for students to express their creativity through public construction of virtual mechanisms. One of the design ideas implemented since the very first version of Mecho is to organize the structure of a virtual mechanism into a well-defined hierarchy. There are simple elements representing the basic mechanical component. They are used to build virtual devices, that can be, in turn, used as components of more complex devices – see *Figure 1*. The virtual 3D environment of Mecho is designed to be attractive and motivating. The software provides a set several types of the scene with different materials, grounds and lights. These types are used to increase the artistic appearance of the models and sometimes to represent the historical background of a device.

Figure 1. Mechanical components (left), a virtual device (middle) and a complex of devices (right)

The development and improvement of Mecho was guided primarily by the idea of providing an easy and intuitive environment fostering constructionismic activities. The interface and the performance were gradually moved to a state where they do not exhibit any problems. Yet, very few students volunteered to build devices. The making of a virtual device was an elective activity for the course, a student may choose to make a project and if successful, this will contribute to the grades. Also, a student may decide not to make a project, thus the grade will be based only on the final exam. The issue of avoiding any elective activities was very important as it indicated problems of how well the constructionism was applied.

After a detailed analysis it was possible to identify some of the key elements that prevented students from getting motivated.

- *Learning Barrier:* The allocated time for the CS section of the course was 15 academic hours (approximately 11 astronomical hours) per semester. This time was insufficient to introduce the students to a new programming language (i.e. Logo), to demonstrate how motion is implemented in computer graphics, to present Mecho and to explain how devices are made. To resolve the learning barrier Mecho and all teaching materials were completely rewritten into C++, a language that the students already know well.

- *Conceptual barrier:* The projects must be interactive 3D applications. Creating software with such properties is cumbersome, especially if students have to deal with visualisation and rendering issues. This barrier was eliminated by redesigning the Mecho software so that all supported activities, like frame generation and navigation, happen "automatically". What students have to do is just to list the virtual components they want to use, and to describe how they are connected.

- *Mathematical barrier:* Although the students have passed a course in Analytical Geometry, they still have no practical sense of 3D motion. For example, it appeared very difficult for them to express orientation in 3D space via Euler angles. This observation led to the decision of trading mathematical efficiency to user friendliness. As a result, the latest few versions of Mecho represent orientation by 4 non-Euler angles instead of the optimal 3 euler angles.

- *Procedural barrier:* The evaluation of each project is done against 25 criteria. Students are introduced upfront to these criteria, but they still experience problems complying with them. The origin of the problem was in the way they started to make their projects – the students were trying to address many criteria at the same time. As a result, they failed to comply with most of them. To overcome the procedural barrier in 2014 the grading criteria have been clustered in a hierarchy of five levels: *compulsory criteria*, *procedural experience*, *visual experience*, *hardware experience* and *software experience*. Initially the students have to focus only on the bottom level of the hierarchy. Once they meet the criteria at that level, they aim at the next level and continue until they reach the top level.

The solutions used to eliminate the four barriers make the construction of devices much easier. The new projects are due in June 2014, so the actual evaluation of this approach will not be available earlier. However, the experience from past years as well as from other constructionism-based courses shows that there is still some conceptual problem. This problem is discussed in section 3.

2.2. Constructionism at Secondary School Level

Inquiry Based Learning (*IBL*) is a concept closely related to constructionism. In IBL students learn by asking questions and finding answers, rather than by listening to a stream of digested facts. IBL is one of the approaches to implement constructionism in education and it is recognized as such by institutions at different scales. This subsection presents an IBL software developed for two complementing projects: *weSPOT* (EC FP7 Programme in Technology Enhanced Learning) and *Role of IT on Application of IBL in Science Education* (Sofia University Science Fund).

The goal of weSPOT is to support realization of IBL through the creation of software tools for personalization of the IBL environment and for the management of IBL activities. The project developed a detailed IBL model of six interconnected phases and over 40 components shown in *Figure 2* and discussed in [9]. The expected result is that students become researchers and scientists by asking curiosity-driven questions to obtain structured knowledge/context of science concepts. Students are expected to gain skills for effective research, collaboration and creativity.

The goals of the second project is to conduct a research on the role of IBL in education by adaptation of weSPOT's results to focus on science experiments, individualization of education and supporting of social collaboration. Several pilot experiments were conducted as a competition between 6-grade classes. The topic of the competition was *My classroom – The most energy effective!* The task was to measure temperature variations, weather conditions and the classroom state (like opened windows, doors, state of air conditioners, number of people, etc.) Each class had to produce a report about their measurement including analysis on what factor affected most (and least) the energy consumption. Finally, the report had to contain suggestions and ideas for reducing the amount of lost energy.

During the first year the students were collecting data for 3 months. This appeared to be demotivatingly long for 6-graders and it was difficult for the teachers to keep the students interested in the competition. From IBL point of view there were two main problems with this kind of pilot tests. Because of the duration of the data collections it was practically impossible to repeat the same experiment twice. It was also impossible to change the initial configuration of an experiment and test how this would affect the outcome.

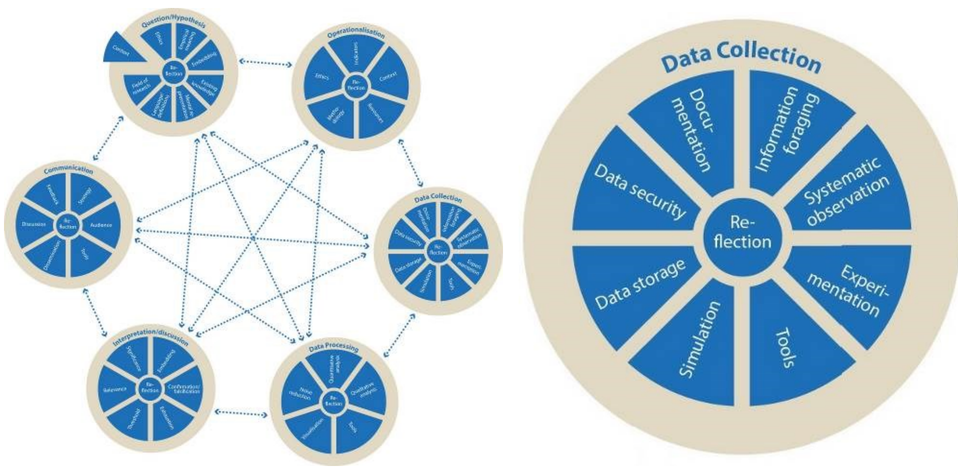

Figure 2. The weSPOT model of Inquiry Based Learning (left) and a close-up of Data Collection phase (right)

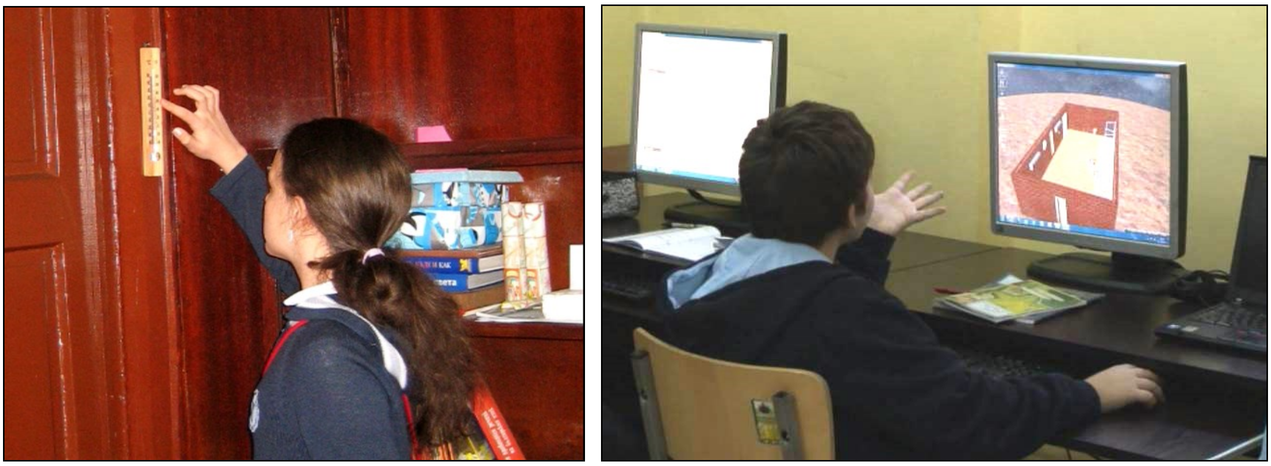

Figure 3. Manual recording of temperature (left) and working with the virtual classroom (right)

For the second year of the project the team decided to provide an alternative approach – *The Virtual Classroom* [10]. This was a standalone interactive 3D application that simulated both the weather conditions and the room configuration. The implementation was based on decisions, that had been considered very risky at the beginning, but that eventually provided a solid foundation for application of constructionism in the classroom.

The first decision was to make c*ontinuous simulation* – there were no buttons to start or stop it. The simulation was running even when the students were setting the initial parameters of their experiments. The second decision was to make *unrestricted simulation* in the meaning of the ability to set unnatural initial conditions. For example, if it is 40 °C and it is snowing, the temperature will smoothly go down until the physical model reaches equilibrium. That is the main feature of the internal simulation mechanisms – it does not use any specific algorithm for calculating the parameters. Instead, it only manages transfer of energy in small quantities towards equilibrium. These two decisions contributed to a better simulation, close to the real world in which students cannot control the fabrics of a phenomenon.

To support the inquiry process the Virtual Classroom was given to the students (and their teachers) *without any documentation*. Thus, they had to find by themselves all features – how to manipulate the model, how to conduct experiments, how to navigate, etc. There was no reference document that described the simulation mechanisms and the impact network between entities, e.g. the only way to learn whether the number of students in the classroom affects the air temperature is … to try it.

The pilots with the 6-graders were video-recorded. The analysis of the recordings shows that the software did provoke inquiry learning and active constructionism. Every student worked at his/her own pace while gaining scientific skill. The pilots were conducted in the spirit of constructionism – students learned by constructing public entities and the process of construction was also public. Thus, students were observing the progress of their classmates and they soon started to exchange ideas and tricks. One of the things that the students learned (this was not planned ahead) was the scientific importance of details. Several students made the “same” experiment, but they got opposite results. The confusion lasted until they found some subtle differences in the initial conditions. This experience was quite valuable; it helped gaining the skill of evaluating what parameters are essential for a specific experiment, and what could be ignored.

3. Deconstructionism in Education

3.1. Phases of Constructing Knowledge

The experience with university and secondary school students shows that it might not be so straightforward to utilize constructionism. Although different tools were created to support this application, students still experience significant problems.

The process of learning through construction can be split in two phases – *deconstruction* and *construction*, shown in *Figure 4*. Within this paper (except for the motto) we will use the word *deconstruction* in the sense of decomposing something into reusable entities. In contrast, the meaning of *destruction* would be to destroy something. The left image in *Figure 4* represents a piece of knowledge about an object or a phenomenon. The first phase of learning is to decompose this knowledge into smaller yet meaningful for the learner entities. Once this phase is completed, the entities are used as building blocks to construct the personal knowledge (which is not necessarily the same as the original). There is a third phase where the learner rearranges the entities in another way, producing new knowledge.

Most of the literature about constructionism is focused on Phase II – the construction. A lot of approaches have been developed in order to ease this phase. ICT solutions implemented by providers of educational content also focus on this phase. The experience with students at Sofia University and secondary school students, where pilots were conducted, shows that the most difficult phases for students are Phase I and Phase III. The creativity phase is usually an optional phase, as long as there is no universal and working algorithm on how to create creativity. Moreover, most of the conventional lessons are designed to reach up to Phase II. This is not the case with Phase I – the deconstruction. It is a prerequisite to the construction phase, so any failure to deconstruct knowledge is a prerequisite to a failure in the construction. Even more, the skills needed for effective deconstruction are similar to the ones used in creative activities.

The issues with the deconstruction phase have been identified long time ago. In a paper published in 1990 Mitchel Resnick describes what he calles *problem-decomposition bugs*, which point to the difficulties of decomposing problems into simpler entities [11]. This problem decomposition is presented as space of two dimensions: *functional decomposition* and *agency decomposition*.

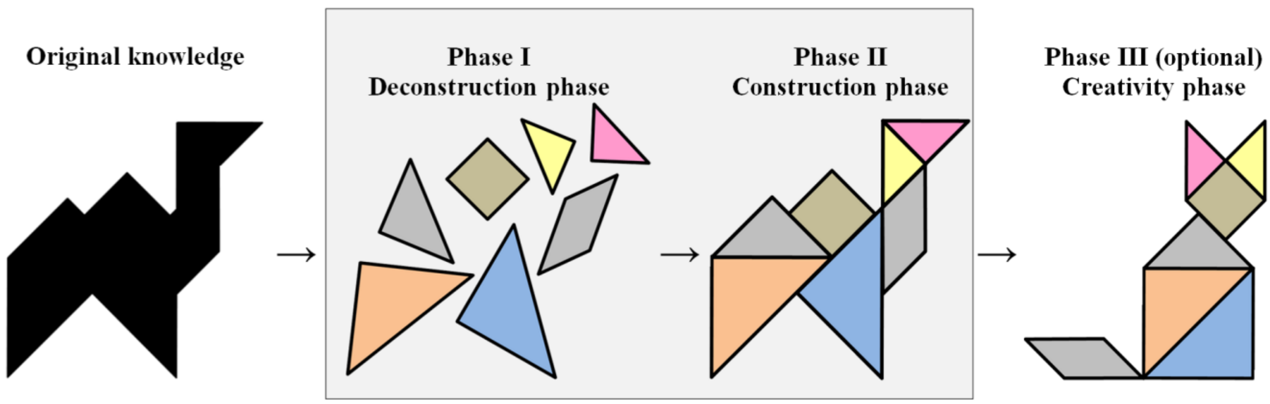

Figure 4. Phases of learning through construction

3.2. Manifestation of Deconstruction

The nature of the deconstruction phase is elusive and vague. It happens behind the scenes and is often interlaced with activities from the construction phase. This makes it difficult to identify the activities that occur during deconstruction. The experience with university and secondary school students shows that the creative deconstruction has many distinct manifestations. The following list provides some of the most observed presentations:

- *Debugging*. From a deconstructionismic viewpoint debugging is the process of decomposing the execution and/or dataflow of a running program. When the decomposition is done well, these entities are used to isolate and track bugs in the program. There are tools helping this process, like program tracers, incremental debuggers, data watches, etc. However, these tools decompose into predefined entities, which often may be inadequate for quick and effective debugging. For example, these tools are good for tracking the expression of a bug, but not the actual bug, which may be located in a completely different area in the code.

- *Animation design*. When creating an animation, students face the problem of representing a motion as a composition of simpler motions based on math functions. This deconstruction appears to be quite hard for the students, because they lack the skills to see (or to imagine) how a composite animation could be represented as an outcome of fundamental functions. While learning some graphical system the students are often unhappy with the provided set of core functionalities – is appears like insufficient to model complex animations. During the course *Fundamentals of Computer Graphics* the students had to model various types of motions typically based on physical models. One of the most difficult steps was to approximate a physically correct representation by a set of approximation functions that are faster to calculate and manage (e.g. a typical approximation is to replace ballistic motion of a bouncing ball with a trigonometric loop).

- *Problem solving*. Solving problems requires an understanding of the problem and its decomposition into entities used to compose a solution. For mathematical problems these entities could be theorems and lemmas, but they could also be algorithms for solving of typical problems. In the case of the course *Geometry of Motion* described in section 2.1, the deconstruction phase contains activities for inventing how to represent some motion as a mechanical linkage. This is traditionally way more difficult than the construction phase, which is when the virtual mechanism is being built following an existing design.

- *Pattern recognition*. Pattern recognition is the ability to identify meaningful entities in an otherwise chaotic appearing texture. Patterns are not only visual. They could also be patterns of algorithms, patterns of methodology, patterns of approaches and patterns of behaviour. A proper identification of patterns contributes to successful constructionism. The manifestation of deconstruction is exactly the process of finding the pattern, i.e. the texture is decomposed into meaningful entities that exhibit the nature of the pattern.

The manifestations listed so far show how divergent is the deconstruction. The main problem of deconstructionism is that it is hard to formalize the deconstruction phase. As a consequence, it is hard to provide methodological, pedagogical and technological tools that support it and the deconstruction phase is almost completely confided to be realized by the student themselves.

3.3. Constructionism and Deconstructionism

A brief explanation of constructionism and its history was presented in section 1. Here we define *deconstructionism* as a distinct perspective on the same objects and processes that are requisites of the constructionism. While constructionism is focused on the personal construction of ideas and relations through the construction of real-life artefacts, deconstructionism is focused on the personal understanding of ideas and relations through the public deconstruction of real-life artefacts.

People are prone of deconstruction; it is not an artificial activity introduced through and for learning only. Traces of deconstruction can be observed in many situations outside the traditional educational context. Here are three examples that demonstrate how deconstruction is actually a part of our lives:

- A child breaks a favourite toy just of curiosity to see what is inside.
- A scientist reverse engineers biological organism to understand and eventually recreate a solution "invented" by Nature.
- A person tries to distinguish the ingredients of a meal by the aroma of its spices.

Similarly to the relation between constructivism and constructionism, *deconstructivism* is about the mental private decomposition of ideas and relations, while *deconstructionism* is about the deconstruction of a tangible artefact or about the public deconstruction of a concept. In this sense, the sequence of phases as pictured in *Figure 4* is not to be considered sequential or linear. In reality, the deconstruction phase is repeated several times, until the initial knowledge is decomposed in proper ingredients that can be used for reconstruction of the personal knowledge. This may take several attempts as indicated in *Figure 5*. The deconstruction phase is not deterministic in the same way as the construction phase is not deterministic. Problems in learning, due to the excess cognitive load or a cognitive barrier, occur predominantly in the deconstruction phase. When students cannot relate a new concept to their previous knowledge, they actually fail to decompose that new knowledge. This is the focus of the deconstructionism.

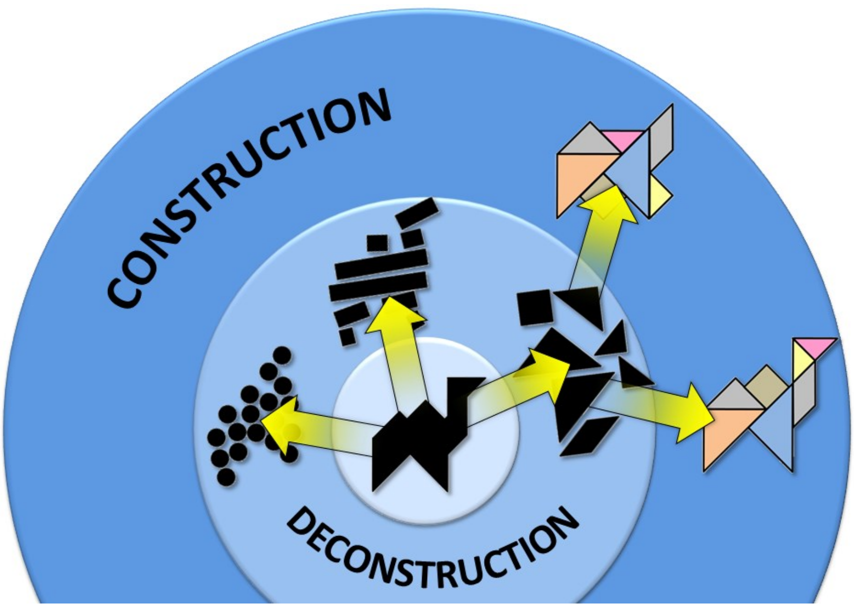

Figure 5. Lack of determinism in both deconstruction and construction

4. Conclusion – The Future of Education

4.1. Deconstruction of Education

In an interview for NewScientist Noam Chomsky said "If you're teaching today what you were teaching five years ago, either the field is dead or you are" [12]. Although he envisioned linguistics, the same is true for all domains in education. The digital era has a tremendous impact on how we learn. People have already created digital content that exceeds the capacity of available storage. The modern technology challenges the traditional pillars of the educational model: student, teacher, textbook and school. The average digital weight (volume of created digital content) of a student overpasses the digital weights of the teacher and the textbook, combined. The accessibility of digital content displaces the school as a main source of knowledge and questions the very nature of the traditional school and textbook.

For centuries education was changing incrementally and now it cannot cope with the exponential development of technology. The attempts to restore the balance do not produce sustainable results and the introduction of ICT in the classroom is unable to synchronize education and technology. The technological gap between generations is irrelevant, because several technological gaps already emerged within a single generation. A renovated education built by reconstruction does not show the expected outcomes. An alternative is to *deconstruct education* into its fundamental components; then to build a conceptually new education. Thus deconstructionism could become the major player for reshaping how people teach and learn. However, as pointed in section 3, the deconstructionism *in* education is hard to achieve, and the deconstructionism *of* education would be much harder.

4.2. Digitality

Several factors may affect the future of education: digitality, ubiquity and transparency. The word *digital* has two meanings related to education. The first one *finger* and it is what education was for centuries – learning was done by hands-on activities. The other meaning is related to numbers and this is what education is trying to become nowadays – learning by manipulation of virtual entities. Unfortunately, the numerically digital education becomes dominant and dislodges some of the best practices in the fingerly digital education [13]. Fortunately, the advances in technology make it possible to merge both digital educations. An example is the educational software used via touch screens – students are now able *to touch an ellipse* and to modify it manually. The introduction of 3D printers in education will allow the conversion of virtual artefacts into real one. Students will be able to create tangible objects out of their virtual constructions.

4.3. Ubiquity

There is a trend of promoting ubiquitous learning (u-learning). This is a learning that "enables anyone to learn at anyplace at any time" [14]. Ubiquity in future education will develop in several aspects. First, ubiquitous learning will span not only over space and time, but also through any media. Learning will happen in parallel through a variety of media including the social media. Thus students will have their own imprint on the learning process. Second, teaching will also become ubiquitous. The relation between u-teaching and u-learning is as the relation between deconstructionism and constructionism. The main goal of u-teaching is the decomposition of learning content that renders it u-learnable – this is a challenge with yet unknown complexity.

4.4. Transparency

Modern technology is getting more transparent and less obtrusive. A lot of technological and educational power is encapsulated in small, yet smart devices. Nowadays we carry such devices (smartphones), but soon we will wear them (smart glasses and watches) or have them as integral parts of our bodies. The advance in technology shifts learning into a new course, e.g. future learners will not learn mathematics, but will experience it. The current model of education creates an image of the world through which people learn about the world. In a transparent future education people will learn directly from the world around them using all their senses. The first attempts in this direction are already laid by the research on virtual, augmented and immersive realities.

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