Constructionism and Deconstructionism

Pavel Boytchev • Sofia University, Bulgaria • boytchev/at/fmi.uni-sofia.bg

> Context • There is a movement to change education so that it is adequate to social expectations and uses the full potential of technology. However, there has been no significant breakthrough in this area and there is no clear evidence why. **> Problem** • A potential issue explaining why education falls behind is the way educators focus on education. There is a possibility that a significant step in the learning process is routinely neglected. **> Method** • Two different approaches to using IT in education are tested in two different environments: a university level course based on constructionism and IBL projects for secondary school students. **> Results** • It is possible to apply constructionism in education, but there are still problems. They are not related to how students construct knowledge, but how they deconstruct knowledge. **> Implications** • The most significant problem of deconstruction is that it requires creative skills. This makes it very difficult to formalize it and to provide effective recommendations for its application. **> Constructivist Content** • Deconstruction is a prerequisite of construction, thus deconstructionism deserves more attention and study. A proper application of deconstructionism will make it possible to reconstruct education in a way that is impossible with the current approaches. **> Key words** • **Deconstructionism, constructionism, future of education, inquiry-based learning.**

Constructivism and constructionism

« 1 » Constructivism in education is a philosophy that advocates the construction of knowledge through real-life or real-life-like experiments fostering learning. The role of the teacher is not to transmit or to impose knowledge, but to guide the learner through his personal journey in learning.

« 2 » The earliest examples of constructivism in education were proposed by John Dewey and Maria Montessori. Dewey (1910) described thinking as a natural act that should be supported by an encouraging environment that is rather different from the monotonous uniformity of classrooms and textbooks. An important factor for the development of creative thinking is the curiosity that leads to exploration. According to Montessori, education starts from birth and "[t]he child must not be considered as he is today […] He must be considered in his power of potential man" (Montessori 2001: 3). She built unique learning environments that are considerate of the student's physiological and psychological age.

« 3 » A significant contribution to constructivism was made by Jean Piaget. He saw learning as a continuous process where a student assimilates knowledge entities into meaningful knowledge constructs. Constructivism, as described by Piaget, is focused on the mental models of the world. This theory was further extended by Seymour Papert in a way that applies it to practical construction. Papert called this "constructionism." The main concept is that constructing tangible artefacts helps the construction of mental understanding of the world. Papert proposed an extensive use of IT in the classroom that supports another important aspect of constructionism, namely, that constructing entities is public in the sense that they are observable by others. More importantly, the process of construction is also public and this makes learning more effective and sustainable.

Constructionism in education

Constructionism at university level

« 4 » The concepts of constructionism have been applied to education and the results are promising. Several courses introduced by the Faculty of Mathematics and Informatics at Sofia University are focused on educational software and real-time computer animation (Boytchev 2007). In these courses, students learn the basic skills and approaches of building complex constructs out of a small set of elements. One of these courses is Geometry of Motion – a multidisciplinary course spanning mathematics, physics and computer science. In it, students become familiar with the fundamentals of geometry, how it is used to describe physical motion and how to implement this as an animation.

« 5 » When Geometry of Motion started in 2007, the computer science component was merely a demonstration of computer animations. Most of the time was spent on discussions about how they had been built. We used a public collection of virtual mechanisms (Boytchev, Sendova & Kovatcheva 2011). However, they were standalone programs that were hard to use as learning objects.

« 6 » In 2010 I developed a library called Mecho (Mechanical Objects). Students could use it to construct their own devices (Boytchev 2013a). Since then, new versions of Mecho have been released annually, the last one being completed in March 2014. This version is a result of the research project DFNI-O01/12, financially supported by the Bulgarian Science Fund of the Ministry of Education and Science. The project addresses contemporary programming languages, environments and technologies and their application in the development of software specialists.

« 7 » The design of Mecho follows the major ideas of constructionism. It provides a tool for expressing creativity through

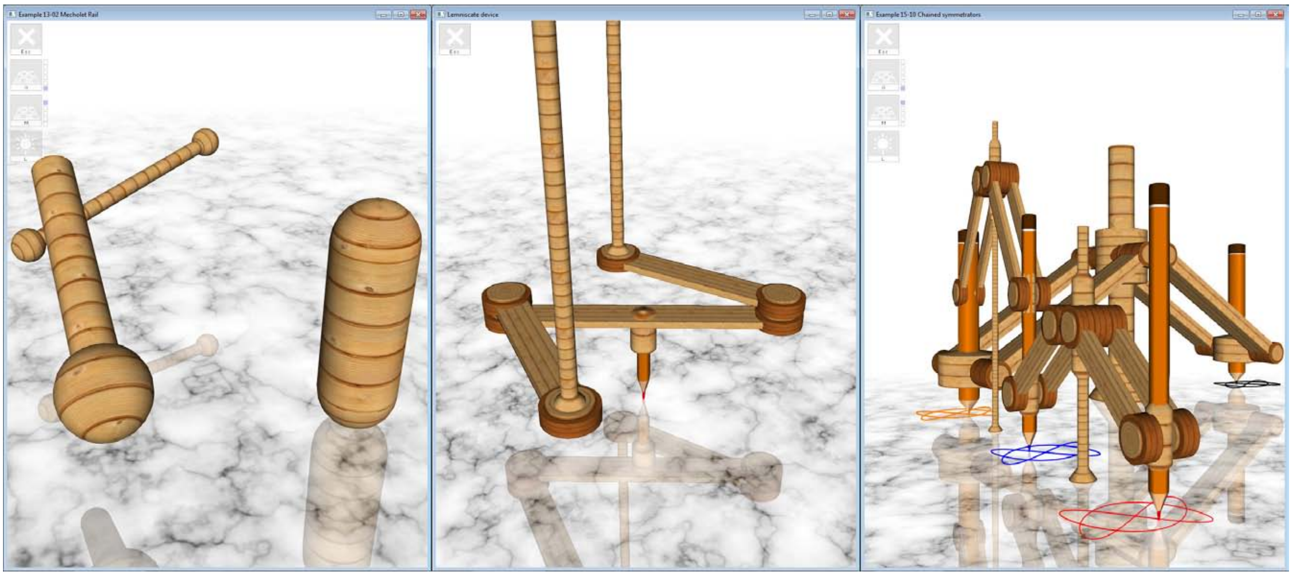

Figure 1 • A virtual component (left), a device (middle) and a machine (right).

public construction of virtual mechanisms. Mecho represents virtual mechanisms as structures with a well-defined hierarchy. There are configurable elements for the basic mechanical components, such as beams and gears. They are used to build simple devices that can be arranged in complex machines. An example of the structural hierarchy is demonstrated in Figure 1. The left image shows individual mechanical components; the middle one displays a virtual device drawing the Lemniscate of Bernoulli; and the last one is a machine exploring chained symmetries.

« 8 » The making of a virtual device is an optional activity for the students. It is up to them to engage in such activity or to ignore it. As a result, very few students have volunteered to build devices. Table 1 shows the number of students for each academic year. During the first three years of Mecho, about 93% of the students avoided it.

Year	Major event	Number of students	
		Enrolled	Working on projects
2007–2008	No projects, just demonstrations	15–20	N/A
2008–2009		15–20	
2009–2010	The course was not offered		
2010–2011	Introduction of Mecho (in Logo)	15–20	3
2011–2012		29	1
2012–2013		36	2
2013–2014	Reimplementation of Mecho in C++	36	20
2014–2015		57	Course is ongoing

Table 1 • Number of students working on Mecho projects.

« 9 » After a detailed analysis of the first three years of Mecho, I identified the key elements that had prevented students from becoming motivated to use it:

- *The learning barrier*: The allocated time for the computer science component of the course was 15 academic hours. This was insufficient to introduce a new programming language (i.e., Logo), to demonstrate motion implementations, to present Mecho and to teach how devices are made. In 2013 I addressed this issue by rewriting Mecho and all teaching materials in C++, a language well-known by the students.
- *The conceptual barrier*: Creating interactive 3D projects is cumbersome, especially if students deal with visualisation and rendering issues. This barrier was resolved by redesigning Mecho so that all activities, such as frame generation and mouse-based navigation, happen "automatically." In this way students focused on the virtual mechanism.
- *The mathematical barrier*: Although students had studied analytical geometry, they still had no practical sense of 3D motion. It was unexpectedly difficult for them to express orientation in 3D space via Euler angles. This

		Compulsory						Procedural						Visual						Hardware						Software						
		0.1	0.2	0.3	0.4	0.5		1.1	1.2	1.3	1.4	1.5		2.1	2.2	2.3	2.4	2.5		3.1	3.2	3.3	3.4	3.5		4.1	4.2	4.3	4.4	4.5		
точки	оценка	proj in time	C::B compat	use mecho	not plag	no 6Lbok	Σ	idea april	proj may	OK file names	PD, CC or GPL	compile OK	Σ	good sizes	5+ elems	has anim	smooth anim	interact buttons	Σ	good joints	mech plausbl	has params	2+ curves	new model	Σ	well format	has // ...	is as class	has docs	resuse in 3.2	Σ	Бонус
16	1.1	1	1	1	1	1	●	1	0	1	1	1	●	1	1	1	1	1	●	1	1	1	0	1	●	1	1	1	0	0	● 3	
0	-0.5	0	0	0	0	0	✗	0	0				✗						✗						✗						✗ 0	
8	0.3	1	1	1	1	1	●	1	0	1	1	1	●	1	1	1	0	0	●	0	0	1	0	0	✗						✗ 0	
1	-0.4	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	
13	0.8	1	1	1	1	1	●	0	0	1	1	1	●	1	1	1	1	0	●	1	1	1	1	0	●	1	0	1	0	0	✗ 2	
13	0.8	1	1	1	1	1	●	0	0	1	1	1	●	1	0	1	1	1	●	1	1	0	1	0	●	1	1	0	1	0	● 3	0
20	1.5	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	0	● 4	1
1	-0.4	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	
13	0.8	1	1	1	1	1	●	0	0	1	1	1	●	1	1	1	1	0	●	1	1	1	0	1	●	1	0	1	0	0	✗ 2	
5	0.0	0	1	1	0	1	✗	0	0	0	0	1	✗	1	1	1	1	0	●	0	0	0	0	0	✗						✗ 0	
1	-0.4	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	
9	0.4	1	1	1	1	1	●	1	0	1	1	1	●	0	1	1	1	0	●	1	0	0	0	1	✗						✗ 0	
1	-0.4	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	
1	-0.4	0	0	0	0	1	✗	0	0				✗						✗						✗						✗ 0	1
17	1.2	1	1	1	1	1	●	0	0	1	1	1	●	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	0	1	● 4	
2	-0.3	1	1	1	1	1	●	0	0	1	0	1	✗						✗						✗						✗ 0	
2	-0.3	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	1
1	-0.4	0	0	0	0	1	✗	1	0				✗						✗						✗						✗ 0	
13	0.8	1	1	1	1	1	●	0	0	1	1	1	●	1	1	1	1	0	●	1	1	1	0	1	●	1	0	1	0	0	✗ 2	
18	1.3	1	1	1	1	1	●	1	0	1	1	1	●	1	1	1	1	1	●	1	1	1	0	1	●	1	1	1	1	0	● 4	1
20	1.5	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	1	●	1	1	1	1	0	● 4	1

Figure 2 • Score chart with students' progress (rows) across the five levels of criteria (columns); circles mark successfully completed levels.

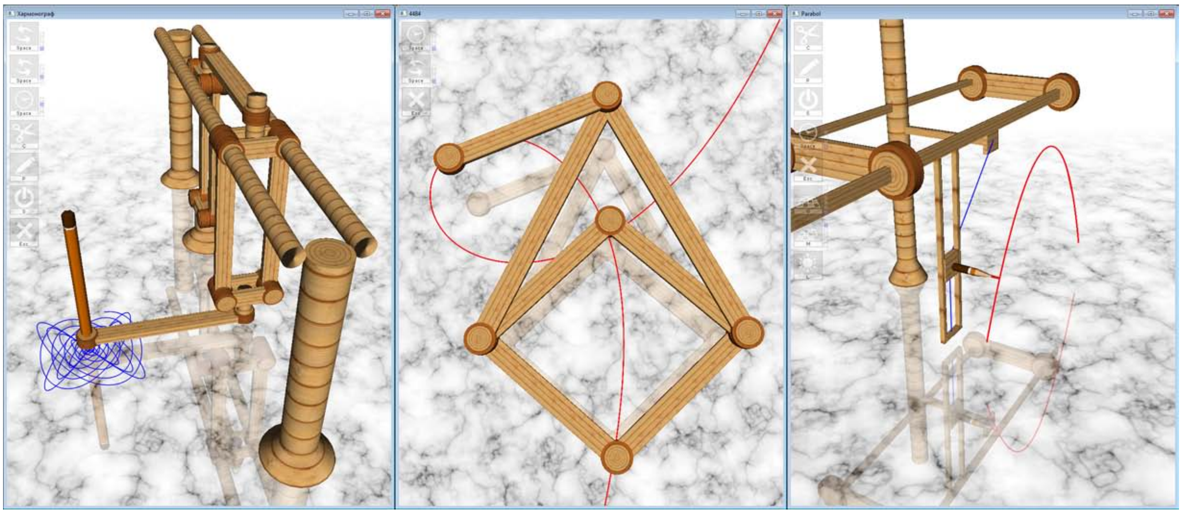

Figure 3 • Virtual mechanisms developed by students.

observation convinced me to exchange mathematical efficiency with user friendliness. I modified Mecho to use comprehensible representations. For example, I implemented 3D orientation by 4 angles instead of the optimal 3 Euler angles.

- *The procedural barrier*: The evaluation of projects considered 25 criteria. Students were introduced upfront to these criteria, but they still experienced problems complying with them. I observed that students were trying to address many criteria at the same time. As a result, they failed to comply with most of them. In 2013 I clustered criteria into five levels and students had to fulfil the levels in a predefined order. The levels represented compulsory criteria, procedural experience, visual experience, hardware experience and software experience (see Figure 2).

« 10 » Our solution for the four barriers made the construction of devices much easier. The number of students almost doubled and their engagement with projects increased eight-fold: from 7% to 56% (see Table 1).

« 11 » The first projects using the redesigned Mecho were delivered in June 2014. Figure 3 shows snapshots of three virtual mechanisms (re-)created by students.

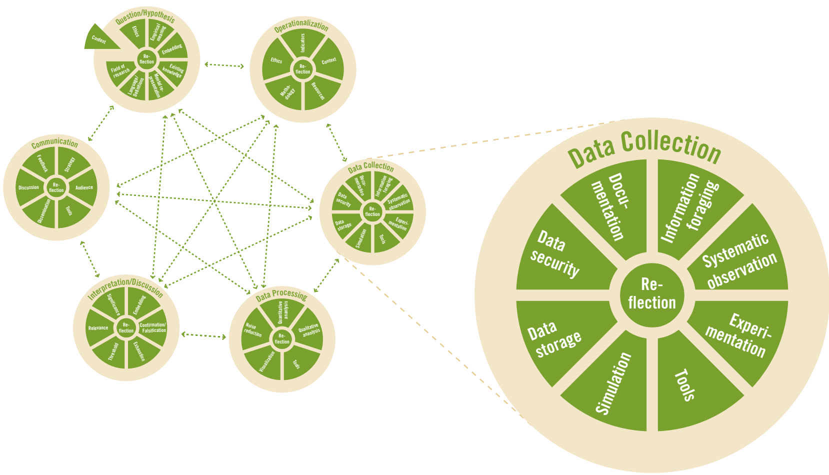

Figure 4 • The weSPOT model of IBL and a close-up of the data collection phase.

Figure 5 • Manual recording of external and internal temperatures.

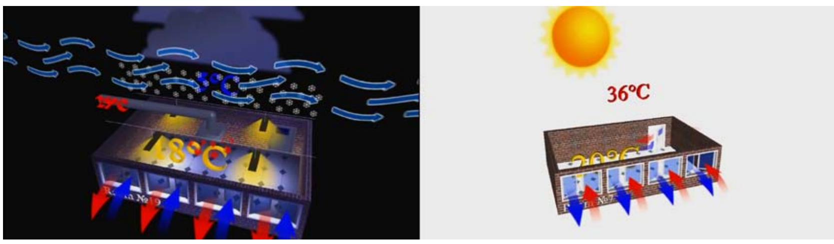

Figure 6 • The classroom simulation software.

Year	Number of students	Grades	Teams
Year 1	60 students (3 classes of 20 students)	Grade 6 (12–13 years old)	Each class was one team
Year 2	60 students (3 classes of 20 students)	Grade 6 (12–13 years old)	Each class was one team, but exploration with the Virtual Classroom was individual or in pairs

Table 2 • Number of students working on energy efficiency pilots of weSPOT.

Constructionism at secondary school level

« 12 » *Inquiry-based learning* (IBL) is a concept closely related to constructionism. In IBL we learn by asking questions and finding answers, rather than by listening to a stream of pre-digested facts. IBL is one of the approaches to implementing constructionism in education and it is recognized as such by institutions at different scales. This section presents software developed for two complementing IBL projects: weSPOT (EC FP7 Programme in Technology Enhanced Learning) and The Role of IT in the Application of IBL in Science Education (Sofia University Science Fund).

« 13 » The goal of weSPOT is to create software tools and know-how for personalization of the IBL environment and management of IBL activities. The project developed a detailed IBL model of six interconnected phases and over 40 components. They are shown in Figure 4 and discussed in Protopsaltis et al. (2014). The hypothesis 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.

« 14 » The goal of the second project was to conduct research on the role of IBL in education. It adapted weSPOT's results and focused on science experiments, individualization of education and social collaboration. Several pilot experiments were conducted as a competition between three grade-6 classes. The topic of the competition was "My classroom – The most energy efficient!" The task was to measure temperature variations, weather conditions and the classroom status (such as opened windows, doors, air conditioners, number of people, etc.) Each class produced a report about their measurement including analysis of factors affecting energy consumption. The reports contained suggestions and ideas for reducing the amount of lost energy. The pilot started on 17 November 2012 – the first day of the European Week for Waste Reduction and finished on 5 June 2013 – World Environment Day.

« 15 » During the first year, the students collected data for three months – see Table 2 and Figure 5. More details about this phase of the project are described in Stefanov, Nikolova & Stefanova (2013) and Stefanov et al. (2013).

« 16 » The duration of the data collection was demotivatingly long for 6-graders. It was difficult to keep the students interested in the competition. From the IBL point of view, there were two main problems with this kind of pilot test. It was 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.

« 17 » For the second year of the project, we decided to provide an alternative approach and developed the Virtual Classroom (Boytchev et al. 2014). This is software containing a non-interactive simulation (see Figure 6) and a standalone interactive 3D application (see Figure 7). The implementation was based on decisions that were initially considered risky.

« 18 » The first risky decision was to make *a continuous simulation*. There were no means to start or stop the virtual classroom. It was running even when the students were setting the parameters of their experiments. The second risky decision was to make *unrestricted simulation*. This is the ability to set unnatural initial conditions, such as snowing at 40°C. In such a case, the air temperature would smoothly go down until the physical model reached equilibrium. The main feature of the simulation mechanisms was that it only managed transfer of energy in small quantities towards equilibrium.

« 19 » Continuous and unrestricted simulation contributed to a better simulation, closer to the actual world, where students cannot control the fabrics of observed phenomena.

« 20 » To support the inquiry process, the Virtual Classroom was distributed *without any documentation*. Thus, students and teachers had to find by themselves all the software's features: from navigation to conducting experiments. There was no description of the simulation mechanism. For example, students conducted experiments to find whether the number of people in the classroom affects the air temperature.

« 21 » The pilots with the 6-graders were video-recorded, and snapshots of the recordings are presented in Figure 8. The analysis of the recordings showed that the software provoked inquiry learning and active constructionism. Every student worked at his or her own pace while gaining scientific skill.

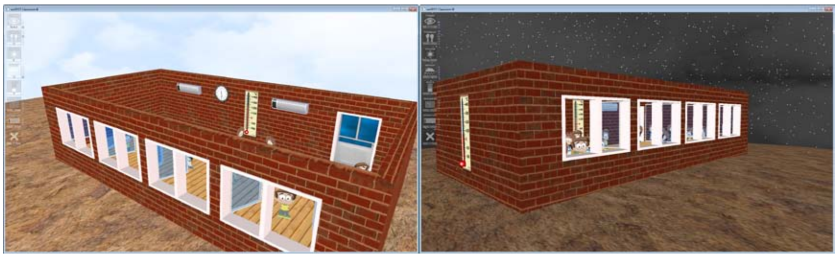

Figure 7 • The interactive virtual classroom.

Figure 8 • Students exploring the Virtual Classroom.

« 22 » The pilots were conducted in the spirit of constructionism. Students learned by constructing public entities. The process of construction was also public. While observing the progress of their classmates the students soon started to exchange ideas. One interesting and unplanned observation was how students experienced the scientific importance of details. Several students conducted "equivalent" experiments, but got opposite results because of subtle differences in the initial conditions. This experience was quite valuable. It helped gain the skill of distinguishing important from unimportant factors.

Deconstructionism in education

Phases of constructing knowledge

« 23 » The experience with university and secondary school students showed that it is not straightforward to utilize constructionism. Although we created different tools to support this application, students still experienced problems.

« 24 » The process of learning through construction can be split in two phases – deconstruction and construction, shown in Figure 9. I use the word *deconstruction* in the sense of decomposing or breaking down something into reusable entities. In contrast, the meaning of *destruction* would be to destroy something. The left image in Figure 9

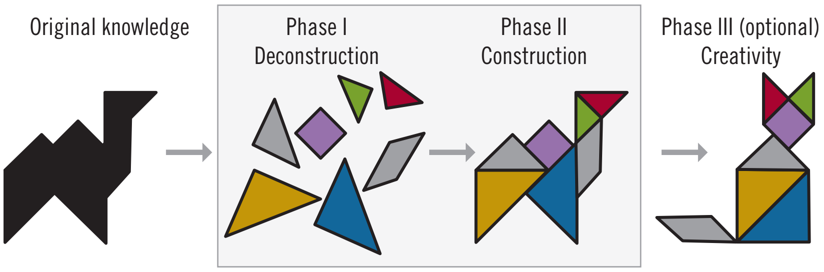

Figure 9 • Phases of learning through deconstruction and construction.

represents some knowledge. The first phase of learning is to decompose this knowledge into smaller yet meaningful entities for the learner. These entities are used as building blocks to construct the personal knowledge, which is not necessarily the same as the original knowledge. There is a third phase where new knowledge is created by rearranging the entities in another way.

« 25 » Most of the literature about constructionism is focused on Phase II – the construction. Many approaches have been developed in order to ease this phase. ICT solutions implemented by providers of educational content also focus on construction.

« 26 » The experience with students at Sofia University and secondary school students showed that the most difficult phases are I and III. The creativity phase is usually optional. There is no universal algorithm on how to create creativity. Most of the conventional lessons are designed to reach up to Phase II. However, Phase I is not optional. It is a prerequisite to the construction phase. Any failure to deconstruct knowledge leads to failure in Phase II. Even more, the skills required for effective deconstruction are comparable to the skills required for creative activities.

« 27 » Table 3 presents the entities of the original knowledge in the discussed cases. The original and the constructed knowledge share the same cells because it is expected that they are the same. The table also lists some of the skills found to support effective deconstruction.

« 28 » Generally, finding deconstruction entities is difficult. Fortunately, in the pre-set educational environment of our pilot cases it was not so hard to identify them. The actual difficulty of deconstruction in education is not the elements in each phase, but the transition between phases.

« 29 » The last row of Table 3 contains ideas of possible creative artefacts. Some of them were partly realized by the students. For example, the left-most mechanism in Figure 3 differs from the traditional implementations of harmonographs, and was invented by a student.

« 30 » The issues with the deconstruction phase were identified a long time ago. Resnick (1990) describes what he calls *problem-decomposition bugs*, which point to the difficulties of decomposing problems into simpler entities. This problem decomposition is presented as a space of two dimensions: *functional decomposition* and *agency decomposition*.

Manifestation of deconstruction

« 31 » The nature of the deconstruction phase is elusive and vague. It happens behind the scenes. It 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 creative deconstruction has many distinct manifestations. Some of the most commonly observed ones are: debugging, animation design, problem solving and pattern recognition.

Debugging

« 32 » From a deconstructionismic viewpoint, debugging is the process of decomposing a running program into entities that help us eliminate its malfunction. There are tools that ease this process, but they are often insufficient for effective debugging. 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. When people debug, they build a mental interconnected and dynamic representation of the functional components of a program, the data flows and the logic in each step of the execution process. Debugging tools still cannot automatically extract this representation and present it in a comprehensible way.

Animation design

« 33 » When creating an animation, students face the problem of representing a motion as a composition of simpler motions based on mathematical functions. This deconstruction is hard for many students. They lack the skills to see (or to imagine) how a composite animation could be represented as an outcome of fundamental functions.

« 34 » During the Geometry of Motion course, the students observe various models of physical motions. One of the most difficult steps is to approximate these motions with a limited set of mathematical functions. An example from Lecture 10 is a pair of cubes bouncing off a vibrating spinning disk, as seen from a viewpoint orbiting the whole scene. All motions in this example are implemented with $sin(x)$.

Problem solving

« 35 » Problem solving requires understanding 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. In the case of the course Geometry of Motion course, the deconstruction phase contains activities for inventing how to represent a given motion as a mechanical linkage. This is traditionally far more difficult than the construction phase, which is when the virtual mechanism is being built following an existing design.

Pattern recognition

« 36 » This 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 construction. 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.

« 37 » The main problem of deconstruction 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. The deconstruction phase is almost completely confined to being realized by the students themselves.

Deconstruction outside education

« 38 » In "Phases of constructing knowledge," I defined deconstruction as the process of decomposing or breaking down something into reusable entities. Because this definition is intentionally all-embracing, it is applicable to things outside education. The rest of this section contains ideas and personal observations on one possible way to map the notion of deconstruction onto a more general context.

« 39 » People are prone to deconstruction. It is not an artificial activity introduced through and for learning only. Traces of deconstruction can be observed in many situations beyond the traditional educational context. Deconstruction is actually a part of our lives. All the following examples are deconstructions:

- A child breaking a favourite toy just from curiosity to see what is inside
- A person trying to distinguish the ingredients of a meal by the aroma of its spices
- A scientist reverse-engineering a biological mechanism.

« 40 » Apparently, deconstruction is not just something that happens sporadically through our lives. It is also a major scientific arsenal. For example, the deconstruction of mathematics leads to the "invention" of its fundamental axioms. It is not a one-way route. Different mathematical sciences, especially the geometries, have been successfully deconstructed into different sets of axioms. Once we have the axioms, we can construct back the corresponding mathematic.

« 41 » With a more global scope, the understanding of nature goes first through its deconstruction into sciences such as physics, biology, chemistry and astronomy. This deconstruction phase is vital. Without it we will be overwhelmed by the complexity of nature. The construction phase is already happening. It is the reverse process of merging back different sciences and building multidisciplinary relations, such as astrobiology and medical informatics. The construction phase will end when all sciences merge coherently into one.

Constructionism and deconstructionism

« 42 » I define *deconstructionism* as a distinct perspective on the same objects and processes that are requisites for the constructionism. Constructionism is focused on the personal construction of ideas and relations through the construction of real-

	University experience with Mecho	Secondary school experience with Virtual Classroom
Knowledge to be deconstructed and then constructed	▪ Expressing complex motion with a limited set of functions ▪ Mapping mechanical linkage to a geometrical curve and vice versa ▪ Transforming abstract mathematical linkage to a physically possible linkage	▪ Finding questions leading to scientific approaches in finding answers ▪ Conducting experiments in a dynamic environment ▪ Studying the behaviour of unknown complex systems
Skills supporting deconstruction	▪ Recognition of graphs of functions ▪ Decomposition of composite functions into fundamental functions ▪ Approximation of functions via simpler functions ▪ Solutions to mechanical collisions ▪ Reversing kinematic ▪ Expressing motion with higher degree of freedom as a composition of several lower degree motions	▪ Observation of real-life and simulated phenomena ▪ Extracting optimal set of parameters capturing observed behaviour ▪ Relating environmental changes to system configuration and vice versa ▪ Eliminating false positives and false negatives ▪ Conducting different experiments to verify a single hypotheses
Entities created by deconstruction	▪ Fundamental mathematical functions (e.g., *sine* and *absolute value*) ▪ Mathematical operations (e.g., *vector addition*, *linear combination*) ▪ Basic mechanical components (e.g., *beams*, *rails*, *gears*)	▪ External factors affecting energy consumption (e.g., *temperature*, *clouds*) ▪ Internal factors affecting energy consumption (e.g., *door*, *air conditioning*) ▪ Mathematical relations (e.g., *energy consumption vs temperature difference*)
Possible artefacts of creativity	▪ A mechanism that is functionally equivalent to existing ones but uses fewer mechanical parts ▪ Know-how about mechanisms with motion that can be expressed by 3rd degree polynomial functions	▪ An algorithm for smart control of energy consumption in buildings, based on precise sensing and forecast of weather ▪ A simple formula for quick approximation of power requirements in a building

Table 3 • Knowledge, skills and deconstruction entities in the university and secondary school experiences.

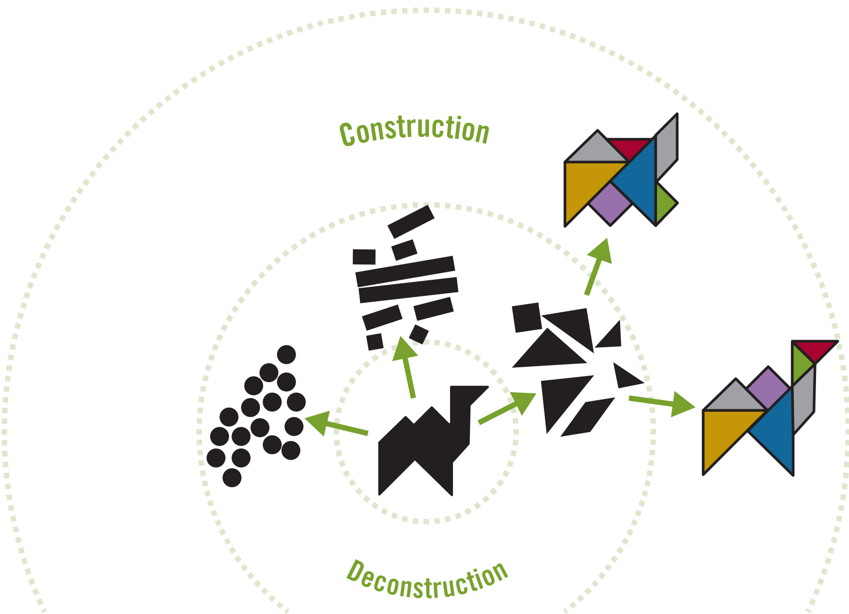

Figure 10 • Lack of determinism in both deconstruction and construction.

life artefacts. Deconstructionism is focused on the personal understanding of ideas and relations through the public deconstruction of real-life artefacts.

« 43 » 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 9 is not to be considered sequential or linear. In fact, the deconstruction phase is repeated several times until the initial knowledge is decomposed into proper ingredients that can be used for reconstruction of the personal knowledge. This may take several attempts, as indicated in Figure 10.

« 44 » The deconstruction phase is not deterministic, just as the construction phase is not deterministic. Problems in learning due to 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 and get stuck. This is the focus of the deconstructionism.

The future of education

Deconstruction of education

« 45 » In an interview for *New Scientist*, Noam Chomsky says "If you're teaching today what you were teaching five years ago, either the field is dead or you are" (Lawton 2012). Although he is referring to linguistics, the same applies for all domains in education. The digital era is having a tremendous impact on how we learn. People have already created digital content that exceeds the capacity of available storage. 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 is overtaking the digital weights of the teacher and the textbook combined. The accessibility of digital content is displacing the school as a main source of knowledge. It questions the very nature of the traditional school and textbook.

« 46 » For centuries, education was changing incrementally. Today it cannot cope with the exponential development of technology. There are two possible paths: either education distances itself from technology, or embraces it. Clearly, technology and education cannot be separated. The attempts to restore the balance between them by mere reconstruction of education do not produce sustainable results. The introduction of ICT in the classroom is unable to synchronize education and technology. An alternative approach is to *deconstruct education* into its fundamental components, then to build a conceptually new education. Thus, deconstructionism could become the major player in reshaping how people teach and learn. Deconstructionism *in* education is hard to achieve. Deconstructionism *of* education will be much harder.

Factors to consider

Digitality

« 47 » Several factors may affect the future of education and *digitality* is one of them. The word *digital* has two meanings related to education. The first one is *finger*. It is what education was for centuries – learning by hands-on activities. The other meaning is related to *numbers*. It is what education is trying to become nowadays – learning by manipulation of virtual entities. Unfortunately, the numerically digital education is becoming dominant and is dislodging some of the best practices in the "fingerly" digital education (Boytchev 2013b). Fortunately, the advances in technology make it possible to merge both digital educations.

« 48 » The pilots discussed in this article could be significantly enriched by this digitality. For example, a future version of the Virtual Classroom may provide a tactile interface to the simulation, while a future version of Mecho may communicate with a 3D printer to produce tangible mechanisms. Thus digitality will allow the students to convert their virtual artefacts into tangible artefacts.

Ubiquity

« 49 » There is a trend of promoting ubiquitous learning (*u-learning*). This is a learning that "enables anyone to learn at anyplace at any time" (Yahya, Ahmad & Jalil 2010: 117). Ubiquity in future education will develop in several aspects. First, ubiquitous learning will span not only over space and time, but through any media. Learning will happen in parallel through a variety of media including the social media. Thus

PAVEL BOYTCHEV
is an associated professor and researcher at the Faculty of Mathematics and Informatics, Sofia University. His research interests are in the areas of developing courses, educational software, authoring software, computer graphics and animation, visualization, multimedia, and design and implementation of programming languages. He has created numerous educational applications and educational programming languages. He is an author of a dozen courses, hundreds of computer-generated video clips and more than a thousand computer demo programs in his areas of interest.

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.

« 50 » A possible impact of ubiquity on the Virtual Classroom and Mecho is to allow students to play with the software at anytime and anywhere. There are already plans for newer versions of the software based on mobile 3D graphics. This will make the Virtual Classroom and Mecho mobile-friendly and platform-independent.

Transparency

« 51 » Modern technology is getting more transparent and less obtrusive. Much technological and educational power is encapsulated in small yet smart devices. The advance in technology is shifting learning to a new course. I expect that 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. In a technologically transparent future education, people will learn directly from the world around them using all their senses. First attempts in this direction have already been made by the research on virtual, augmented and immersive realities.

« 52 » It is hard to imagine what the virtual classroom would look like in a future of immersive technologies. Most likely, the virtual and the actual classroom will be indistinguishable, or even the same. Because of digitality, ubiquity and transparency, the concept of classroom may become void.

Conclusion

« 53 » Constructionism approaches are applied to education with variable degrees of success. This article describes the application of constructionism to university and secondary school levels. One of the cases is a new course, where students construct virtual mechanisms exhibiting or representing mathematical properties. The other case is of interactive software for inquiry-based learning. This software allows students to conduct experiments in a simulated microworld, to collect data for raising or proving hypotheses and to investigate unknown relation between entities. Although both cases provide an interesting and motivating medium fostering education in a constructionistic way, there is one specific phenomenon that emerges from every pilot case. It is the phase of deconstruction, which is routinely neglected. A possible reason is the inherent difficulty of the deconstruction. This makes it as hard to achieve as it is to teach creativity.

« 54 » Deconstruction is an important aspect of science and education. Yet, there are no methodological, pedagogical and technological tools that support constructive deconstruction. Education has been incremental for centuries. It cannot cope with the exponential growth of technology and is falling behind. There are efforts to shape the education of the future, including utilizing constructivist and constructionist approaches. However, I advocate that to be able to construct a completely new and adequate education, two steps are needed upfront: (1) acknowledging and supporting deconstruction in education; and (2) the deconstruction of education itself. When these two steps are completed, it will be possible to construct a new type of education. Meanwhile special attention must be paid to three factors: the symbiosis of the two digital educations, ubiquity of learning and teaching and the increasing transparency of technology.

Acknowledgements

The work described in this article is financially supported by: project DFNI-O01/12 Contemporary Programming Languages, Environments and Technologies and their Application in Development of Software Specialists, supported by the Bulgarian Science Fund; project FP7 318499 weSPOT, supported by the EC ICT FP7; project 108/19.04.2013 The Role of IT in the Application of IBL in Science Education and project BG051PO001-3.3.06-0052 Forming a New Generation of Researchers by Supporting PhD, Post-PhD and Young Scientists, supported by the Sofia University Science Fund.

Received: 20 February 2015
Accepted: 21 April 2015