Constructing µLearning Content

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ABSTRACT
This paper presents an approach of embedding µLearning concepts into educational content. Two general domains of content are discussed: interactive virtual µWorlds and short µAds. The µWorlds are small standalone 3D environments, which students can use to learn and experiment with basic topics from Stereometry. The µAds are short animations expressing scientific concepts and ideas in a non-obtrusive yet attractive way. More than two hundreds of such animations are publicly available and some viewers' reactions are presented in the paper.

Categories and Subject Descriptors
D.2.6 [**Software Engineering**]: Programming Environments – *graphical environments.* H.5.1 [Information Interfaces and Presentations]: Multimedia Information Systems – *Animations*, *Artificial, augmented, and virtual realities*. I.3.8 [**Computer Graphics**]: Applications. K.3.2 [**Computers and Education**]: Computer and Information Science Education – *Computer science education*.

General Terms
Design.

Keywords
Educational content, 3D visualization, Microlearning

1. THE E-UNIVERSE
In an answer to a question posted 15 years ago about the number of stars in the Universe, Whitlock [6] provides an estimation of 10^{21} stars. Research work and updated analyses reported at the 25th International Astronomical Union General Assembly in 2003 raised the number of stars to 10^{22}. New discoveries from 2010 point to a larger number of stars due to revised numbers of low-mass stars [5]. Currently it is assumed that the number of stars in the observable Universe is between 10^{23} and 10^{24}.

There is another Universe that people live in – this is the Digital Universe, also known as e-Universe. It is created entirely by people and contains no stars, but data. The e-Universe is rapidly expanding. New data are created by using devices that capture, generate, transmit and store digital data. According to EMC the data in the world doubles every two years. In 2010 people cracked the 1 zettabyte barrier for the first time. In 2011 the number of bits created or replicated is estimated to be about 10^{22} [1].

The e-Universe also contains transient data that is not stored, like broadcasted digital TV programs, voice calls via Internet, digital radio, communication within Wi-Fi networks, etc. One bit of physically stored data could be replicated as much as into 10^6 bits of transient data. 2007 was the last year in human history when the volume of data, generated by people, could be physically stored. Since then, the amount of data in the e-Universe is larger than the capacity of the available physical storage. According to Cisco CTO the data transmitted over networks was 10^{20} bits in 2007 and will be more than 10^{21} by 2013 [3].

All estimated numbers show that there are as many bits in the virtual e-Universe, as there are stars in the real Universe. While the number of stars of the real Universe gets updated by astronomical observations and scientific analyses, the volume of the e-Universe expands continuously. For example, every minute people send 11 million SMS messages worldwide [4]. Every minute people watch 70000 hours of video (and upload just 60 hours of video) on YouTube alone [2].

2. IMPACT ON EDUCATION
The traditional educational model relies on the school as a major educational institution. This model assumes that teachers and textbooks are the sources of educational content. This renders the in-school environment as the place where students learn. External sources of content, like books, parents and peers cannot (presumably) provide the quality and the quantity of content. This situation of conventional education is shown in **Error! Reference source not found.**.

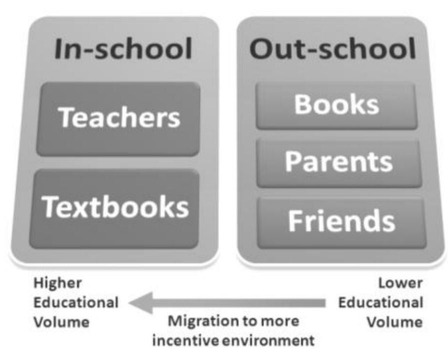

Figure 1. Traditional sources of content. Higher educational volume and more incentive content causes migration towards in-school environments.

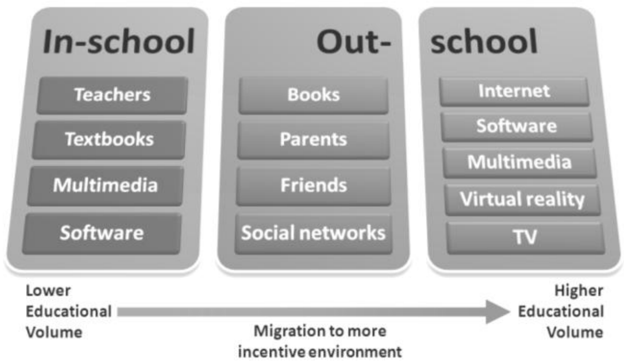

Figure 1. Modern sources of content. Higher educational volume and more incentive content causes migration towards out-school environments.

The higher educational volume of in-school environments provides higher incentive stimuli and causes the students to migrate towards the school. As a result, if a child is expected to learn something, the best thing to do is to go to school.

Nowadays, the e-weight of a person is about 166 GB. This is the average volume of digital data a single person creates, transmits or receives. This puts the education in a very inadequate position, because most of the e-weight for students is not related to the school and the education.

The total volume stored in books comprises 0.000003% of the e-Universe. Additionally, the textbooks are a small fraction of all books. The result is that the amount of formal educational content is vanishing rapidly and it cannot compete with the volume of other content. This puts the school and the textbook as educational concept to a very risky and unenviable position. The information outside school is more interesting and dominates students' life. Subjectively, it is also more useful. For example, a student watching 20 videos a day (a possible underestimation) is exposed to more information that an average lesson in a textbook.

New generation perceive digital information and the e-Universe in a conceptually different way. Elder generations are taught to live in the e-Universe, while the younger generations are actually born in the e-Universe. This calls for conceptually different approaches to education and especially to the creation of educational content.

Presenting information in the form of a textbook is less attractive for nowadays students. Even the use of electronic textbooks does not change the situation, as long as the majority of the electronic textbooks are just electronic representations of conventional textbooks. The situation is getting worse if we consider the pace of advances in technology. A lesson in a textbook that features a specific software product may soon become obsolete. Also, the emerging disciplines may invalidate whole branches of the educational content. This is particularly evident in the curriculum programs in Computer Science, Bioinformatics, etc.

The development of interactive educational tools that provide the option to explore scientific concepts is an important trump. Unfortunately it is still hard to recapture the interest of students in respect to the educational content (either off-line or on-line).

Figure 1 represents the sources of content nowadays. Pure educational content provided in school environments is enriched by multimedia content and interactive software tools. However, students find a lot more information outside the school. The term "educational", which is used in the figure, refers to "content to learn from" rather than "content with high educational value".

The introduction of multimedia and interactive software in the classroom is an attempt to bring the students' interest back to school. This approach worked well for some time by arming the school with attractive and engaging educational tools.

Home schooling is another approach attempting to export the educational process outside the school. However, it is effectively exporting the education into a replica of the school. Although less restrictive, home schooling provides the same set of characters roles.

3. RECAPTURING STUDENTS' INTEREST

A next step in the attempt to recapture student's interest is to open the school environment, by allowing non-school information channels to be used in a controlled educational manner. Learning objects based on the use of internet and virtual reality have been introduced, as well as adding features of software networking within school networks.

Recently institutions and individuals engaged with education move to a more non-traditional approach for delivering educational content. Instead of trying to modify the school and the curriculum by introducing new approaches and technology solutions in the school, they export educational content out of the school.

Nowadays there are many providers of educational content that use this approach. Kahn Academy (http://www.khanacademy.org), Massachusetts Institute of Technology (http://ocw.mit.edu), and Open University of the Netherlands (http://www.ou.nl) are just a few of the many organizations providing out-school access to educational content. This access both provokes and addresses several important issues that were irrelevant in the past:

- *ubiquitous learning across space* so that educational content is now delivered to virtually any point on the earth, thus allowing access from people with various educational and cultural backgrounds;
- *ubiquitous learning across time* – educational content can be reached any time throughout the day and throughout the human life.

Although this approach exports education into other media, it essentially does not change the fabrics of the content. It is still represented as lesson units, where each unit focuses on a single scientific concept or topic. Also, this approach is just a more up-to-date variant of the older TV-based programs.

Another approach is to provide content through other out-school channels, like video games. Figure 2 represents the more global approach of using cross-age techniques.

Figure 2. Using approaches developed for other age groups.

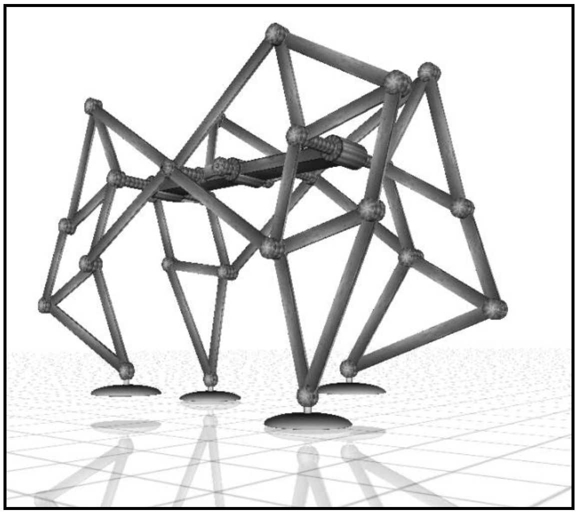

Figure 3. Virtual walking mechanism. An animation can be seen at http://youtu.be/WEwqiMcjLMU

Project based learning (PBL) is an adaptation of andragogy techniques used in adult education. The adaptation allows the application of these techniques in child education. There is a similar idea implemented in the opposite direction. Games, which are typical for children, are now being transformed to serious games, which are used in adult education.

The cross-age approaches attempt to hide the educational content under a set of activities. In the case of PBL the learning happens in the process of working on a project. In the case of serious games the learning happens in the process of playing.

4. µAUTHORING

This section provides an overview of the author's personal approach of (re-)constructing educational content. The major idea about approaching µLearning is to explore the triplet of *µAuthoring*, *µWorlds*, and *µContent* in different contexts.

µAuthoring is an approach of creating content in small steps. The micro element is mainly in respect to the process of creating. A typical example of µAuthoring is the use of the Logo programming language. This is one of the oldest programming languages. The first Logo was created by Seymour Papert and Wallace Feurzeig in 1976. For the last 40+ years there are created more than 260 Logo dialects and version.

The main aspect of Logo that fosters µAuthoring is the incremental style of programming. Users type a Logo instruction and it is immediately executed. This provides a step-by-step construction of a Logo program and an immediate feedback during this process. Individual commands, used in such interactive immediate mode, can be later packed into procedures and reused in creating other Logo programs.

One of the modern Logo environments is Elica (Educational Logo Interface for Creative Activities). Created in 2000 it is nowadays used to build interactive and educational software and to model scientific phenomena and processes.

5. µWORLDS

The concept of *µWorlds* was introduced by Seymour Papert in 1980. They are small playgrounds of the mind where learning is done by building things. The Logo language itself could be considered a *µWorld*. Two of the most attractive µWorlds created with Elica are Mecho and DALEST.

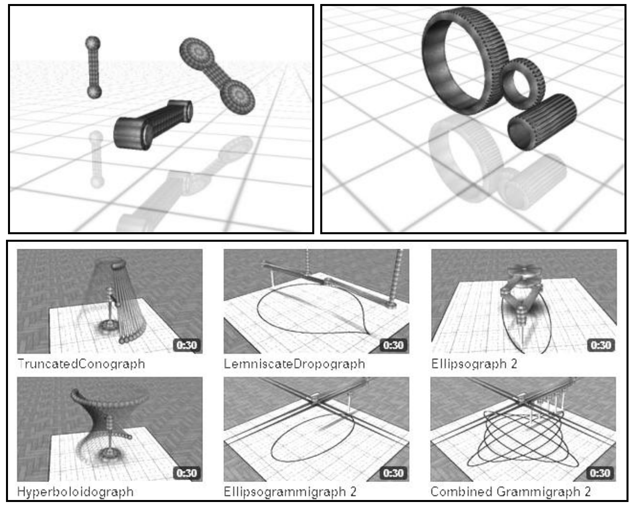

Figure 4. Some of the elementary mechanical parts that can be used in Mecho (top) and the predecessor of Mecho (bottom)

Mecho is a programming library and virtual environment where students may construct and animate virtual mechanisms – see Figure 3. They do this by attaching models of elementary mechanical parts like beams, rods, gears (Figure 4, top) and providing description of how they are connected – what motions are possible, what behaviour is applicable, etc.

Mecho µWorld is successor and extension of a non-interactive collection of mathematical devices. They have been used as demonstration content in a way that students can observe various mathematical and physical concepts (the full collection is at http://www.youtube.com/playlist?list=PL6534E936D46257BF)

Using Elica itself is comparable to full-feature programming, including software design and debugging. As a µWorld it might be too demanding for users who are not familiar with programming. The µWorld Mecho, on the other hand, is still a programming environment, but it provides a much easier and simpler tools.

The other µWorld, DALEST, is an example of interactive educational environment where no programming is required from users. This µWorld is developed within the scope of the DALEST (Developing Active Learning Environment for STereometry) project. It is actually a collection of 10 µApplications. Their major advantages is that they are engaging, multidisciplinary and do not require training. The µApplication are grouped in several categories, as shown in Figure 5.

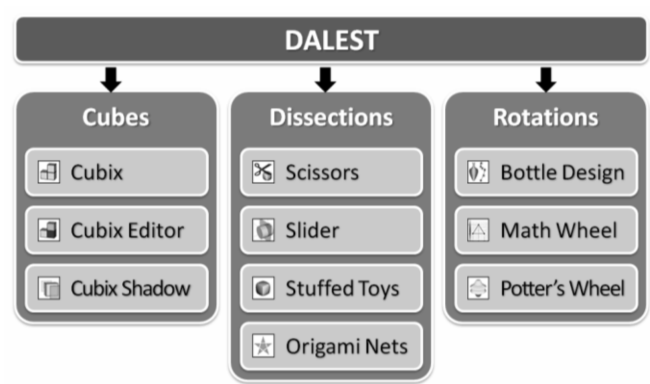

Figure 5. Categories of DALEST µApplications.

Figure 6. Students' reactions

Cubix, *Cubix Editor* and *Cubix Shadow* realize a virtual world made of cubes that can be arrange in different configuration for problems, puzzles or free-form construction. *Scissors*, *Slider*, *Stuffed toys* and *Origami nets* can be used to develop spatial skills by dissecting and assembling various objects. *Bottle design*, *Math wheel* and *Potter's wheel* allow the construction and the mathematical study of rotational solids.

The use of μApplications in education provides a new type of interaction between the student and the learning objects. Students perceive them not as something to be studied, but as something to be played with – Figure 6. This forms a general shift of students' attitude towards educational content and it provided ideas for the development of a more compact educational μContent.

6. μCONTENT

Most of the educational μContent developed with Elica is in the form of scientific "advertisements". Advertisements represent attractive information in a limited time scope. They are focused on a specific service, product or idea. The goal of ads is to create and sustain interest in this service, product or idea. There are two main features in this approach as applied to educational content:

- The educational content is targeted towards out-school environments. The new component in this feature is that this targeting is inherent, rather than enforced.
- The content is represented in a non-educational manner. This feature makes this approach different from other attempts, as long as the educational goals are elusive. The feature replies on indirect depiction of ideas.

The reconstructed educational content is delivered in the form of video animations. The features that are "borrowed" from advertisement design are:

- The video animations are short. Most of them are just about 30 seconds long. Longer play times may make watching boring, shorter play times may be insufficient to represent a concept.
- The video animations do not picture textual descriptions and textbook-like illustration. Instead, they recreate a scene, which demonstrates a scientific concept without explicitly explaining it.
- The video animations are trying to be attractive by using 3D objects and motions. This feature contributes to the initial wow-factor which is responsible for capturing and holding viewers' attention.
- The video animations are provocative in the educational meaning of the word. They do not show the full knowledge and analysis about a concept, but just hints about it. The goal is to provoke some thinking, which continues for a long time after the video is being watch.

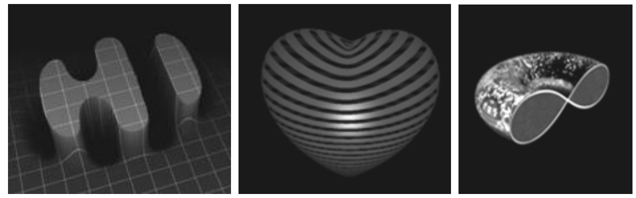

Figure 7. Frames from *Mathematics says you … Hi, Mathematics ... loves you* and *Mathematics ... is sweet*.

A few hundreds of the educational advertisements, developed by the author, are uploaded in his YouTube channel, thus providing ubiquitous dissemination across space and time. All of the animations are made with Elica. This is a software environment that is developed by the author and is used in a number of courses in Faculty of Mathematics and Informatics at Sofia University. The courses are bachelor level: "Languages and Environments for Education", "Computer Graphics" and "Geometry of Motion"; and master level: "Computer Graphics in Education".

The idea of using advertisement format of clips did not appear spontaneously. Initially, short animations were uploaded to the channel in order to demonstrate various techniques for using the Elica environment. Later on, more complex animations were added, like models of processes and concepts as well as visualizations of theorems. Additionally, prospective students' projects were also converted into animations and included in the channel.

The majority of animations are about Mathematics. They present an iconoclastic perspective of mathematical ideas and concepts. As a result, most of the clips could be considered as advertisement spots about Mathematics.

7. EXAMPLES

Some of the clips visualize ways of generating non-mathematical objects with mathematical formulae and vice versa. The first two video clips *Mathematics says you ... Hi* (Figure 8, left, available online at http://youtu.be/A9afxMAfbwM) and *Mathematics ... loves you* (Figure 8, middle, http://youtu.be/nRF7cUQIAnM) represent mathematically defined surfaces. The idea delivered by these ads is that knowing the properties of functions and grouping them appropriately will allow the construction of entities of our choice. For example, we can construct a formula generating human-readable text in a native language:

$$f(x,y)=e^{-x^2-\frac{1}{2}y^2}\cos(4x)+e^{-3(x+\frac{1}{2})^2-\frac{3}{2}y^2}$$

and a formula for a surface shaped like a heart:

$$(2x^2+y^2+z^2-1)^3-\tfrac{1}{10}x^2z^3-y^2z^3=0$$

Another example is called *Mathematics ... is sweet* (Figure 7, right, http://youtu.be/eADcA3iouCk). It shows a method to construct a Lemniscate of Bernoulli as an intersection of a torus and a plane. This reveals that sometimes there is unexpected relation between geometrical shapes, as well as that some concepts could be demonstrated with hands-on activities.

There are animations used to advertise scientific concepts with a multidisciplinary touch. The viewers are not enforced to perceive any particular idea, pictured in these animations, nor it is required that they understand all aspects of the multidisciplinary application.

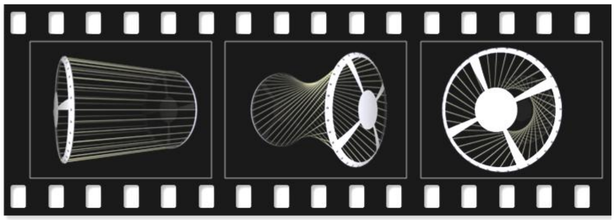

Figure 8. Frames from *Twisting Cylinder into Hyperboloid*

Reuleaux triangle with additive RGB colours (available at http://youtu.be/JZWgOzdmFa0) shows the construction of a Reuleaux triangle as an intersection of circles. The shape of the triangle (i.e. the white curved shape in the last frame) is used in mechanical engineering, because it has useful properties. The circles in the animation are built as light beams of pure red, green and blue lights. So, in addition to the Mathematics and Mechanics, the video shows the primary RGB colour arithmetic.

The other clip, which is about constructing a hyperboloid from a cylinder (Figure 8, http://youtu.be/a8VrcGgF_BQ), refers to two distinct concepts. The first one is the mathematical common origin of cylinders and hyperboloids as ruled surfaces. The second one is the engineering concept of building stable constructions, like the hyperboloid wet cooling chimneys.

Another group of video clips demonstrates visual representations of several famous theorems. The first example from this group is the animation clip called *Pizza ordering dilemma* (Figure 9, top, http://youtu.be/_IVRTK5ezo0). It shows a practical application of the Pythagorean Theorem. The animation starts with three pizzas – small, medium and large. The dilemma is which is bigger – the two smaller ones combined, or the large one. And this dilemma must be solved without measuring with a ruler and without any calculations. By using the Pythagorean Theorem it is possible to show that if we can construct a right triangle from the pizza halves, then both choices are the same. The actual challenge is to figure out how to measure whether the triangle is right or not without measuring it!

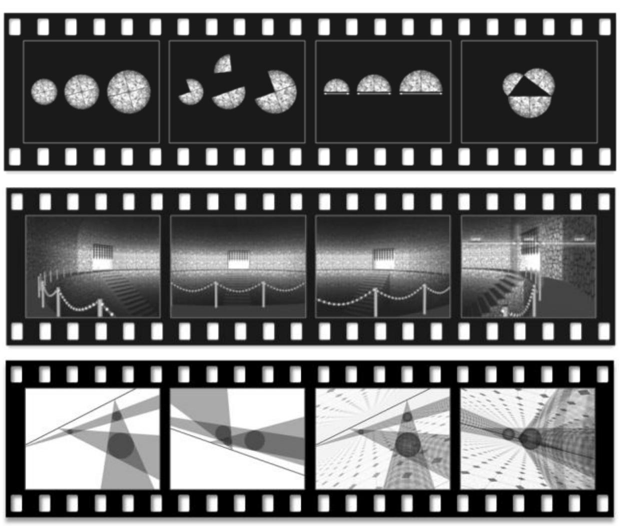

Figure 9. Frames from animations *Pizza ordering dilemma Believe it or not* and *Monge's Circle Theorem*.

Figure 10. Frames from *Equirectangular Projection*

Believe it or not (Figure 9, middle, http://youtu.be/00Y200p9dU4) is based on scene with aliens, but is actually visualizing a situation that is explained with the Inscribed Angle Theorem. The visual width of a gate is always the same independent on our viewing position, which is along the perimeter of a circle.

The third video clip from this group is the *Monge's Circle Theorem* (Figure 9, bottom, http://youtu.be/LE3gQKeIyLM). The clip visualized an idea for a proof of the theorem by constructing 3D solids from their 2D silhouettes. The theorem itself deals with circles and tangents. In the 3D reconstructions they are represented as spheres and cylinders.

The *Seismic Membranes* (http://youtu.be/KVRov7VWHno) clip shows a 3D view of the Earth with marks of 5000 earthquakes for which the depth is known. Seismic maps are usually 2D, while this 3D graphical representation reveals some structures in depth – the seismic membranes. Apart from this, the clip demonstrates the use of spherical coordinates as well as the statistical importance of accumulating data over a long period of time.

The last animation is called *Equirectangular Projection* (Figure 10, http://youtu.be/3Ic5ZIf74Ls). The mathematical dimension of the animation is about the mapping of a spherical surface onto a cylinder. This mapping is one of the many possible projections, but is one of the few that are used by … computer artists. Textures, prepared for spheres and ellipsoids, are generated in this non-conformal equirectangular projection, because it is much easier to map them back onto a sphere.

8. VIEWERS' REACTIONS

All the video clips can be seen from the YouTube channel of the author. As long as the videos are not provided as a compulsory educational content, viewers are free to discover by themselves the educational content and its messages.

The reactions are quite interesting. Some viewers get triggered into explaining the mathematical backbone of the animations; others just enjoy them as visual piece of art; and there are also viewers that suggest improvements or got inspired to do something on their own. Here are a few of the comments (the spelling and character case is kept authentic):

- *Although my understanding of the math is at this point inadequate to fully grasp the fundamental mechanics behind your animations, I still enjoy them very much. You are what makes youtube a wonderful place to go. Thank you.*
- *WHY DIDNT I HAVE THIS WHEN I TOOK ALGEBRA 5 YEARS AGO!*
- *OMG its a perfect oval...*mind blown**
- *wow i didn't know it was that simple. lol thanks*
- *Mathematics can be beautiful!*

- *get the gearing right, put some LED's on it, and you might just have a conversation piece... your videos are giving me a lot of ideas :D.*
- *WHAT DA HELL*
- *You know this actually makes a lot of sense. If you aren't observing the function algebraically (where your asymptotes are whenever your function becomes non-continuous, due to cos[x}=0), it actually uses that extremely basic rule where if you have to pick up the pencil the function is non-continuos, or in this case whenever the device has to flip to the other end of the pencil, there is an instant where it is making no contact with the graph at all. Dammit....this would have helped in trig!*
- *Great. Now I am forced to make the polar equation for this. :D*
- *GENIUS!!! That's what every math teacher should do to explain it!!!*

9. CONCLUSION

The e-Universe of the 21^{st} century is a significant factor affects humans and their everyday life. It also affects the education by imposing new rules and new processes. Educators, teachers and content providers around the word strive for creating educational content that reflects the new reality. The last generations have conceptually different vision of the e-Universe and this vision should be harnessed into the construction of educational content of new type.

Nowadays science concepts are implemented in other media. Tutting, for example, is a modern street dance in which the performer constructs and deconstructs geometrical shapes by arranging body parts in specific configurations. This dance style is a typical example of using Mathematics in non-mathematical environment. Tutting dance with a sharp focus on 3D geometrical shapes has already been used commercials.

Educational materials can also be presented in the form of advertisements – short 30-seconds video clips which feature various topics and concepts from science in an attractive and unobtrusive way. The main advantage of this approach is that in-school education could be started in an out-school time. Some of the concept taught in the classroom might be presented “concealed” as short animations. Being not a part of the regular educational regime, such content will be considered with a different attitude. Being 3D and visually attractive, such content will captivate interest and (eventually) provoke further thoughts and recollections.

The current volume of scientific concepts being converted into advertisements is manly from the area of Mathematics. Further development includes incorporating other science domains, like Physics, Chemistry, Biology, etc. Currently the collection uploaded to YouTube contains about 200 video clips. New clips are added regularly, but without focusing on the comprehensive traversal of concepts. For example, a video clip about some theorem might be followed by a demonstration of Computer graphics technique, which might be followed by an animation based on a student’s project.

If the advertisement approach becomes successful this might change the role of school. Students will “grasp” raw knowledge from information streams outside any formal educational environment. This knowledge will be unshaped and will possibly contain some undesired fluctuations. The role of the school will be to polish this knowledge by to removing defects and clearing uncertainties, to rationalize and formalize it.

The common ground of µAuthoring, µWorlds and µAds is to break up knowledge and skills into small pieces that can be “absorbed” even subconsciously and later on reconstructed internally. The major benefit of µLearning is that the minimal size of learning objects makes learning continuous and smooth – there are no thresholds and barriers as they appear in conventional learning approaches. In this respect, µLearning represents the quantum of learning and teaching. The small size allows to group learning entities in configurable chains and thus reaching higher levels of adaptability and personalization. µContent can be naturally embedded in traditional learning objects and units. After all, µLearning makes it possible to apply a true distributed and ubiquitous learning that spans across space and time.

10. ACKNOWLEDGMENTS

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