Technology Enhanced Technology Enhanced Learning

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Abstract

The application of modern technologies in education does not necessarily lead to positive results. An important factor is how these technologies are used. This paper describes some ideas about using technology to enhance Technology Enhanced Learning itself. Three different but complementing approaches are discussed in the paper: building interactive applications that provide multiple viewpoints on a specific problem; implementing intuitive tools that utilise the centuries-long learning patterns of humans; and amalgamating education and entertainment into a single activity. Each of these approaches is illustrated by several software applications developed for three different projects – Elica, DALEST and InnoMathEd.

1 Introduction

Technology Enhanced Learning (TEL) includes various approaches and methods for enhancing learning through the proper use of technology. This is a relatively new term emerged in the attempts to incorporate effectively new technological achievements in the learning and teaching processes. Traditional education (like in Mathematics) is based on a centuries-long experience of te-aching. Some of the techniques used in contemporary education are the same as the ones used several decades and even centuries ago.

The invention of technological tools affected education in an unrevocable way. When we talk about TEL, we do mean the modern technological inventions, like computers and multimedia devices. Being related to technology, these inventions are neutral to the educational process. Whether they enhance or worsen it, it is a matter of how they are applied. The same tool, e.g. a software application, can improve the learning process, but it can also be an obstacle for effective learning.

This paper discusses an attempt to make TEL more effective through incorporating Virtual Reality into educational software, which can be used for interactive work and for non-interactive demonstrations.

2 Recursive Enhancement

A mere use of computers in education does not necessarily render an effective TEL. For example, reading electronic book does not imply a better understanding of the material. An illustration of a geometrical theorem on a computer screen might not provide a better understanding than the traditional picture in a paper textbook.

Educators lack the long experience of applying technology into education, because we do relate the technological component of TEL only to the modern techno¬logical achievements, like digital devices, which exist for quite a limited time now. The main consequence is that people are still looking for the most effective use of hardware and software, and trying to do this results in some successful and some not so successful attempts.

While the majority of efforts are focused on how to apply technology to enhance learning, this paper refers to a somewhat side aspects – how to apply technology to enhance the application of technology in education.
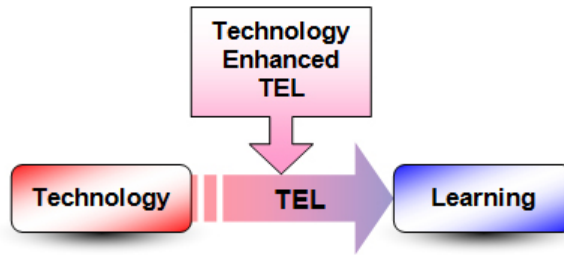
Fig. 1 – Technology enhanced TEL

It is obvious that whatever solution is applied, it can never be the best – there is no best TEL or best TETEL. The reason for this is that learning is a subjective process. If something works for one person this does not mean it will work for another one too. This makes it impossible to find the best solution for all people.

The main approaches of using technology to enhance TEL rely on several factors:

- Broad perspective. Topics in the curriculum can be covered from several points of view simultaneously. Different perspectives could be controlled by the learners themselves.
- Natural learning. Although listening and memorizing is the predominant method of learning nowadays, they do not provide a complete and natural background for learning. People study by blending several activities including hand-on activities, experiments and others.
- Exported education and imported entertainment. The border between in-classroom education and out-classroom entertainment can be blurred and even eliminated by exporting education from the classroom to outside, and bringing in the entertainment.

These approaches do not guarantee effectiveness of TEL, they are only conductive to its successful application. The main factor for the success is the teacher. Modern technologies cannot replace teachers; instead, they can only sharpen their role in the educational process. One of the most often mistakes is to introduce a piece of software as a replacement for the teacher. Learning by using such software could be beneficial only for a limited range of students – those who already have learning skills.

3 Broad perspective

A topic introduced in a conventional paper textbook usually presents it from

a single point of view – the one that the authors of the textbook consider most appropriate. However, effectiveness of learning can be improved by interconnecting facts and knowledge from different topics, as well as studying a topic from many perspectives.

Let us consider a "trivial" example – the Pythagoras theorem. A typical lesson in a textbook features an illustration, a textual description and a mathematical proof. Additionally there might be a set of problems to solve. In an attempt to get the most neutral illustration, it usually uses a right triangle, which catheti lengths are neither too small nor too large. This is the most suitable decision for a static illustration. Figure 2 represents several modern illustrations as well one from the pre-computer era. The most acute angle in the right triangle is somewhere between 25 and 40 degrees. Bigger or smaller angles are exceptions.
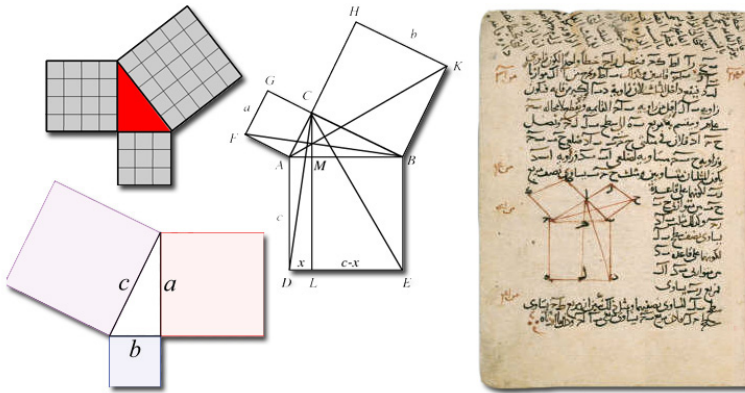

Fig. 2 - Static representation of Pythagoras theorem

A TEL representation of the Pythagoras theorem can utilize the power of dynamic geometry and can present an illustration that the user can modify interactively. In this way, it is possible to study specific cases – equilateral right triangles or triangles distorted to a segment.

The interactivity can be extended to a higher level that has some pedagogical implications. Many mathematical proofs are bidirectional, they prove that situation A leads to B, but the same proofs when reversed show that B leads to A.

An interactive dynamic bidirectional representation of the Pythagoras theorem is built using the Elica system (Educational Logo Interface for Creative Activities[1]). The proof is based on a sequence of 7 phases showing how the

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[1] Elica project website, www.elica.net

two smaller squares can be cut into pieces and how to regroup the pieces back to form the biggest square – Figure 3. The bidirectional feature means that one can start from the last phase and go backwards proving that the biggest square can be decomposed and recomposed into the two smaller ones. The interactive illustration is constructed with one free parameter – an angle. The availability of this parameter defines a level of one-degree freedom. This freedom is utilised by the student who can modify the angle (and the whole illustration) at any phase.
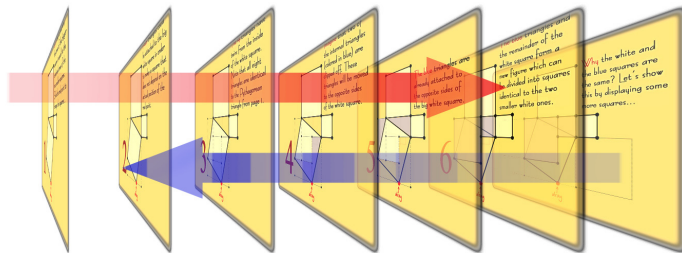

Fig. 3 – Bidirectional proof

We can organise the set of possible situations as a 2D space, see Figure 4, where phases are horizontal rows and angles are columns. A traditional proof goes from initial position A down to final position B and that is all. No other alternative is available. By using an interactive bidirectional application, it is possible to start from position C and reach D following mathematically correct paths.
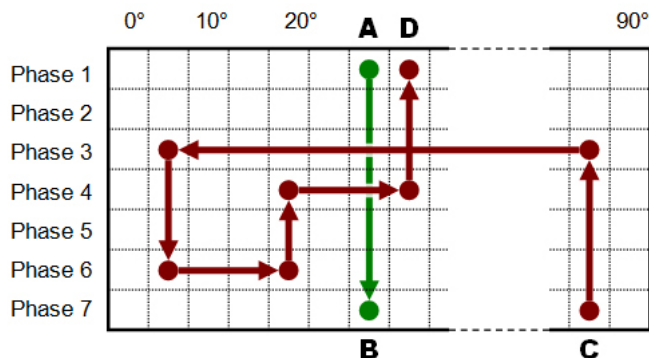

Fig. 4 – Problem exploration space

The broad perspective provided by bidirectional interactive applications demonstrates the power of this approach. It is a challenge to extend it to other problems. The second example is implemented in another Elica application – the Equation Balance. It features scales with two types of objects – golden bars (units) and boxes (variables) representing a linear equation.

Figure 5 shows snapshots from the application. The first one is an initial problem – the left plate has 12 boxes and 3 bars, the right one has 51 bars. This setup is equivalent to the equation 12x+3=51. By changing the number of objects and keeping the balance at any time, it is possible to reduce the number of boxes and bars to a minimum – 1 box and 4 bars. This configuration is shown in the middle image and it corresponds to the solution x=4.

Finding this solution is not the end of using the application. The solution x=4 is an equation by itself, so it can be modified by the same rules. In this way, any future modification will actually generate a new equation. The right image in Figure 5 shows the new equation 7x+11=39, which has the same solution x=4.
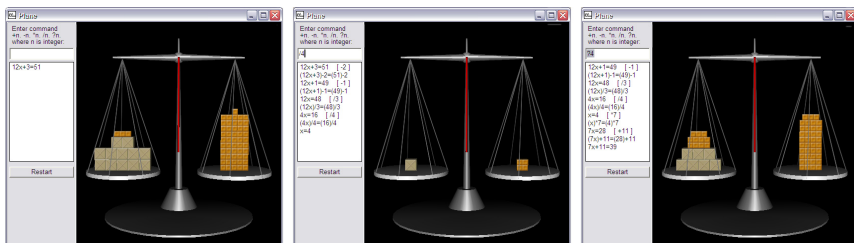

Fig. 5 – Equation Balance – problem solver and problem generator

The applications Pythagoras Theorem and Equation Balance are just two examples of how technology can help us build more enhanced TEL applications. The focus of this enhancement is not on the technology (like using more sophisticated features), but on the pedagogical and educational component of TEL. It is possible to broaden the educational horizon of any topic by allowing students to view it and explore it from different perspectives. More over, this is supposed to contribute to a better and a more stable understanding, because it gets learning closer to the...

4..Natural learning

People learn new things by observing, repeating and creating something by themselves. This is the most natural method and is probably the most bio-logically determined one. It has been used for thousands of years and is still

used nowadays especially by kids. Unfortunately, modern education tends to estrange from this by using techniques that prevents students from being natural. That why there is a saying that during their first two years we teach them to walk and talk … but the next 15 years we force them to stand still and keep silence.

If possible and if not ashamed, many people prefer to do hands-on activities while they learn something new – this is the fabrics of natural learning. Most likely there is some biological reasons for this, because other primates also use this techniques when they examine things by hands-on activities.

When an educational content is transformed into a software application, it is not quite straightforward to determine the type of hands-on activities that are supported. Using the keyboard, the mouse or the joystick does not provide the same sensory feedback as if students examine a real object. Fortunately, today's consumer devices are capable of presenting 3D virtual worlds in real time and this seams to be a feature, that can "substitute" twiddling an object with hands. An educational environment can be created in a virtual world and with appropriate interface students can examine the environment like they do in reality.

Consider a very fundamental 3D scene – a board with cubes on it. Users can add, remove and replace cubes; they can rotate the scene to see it from different points of views (this is a physical implementation of the broad perspective approach described in the previous section). The use of such application for educational purposes could be classified as TEL, but except for some convenience, does it really provide some added educational value?

As mentioned in the beginning, technology is neutral in respect to education. The most important factor is how it is used. A simple application for building virtual constructions from cubes could be used to do things, which are not quite easy to do in reality. For example, cubic-based constructions can be used in 3D puzzles like the ones in the Cubix Shadow application, see Figure 6. This application shows a three-dimensional view of shadows casted by an invisible object. The users have to reconstruct the object using a given number of cubes. This application is a part of a larger set of applications developed for the European DALEST project (Developing an Active Learning Environment for Stereometry[2]).

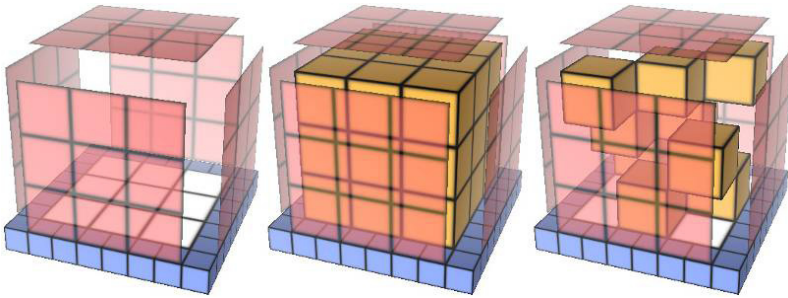[2] DALEST-Elica project website, www.elica.net/site/museum/Dalest/dalest.html

Fig. 6 – 3D puzzle in Cubix Shadow

The left image in Figure 6 shows a simple case of an object casting five 3x3 shadows. The middle image is the trivial solution with 27 cubes and the right one is the trickiest solution with just 9 cubes.

Another example could be to use the Cubix Constructor application to build 3D figures, which are then explained with words, so that they could be re-constructed by other students (Sendova *et al.*, 2007). The variety of shapes and the intuitive interface unleashes the students' creativity. Figure 7 illustrates some of the students' works.
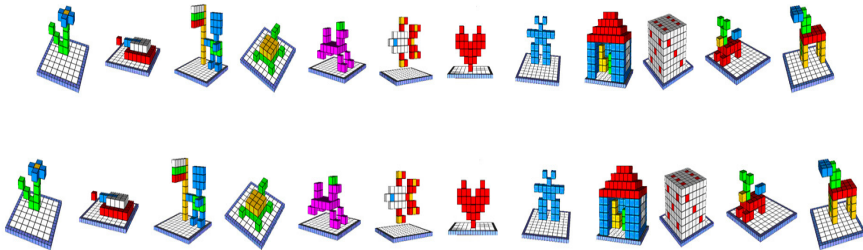

Fig. 7 – 3D figures made by students

One of the most intriguing results of classes where DALEST applications were used is that students were so engaged with solving the problem, that they did a lot of additional work – something that would not be possible in a forced educational environment.

Figure 8 presents two papers prepared by students in their math classes. The left one is a description of a 3D object using non-mathematical language, the right one is a description of another object using 3D coordinate system.

Interesting phenomena are that applications with virtual reality inspire students to spend more efforts without getting the negative consequences like

tiredness and boredom. A full page of wordy description is something untypical for math classes and as for the right image – the coordinate system was a personal discovery entirely invented by the student. Instead of numbers along axes, he used letters similarly to the naming of chessboard cells.
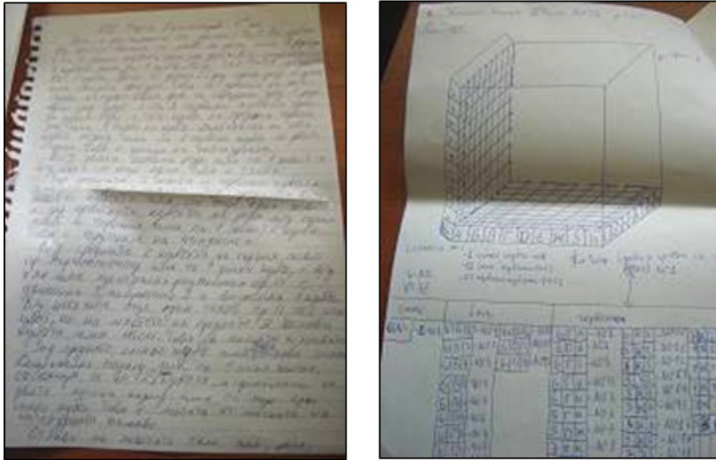

Fig. 8 – Student works in math classes

There are other examples that show the power of technological enhancements for TEL. The Scissors application, Figure 9, is based on the provision of broader perspective and support for intuitive learning. Traditionally, problems with nets are focused on folding a net into a solid. The Scissors implement the reversed problem – to unfold a solid into a predefined net. Although similar, the reversed problem requires a different pattern of thinking and involves a significant amount of virtual twiddling.
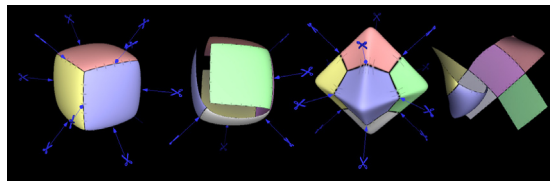

Fig. 9 – The Scissors application

The natural learning achieved by the DALEST applications can be observed during classes. The time spent by students on learning how to use the applications (this includes the mouse control and manipulation of 3D objects in a

virtual world) is almost just a couple of seconds. They are able to work with the application from the very first moment.

The same applications are not so easy for their teachers. Sometimes adults are afraid of using the programs. There are several psychological reasons for this: they do not want to break the program if they press a wrong key; they are ashamed that they might not be able to solve a problem; they are scared what to do if the situation goes out of the prescribed lesson plan. Fortunately, experienced teacher educators can free teachers from these obstacles and let them be proud of their creativity (Stefanova *et al.*, 2009a; Stefanova *et al.*, 2009b).

Fig. 10 – Students' and teachers' reactions

5 Exported education and imported entertainment

A factor that contributes to successful TEL might be the possibility to export educational activities outside the classroom. For many students the classroom and home are two different worlds. What happens in one of them never occurs in the other. Exporting education is based on the idea that educational process could be made so engaging and interesting, that students are willing to continue it when they are at home. Virtual reality is one of the modern technologies that can make educational process exportable. The other side of the same process is the import of entertainment. When educational software is as inspiring and attractive as the 3D computer games played at home, then it is possible to import entertainment in the classroom.

Next examples will come from another European project – InnoMathEd (Innovations in Mathematics Education on European Level[3]). Several dozens of 3D virtual simulations are implemented as software applications. Let us demonstrate a few of them – those that are related to the conic sections.

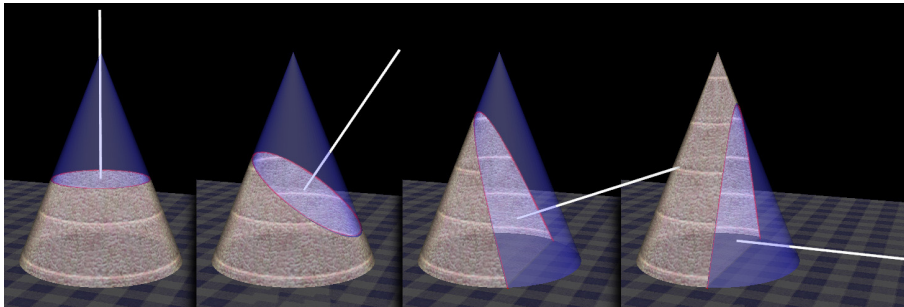[3] InnoMathEd project website, www.math.uni-augsburg.de/prof/dida/innomath

Fig. 11 – Traditional representations of conic sections

One of the applications is an interactive virtual world where students can manipulate the intersection of a plane and a cone in order to produce all kinds of conic sections. Figure 11 is a sequence of snapshots showing this traditional representation. Although interactive and virtual, this application presents the material in a way that is close to the textbook. Fortunately, conic sections can be made "less" mathematical. The math can be transformed in shapes that are closer to students' reality. Several applications for InnoMathEd feature methods for generating circles, ellipses, parabolas and hyperbolas using objects from students' everyday life. These applications embed virtual reality and interactive control. They also broaden the students' perspectives, foster natural learning and make it possible to do educational activities at home.
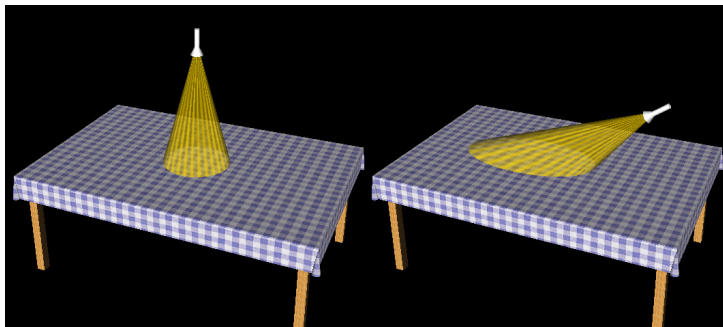

Fig. 12 – Conic sections with light

One of the applications, see Figure 12, is a virtual model of making conic sections with light. The light cone represents the mathematical cone and the table is the intersecting plane. By changing the orientation of the light source, it is possible to generate all conic curves.

Another set of applications implement a reversed environment – conic sections generated by shadows – Figure 13. Everyone can make these models at home. The fact that they do not look too mathematical does not mean there is no mathematics in them. The position of the light bulb in respect to the top point of the ball determines the type of the curve and the position of the ball determines the focus of the curve.
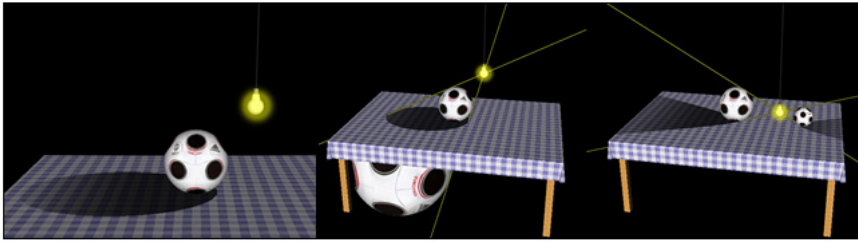

Fig. 13 – Conic sections with shadows

For more advanced students there is a set of applications, which recreates virtual mechanical devices that draw conic curves in a variety of ways[4]. Each of these ways has a solid mathematical background, so it is possible to analyse the animations and "extract" mathematical knowledge.

The most traditional device for drawing conics is a pencil attached to a rotating disk. The pencil glides on the surface of a cone and leaves traces on the paper, which is the intersecting plane. The angle of rotation determines the slope of the cone and the type of the curve. This mechanism is shown in Figure 14/left. The pencil can slide forward and backward depending on the closeness of the paper. When the paper becomes closer the pencil is pushed backwards, when the paper moves away, the pencil slides forward. The drawing of a two-branched hyperbola is based on a double sided pencil which slides in the appropriate direction forced by gravitation.
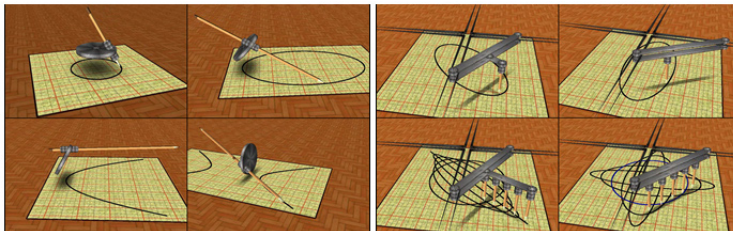

Fig. 14 – Virtual mechanisms for drawing conic sections

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[4] Mathematical devices, www.youtube.com/elicateam#g/c/6534E936D46257BF

Conic sections can be also generated by sliding the ends of a segment along two lines. The position of the pencil in respect to the sliding segment determines whether the drawn curve is a circle or an ellipse. The device pictured in Figure 14/right presents the link between circles and ellipses, and between ellipses and segments.

A third group of models provide yet another viewpoint on conical sections. The left snapshot of Figure 15 presents a device drawing an ellipse formed by the sum of two vectors rotating with the same angular speed but at opposite directions. The sum of the vectors is implemented as parallelogram, which is very close to the mathematical illustration of vector addition. The right image represents a hyperboloid – a rotating segment creates the profile of a hyperbola.
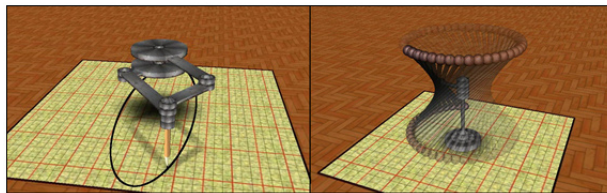

Fig. 15 – Ellipse and hyperbola

The virtual models for mathematical curves are still under development. New models are continuously added, covering a wide spectrum of curves. The latest additions span on other areas of geometry – they a virtual devices implementing homothety, central symmetry and reflective symmetry. Other devices model 3D surfaces like the hyperboloid in Figure 15, the helicoid or the Möbius strip. Animations of all devices can be seen online in [7].

Future plans

This paper presented examples of software packages developed in the context of three projects – Elica, DALEST and InnoMathEd. All applications use virtual reality in order to present mathematical concepts in an intuitive, entertaining and easy to understand way. The work on these applications is a result of continuous attempts to (re)shape tools for Technology Enhanced Learning that capture and explore the true benefit of using technology in education.

Some of the applications are already used by students and included in official geometry textbooks for secondary school classes. Other applications are still under development, and a third group is in their planning stage. Several European institutions are interested in developing more applications based on

Elica, applications that will provide both adequate motivations for students to learn and teachers to apply new technologies.

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