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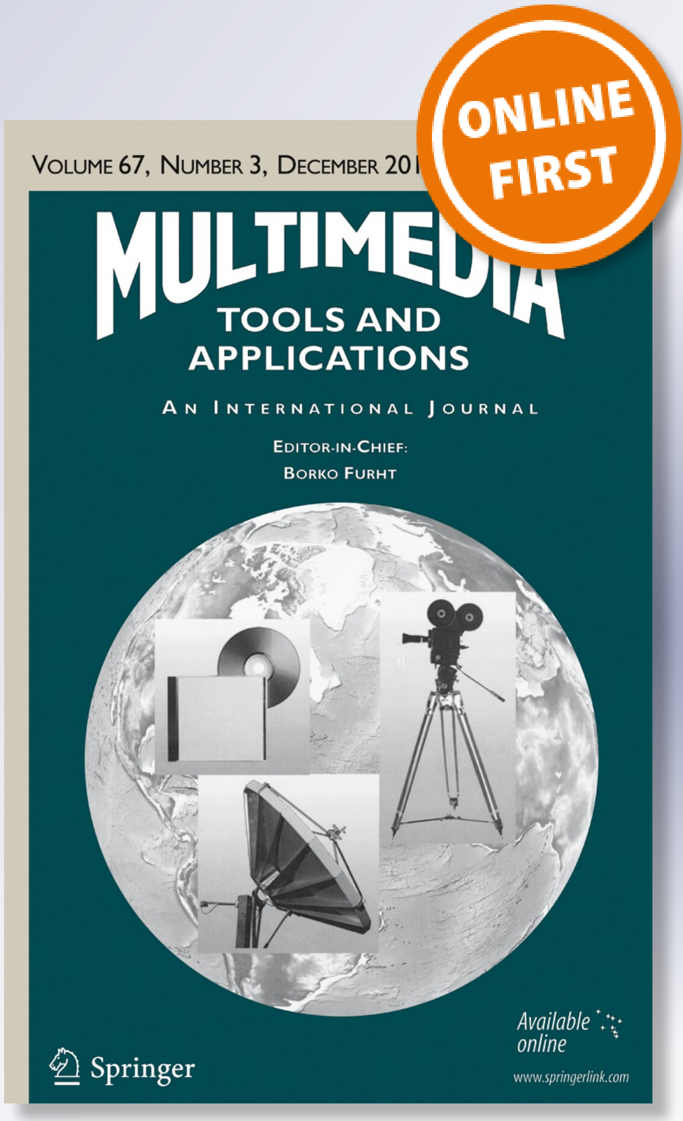

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A classification of eLearning tools based on the applied multimedia

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Abstract This paper proposes a classification that should help understanding key aspects of multimedia application in eLearning tools. The classification tries to cover important aspects of multimedia application in eLearning tools: communication channels and exchange of different types of contents throughout the channels, understanding in communication, and the ways of object manipulation in the user-tool interaction. Types of contents are classified according to the senses they affect on both sides of communication channels. The paper presents characteristics of 30 representative tools through a uniformly structured text. The presented tools are analyzed according to the proposed classification. A view of the future challenges, based on an analysis of the global trends in the area, is given.

Keywords Multimedia tools · eLearning tools · Multimedia in education · Applied multimedia

1 Introduction

There is an old and frequently cited saying: "When you hear - you forget, when you see - you remember, when you do - you understand," written by famous Confucius over 2500 years ago. It took human civilization lot of time to create the technology needed to exploit such wisdom in education fully. According to Confucius, education process cannot be based on verbal explanations only, which was the primary educational method for many years. Instead, a good method of visual representation of knowledge must be used, and even then, it is not enough for a person to understand, but only to remember. In order to make someone truly understand (know) something, he/she has to be able to do it. That is why the role of interactive multimedia

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tools for education is a very important one in a modern education process, as demonstrated in [11, 19, 29, 30, 32, 33, 35, 55].

A huge number of multimedia educational tools appeared in the last decades. There is a special challenge to create a comprehensive classification of approaches that would help one gain a global perspective on the whole area of applying multimedia in educational tools. Consequently, one of the goals of our research is to find representative eLearning tools that distinctly illustrate the application of multimedia in very different scientific areas.

Related work includes a satisfying number of particular approaches that we used for selection of the representative ones, presented in this paper. We noticed that there are no survey papers trying to demonstrate diversity of multimedia used in eLearning tools, and trying to classify the usage of multimedia in the tools in the whole scientific area. However, there are several very thorough survey papers that analyze and compare eLearning tools in some specific educational areas. In [52] the authors are surveying program visualization and algorithm animation systems. They surveyed 18 different tools and evaluated these tools based on their usability and educational effectiveness. In [36] the authors are surveying simulators suitable for teaching courses in computer architecture and organization. They surveyed 28 different simulators and evaluated them based on the covered topics of the educational area and on the simulation features. In [40] the authors are surveying network modeling and simulation tools used in computer networks education. They analyzed 100 tools, based on that analysis established classification, presented most representative tools according to the classification, and compared tools in each class based on the tools features. At the end of each survey paper, the global view and recommendations for future development of the analyzed tools are given. Several works had the common goal (to a certain point) with our work, but from different perspectives. In [9] the author tries to create a classification of different types of learning objects. In [2, 27] the authors focus on evaluating multimedia learning resources. In [38] the author is attempting to identify research directions for future development of multimedia learning environments. Since none of these and other papers we are aware of give a global view on multimedia used in eLearning tools, the motivation to do it appeared and challenged our work.

In order to illustrate diversity of multimedia used in eLearning tools we selected 30 representative tools that would cover broad spectrum of education areas. We included approaches that properly illustrate classes of senses and contents introduced in the proposed classification, that properly cover diversity of educational domains, that had considerable impact to scientific community, and that are recent enough to demonstrate technologies that are not out of date. We presented approaches trying to answer the "7w" questions: who, when, whom, where, what, why, how, and more. Each approach is described using a uniformly structured text, containing general information (its name, the origin of the approach, and the year of publishing), the main purpose of the tool, its structure, its functionalities, its evaluation (advantages and disadvantages), its further development trends, and its position in our classification. Views presented in this paper are influenced by our previous experiences in the area of educational tools, published in [7, 12, 36, 44–47, 49].

Finally, we analyze and discuss the proposed classification and the representative tools in the context of this classification. In order to do that in an easy-to-comprehend way, we analyzed: the excitation of different human senses in multimedia tools, with special attention dedicated to the different multimedia content types that affect each of the human senses; the excitation of a tool's "virtual senses", with special attention dedicated to the different types of user's responses which affect each of virtual senses; the understanding in the user-tool communication and the ways of object manipulation in the user-tool interaction; and general characteristics of eLearning tools, independently to the use of multimedia in them.

Additionally, we analyzed how the selected tools fulfill some design principles for multimedia educational tools.

The rest of the paper is organized as follows. Section 2 introduces a new classification into the field, Section 3 presents the analyzed tools according to the defined template, Section 4 evaluates the applied classification to the presented approaches and discusses challenges for the future, and Section 5 concludes the paper.

2 Classification

The main goal of our classification is a characterization of eLearning tools from the applied multimedia viewpoint. Use of multimedia is especially interesting in eLearning tools, since there are many studies [13, 42] showing that the use of multimedia in education tends to give excellent results. We believe that the proposed classification may help better understanding of implications of the usage of communication channels supported by eLearning tools and exchange of multimedia contents between the user and eLearning tool through the channels.

There are several different views on the area, from different perspectives and by various participants. Two basic groups of participants are: Users of the tools (educational institutions, professors, and students) and creators of the tools (computer industry, developers, and researchers). Users of the tools could benefit from the classification proposed in this paper, if it were to be wider adopted, in such a way the users may benefit from any classification – their understanding of the area would be facilitated and they would spend less time in order to be properly informed about the tools' of interest multimedia features. Creators of the tools could use our classification to identify class-gaps in the sets of multimedia eLearning tools intended for some educational area. We do not believe that the gaps that we found based on the analysis of the 30 selected tools are the ones that this group of users could instantly use. Instead, we would suggest that they use our classification to analyze more tools in some specific area of interest to them and then recognize class-gaps in that specific area and eventually try to fill in those gaps.

Our experience teaches us that the best survivability is found with very simple classifications based on a very simple (almost intuitive) set of criteria. An example is Flynn's classification of computer systems (SISD, SIMD, MISD, and MIMD) [18]. It was the reason that we tried to formulate the proposed classification simple and intuitive, as much as it was possible. The classification applied to existing tools sets their positions in a multidimensional classification space, and opens some visions for ways of applying multimedia contents and interaction in newly created tools.

The proposed classification is based on two crucial aspects of the multimedia concept understanding with special impact on eLearning tools: (1) interactive exchange of (2) multiple types of contents. Interactive communication requires outputs and inputs on both sides of a communication channel. To accept a piece of information exchanged over the channel, a sense on the recipient side has to be excited. Multimedia contents affect the user's natural senses. The user accepts the presented contents through five senses: Visus (Sight), Auditus (Hearing), Tactus (Touch), Odoratus (Smell), and Gustus (Taste). We will use Latin words for naming senses only to provide unique first letters and to make concise notation for the taxonomy this way. Consequently, that will introduce VATOG vector: [V, A, T, O, G]. In a similar way, we can say that the tool acquires its inputs through "virtual senses", so we can use VATOG vector notation to describe information acceptance at both sides of a communication channel.

Independently of the exchanged content type and the appropriate senses excitation on communication channel ends, there are additional two aspects of interaction that also have important impact on an eLearning tool. The first one concerns the understanding on the tool's side in user-tool communication, and the second one concerns the way the user manipulates objects presented by the tool. We will refer to this division as UM (Understanding/Manipulation) classification.

One of the important issues when considering eLearning tools is the effect of the used multimedia contents to cognitive processes in education and learning process improvements. There are many studies [11, 29, 30, 32, 33, 55], and [31] that are trying to analyze this issue. We included in our analysis of the selected tools elements of cognitive theory that shape design principles for multimedia education tools development, proposed in [31]. Although the used classes of tools are not part of our classification, we wanted to characterize tools by analyzing how they fulfill proposed design principles to enlight this important aspect in tools classification.

It would also be interesting if we were able to correlate the effectiveness of the selected tools with the classes they belong to in the classification we proposed in this paper. In order to have credible results in such an analysis it would be necessary to estimate effects of all of the selected tools under the same conditions. Having in mind the versatility of educational domains covered by the selected tools, as well as very different populations of typical users (for example software engineering students and pupils of music schools), this kind of research is unfortunately unfeasible. If we were to try to discover this kind of correlation based on the evaluations of the tools provided by their authors in the papers that introduced them, we fear that the results obtained would not be fair, since different authors may have different metrics for estimating impact of multimedia to learning improvement.

2.1 VATOG classification

Through the interactive communication, a user of an eLearning tool receives different types of contents, which present outputs of the tool. It may be observed that each type of content excites one of the user's senses. Table 1 presents different types of contents presented by an eLearning tool and accepted by appropriate user's sense. Since we are not aware of educational tools characterized by two last coordinates of VATOG vector yet, we have shortened the vector presentation on the first three coordinates. Again, we used terms with unique first letters for content description per sense.

On the other hand, the user's responses to the presented contents are perceived by the tool through inputs of multiple types, which are accepted through virtual senses of the tool. Table 2 presents different types of user's responses perceived and recognized by an eLearning tool through the tool's virtual senses.

Table 1 Types of presented contents in multimedia eLearning tools (system outputs)

Visus (Sight)	Auditus (Hearing)	Tactus (Touch)
Text	Voice	Roughness
Hypertext	Music	Mechanical resistance
Image	Ambient sound	Warmth
Movie	Electronic sound	
Animation		
Virtual reality		
aUgmented reality		
Physical reality		

Table 2 Types of user's responses in multimedia eLearning tools (system inputs)

Visus (Sight) [computer vision]	Auditus (Hearing) [computer hearing]	Tactus (Touch) [computer touching]
Scribing rec.	Voice rec.	Typing
Drawing rec.	Music rec.	Pointing
Eye tracking	Ambient rec.	Clicking
Mimics rec.		Dragging
Gesture rec.		Warmth rec.
		Force rec.
		Manual Manipulation
		Virtual Connecting

For each tool, it is possible to determine channels of communication. Each channel of communication is described with the presented content type by eLearning tool and the type of user's response. Consequently, each tool can be described with an appropriate notation that formally describes interaction between a user and an eLearning tool. The proposed description of interaction is formulated as an M:N mapping, i.e. table of pairs (natural sense of the user/presented content type, virtual sense of the tool/user's response type). Each pair in the table presents a channel of communication in the interaction. If the channel is unidirectional, symbol "-" is used in the column of the side that passively accepts the information from the other side. We will name the classification as VATOG×VATOG or VATOG^2 classification. For example, Table 3 presents an example of VATOG^2 classification of a tool.

Though the presented VATOG^2 classification characterizes the interaction very precisely on the level of communication channels, the classification is relatively cumbersome for many purposes. This is the reason for proposing a simplified version of the classification, named 2VATOG classification. According to this classification, separated information on presented contents as tool outputs on one side and user's responses as tool inputs on another side, will be displayed in two VATOG vectors for each tool: first one for the tool outputs (O), and second one for the tool inputs (I). For each VATOG vector coordinate letters identifying contents that excite the appropriate sense will be given. The example presented above in VATOG^2 classification would be presented in 2VATOG classification as: O[V:TI, A:VM, T:-]+I[V:S,A:V, T:TPCD].

2.2 UM classification

Contrary to the above proposed VATOG classification, which focuses on excited senses by different contents, UM classification focuses on the other aspects of communication: understanding in communication and the ways of object manipulation in the user-tool interaction.

Table 3 Example of VATOG^2 classification of an eLearning tool

Sense of the user/Presented content type	Sense of the tool/User's response type
Visus/Text	Tactus/Typing
Visus/Text	Visus/Scribing
Visus/Image	Tactus/(Pointing, Clicking, Dragging)
Auditus/Voice	Auditus/Voice
Auditus/Music	-

Generally, the user-tool communication can be formal or informal, while the object manipulation can be direct or indirect. In the formal communication, the user explicitly and precisely tells the tool what to do while the tool unambiguously reacts. On the other hand, in the informal communication, the user approximately expresses some goal and the tool reacts according to its best understanding trying to reach the goal. The object manipulation classification is essentially applicable only to formal communication.

We will consider that user directly manipulates objects when the user works with objects with immediate response of the tool. We will refer to this type of formal-direct interaction as "Direct manipulation" (DM). For example, the user can manipulate an object in a stereoscopic 3D scene by using special equipment like a glove.

On the other hand, indirect object manipulation represents a "ping-pong" model of communication in which the user issues commands and gives some data, and the tool responds. We will refer to this type of formal-indirect interaction as "Precise instructing" (PI). For example, the user should select a menu item to open a dialog and to define parameters of geometry transformation, but the transformation would be applied to the object only after clicking on the Apply or OK button.

In an interaction based on informal understanding, the user just informs the tool about his/her intention in a descriptive way. We will refer to this type of interaction as "Informal communication" (IC). Then the artificial intelligence based tool should recognize some semantic in the received content, on the best-effort base, with as much as possible high probability to do exactly what the user wanted to be done. For example, the user can ask the tool something by using a natural language (on many different ways: by typing the sentence, scribing the sentence, speaking the sentence or telling the sentence on the sign language for deaf-mute people). This is very interesting aspect of multimedia interaction, especially in eLearning tools for young children or for people with special needs.

It should be noted that sometimes similar sequences of user actions may be classified differently by UM classification. For example, eye tracking mechanism may be used to capture eye focus on a button, when user's blink would be treated as a click on the button, so the precise instruction is issued. On the other hand the same eye focusing mechanism would be used to track user's interest for parts of the screen, to adapt the following contest to user's predominant interests, which presents an informal communication.

Table 4 lists some examples of appropriate interaction classes.

2.3 Design principles

In [31] design principles for the use of multimedia in education have been defined. These principles are based on the analysis of the effects of multimedia in education. That is why we have decided to finally classify the tools by criterion how they apply these principles. The design principles that are used for classification are *multiple representation*, *contiguity*, *split-attention*, and *coherence* principle. The *individual differences* principle could not be evaluated based on information that was available to us. *Multiple representation* principle states that it is better to present information using two or more different representations than just one. *Contiguity* principle suggests that when presenting information using several different representations, these representations should be presented at the same time. *Split-attention* principle implies that when using several different representations to present information these representations should be devised to influence different senses rather than only one sense. *Coherence* principle explains that in multimedia presentations of information only the most relevant information should be shown.

Table 4 Classes and examples of multimedia interactions

Class	Examples
Direct manipulation	2D manipulation (Pointing, Selecting, Dragging,…)
	3D manipulation (same as in 2D man. + Force recognition)
	RealWorld manipulation (Robotics, musical instruments)
Precise instruction	Textual commands (console-based command issuing)
	GUI commands (Commands, Menus, Toolbars, Dialogs, …)
	Voice commands
	Eye commands
	Gesture commands
Informal communication	Natural language understanding (Typed sentence, Scribed sentence, Spoken sentence, Sign language sentence)
	Mimics understanding (Emotion)
	Eye focus understanding (Concentration)

3 Overview of selected eLearning tools

In this section we selected the eLearning tools that are the most appropriate to illustrate our classification. Several criteria were used to eliminate some tools from detailed consideration. First, we wanted to cover as many different multimedia contents and technologies as possible. Second, we wanted to cover as many different education areas as possible. Third, we wanted to cover tools that have recently emerged. Fourth, we wanted to cover tools for which the research papers that introduced them had noticeable impact on the scientific community. Instead of using ranging selection criteria we used the above mentioned criteria as guidance for eliminating some tools which quantified characteristics are under a set of defined thresholds. The quantifier for the first criterion was calculated as Q1=(NDTC+NDTR) * NDS, where NDTC is the Number of Different Types of Content, NDTR is the Number of Different Types of Responses, and NDS is the Number of Different Senses that the tool uses. The second criterion was not used to eliminate individual tools, but instead it was used to limit the percentage of tools from a single educational area. The quantifier for the third criterion was calculated as Q3=15 - (2013 - YP), where YP is the Year of Publication of the paper describing the tool. The quantifier for the fourth criterion was calculated as Q4=NC/(2013 - YP), where NC is the Number of Citations of the paper that introduced the tool and YP is the Year of Publication of the paper describing the tool. Our guidelines (thresholds) in selecting appropriate tools were that Q1≥5, that no more than 20 % of selected tools are from the same educational area, and (Q1+Q3+Q4)≥15. Based on these considerations, we have searched and found many tools, from which 30 representative have been selected. These tools use 15 various multimedia contents, utilize 10 different user's response types, cover 12 different educational areas, the papers that introduced them have significant number of citations (in total more than 2200), and have been published in the last 15 years (90 % of the tools published in the last 10 years, 50 % of the tools published in the last 5 years, and 40 % of the tools published in the last 3 years).

We present all of the selected tools in a table that contains elementary information about them (Table 5), which include: title of the tool, country at which the tool was invented and the year of publication, tool's website, reference that describes the tool, and domain of the tool application. Website column contains the link to the website from which the tool can be downloaded or purchased (for tools that have this kind of website) or the link to the website

Table 5 Overview of the described tools (last website access: September 2013)

Title	Country and year	Website	Ref.	Domain
Alice tool	USA; 2000.	http://www.alice.org/	[10]	software engineering
ArabicTutor tool	Qatar; 2012.	http://qspace.qu.edu.qa/bitstream/handle/10576/10869/ArabicTutor-ICMCS12-Camera-Ready.pdf?sequence=1	[14]	foreign language
BlueJ tool	Australia, UK; 2003.	http://www.bluej.org	[26]	software engineering
CSA tool	Thailand; 2013.	http://ijcsi.org/papers/IJCSI-10-2-2-509-518.pdf	[48]	computer science
CWRU tool set	USA; 1999.	http://drushel.cwru.edu/375/index.html	[6]	engineering
Dictation tool	Serbia; 2011.	http://library.iated.org/view/SPASOJEVIC2011DEV	[45]	writing
Digital 3D Lego tool	USA; 2011.	http://coitweb.uncc.edu/~wwang22/research/papers/IEEE-TLT-Wang.pdf	[54]	computer science
Digital Violin Tutor tool	Singapore; 2005.	http://www.comp.nus.edu.sg/~wangye/	[53]	music
EDCOMP tool	Serbia; 2005.	http://www.ece.uah.edu/~milenka/	[12]	computer science
Explore! tool	Italy; 2008.	http://ivu.di.uniba.it/people/ardito/Software/Explore/index.htm	[3]	history
Exspot tool	USA; 2005.	http://www.exploratorium.edu	[23]	general purpose
Family Ensemble tool	Japan; 2004.	http://www.vis.uky.edu/~cheung/courses/ee639_fall04/homeworks/p556.pdf	[39]	music
Haptic/Aural tool	USA; 2011.	http://research.vuse.vanderbilt.edu/MEDLAB/research_files/haptics.htm	[50]	mathematics
HRITEH tool set	Switzerland; 2005.	http://www.hystsim.ethz.ch/	[21]	medicine
Humanoid Robots tool set	Taiwan; 2010.	http://hci.csie.ncu.edu.tw/	[8]	foreign language
Hyperscore tool	USA; 2004.	http://hyperscore.wordpress.com	[15]	music
Jeliot 3 tool	Finland; 2004.	http://cs.joensuu.fi/jeliot/	[34]	software engineering
MLAUCS tool	Malaysia; 2011.	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6235383	[41]	computer science
MLTIGS tool	Chile; 2010.	http://personales.dcc.uchile.cl/~luguerre/papers/WCES-10b.pdf	[20]	writing
MLVLS tool set	China; 2010.	http://www.carstenullrich.net/pubs/Ullrich10Mobile.pdf	[51]	general purpose
MTM tool set	USA; 2003.	http://www.csc.villanova.edu/~klassner/	[25]	computer science
PathFinder tool	Spain; 2009.	http://oa.upm.es/4238/1/INVE_MEM_2008_59184.pdf	[43]	mathematics
PRAR tool set	South Korea; 2009.	http://cgit.nutn.edu.tw:8080/cgit/PaperDL/CUC_110118152121.PDF	[28]	general purpose
Quest Atlantis tool	USA; 2005.	http://atlantisremixed.org/	[5]	social science

Table 5 (continued)

Title	Country and year	Website	Ref.	Domain
Robovie tool set	Japan; 2005.	http://www.irc.atr.jp/~kanda/	[24]	foreign language
SDLDS tool	Serbia; 2013.	http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6280603	[47]	computer science
Seeing Sound tool	Australia; 2005.	http://web.arch.usyd.edu.au/~andrew/	[16]	music
Smart Pen tool set	Poland; 2010.	http://iospress.metapress.com/index/36G0558G4536566M.pdf	[37]	writing
Tactile Thermal Display tool	USA; 2011.	http://dl.acm.org/citation.cfm?id=2049577	[22]	art
USIM tool set	USA; 2002.	http://www.hpl.hp.com/research/papers/2002/ubiquitous.html	[17]	general purpose

where the paper or documentation about the tool can be accessed (for tools that do not have the first type of website). Domain column includes the information about the area of education in which the tool can be used.

The following paragraphs describe each one of the selected tools and, as indicated before, are organized as follows: Information, purpose, structure, functionalities, evaluation, trend, and class. Opening sentence of each paragraph includes information related to most of the answers to questions concerning the origin of the tool. The second sentence describes the purpose of the tool. The third sentence gives the coarse grain structure of the tool. Since each one of the tools is characterized with numerous contributions on the level of functionality and interface details, the functionalities that deserve a special attention are described in the fourth sentence. In the fifth sentence, the essential differences among the tools, compared to other relevant tools in the same category, are given as the advantages and the disadvantages. Our opinion of possible improvement and innovation focus for each one of the tools is given in the sixth sentence. Finally, in the seventh sentence, we classify each one of the tools according to the proposed classification.

The Alice tool [10] was created at the Carnegie Mellon University in USA, through a project supported by Electronic Arts, Sun Microsystems, DARPA, Intel, Microsoft, NSF and ONR, in the period of 1999 to 2011; it is available for download from the Internet and it can be used for free.

Purpose: The Alice tool is a 3D interactive animation environment developed to help students who learn programming to understand how to apply problem solving techniques in their programs and how to use common programming constructs.
Structure: (a) 3D graphics environment, which enables students to immediately see the execution of the programming scripts they wrote, (b) the Alice scripting language for writing programming scripts that move or change 3D objects shown in the 3D graphics environment, and (c) Python programming language, which is the underlying language for the tool.
Functionalities: (a) actions, which are built-in action commands that tell an object to perform a motion or to change its physical nature, (b) named instructions, similar to the procedure concept in many other languages, but with intuitive sense of why some instructions are grouped together, and (c) interactions, which implies the support for event handling and GUI creation that enables users to interact with the animated world.
Evaluation: advantages: (a) its ease-of-use, students are not required to learn the underlying language; instead, they can concentrate on learning the programming concepts, and (b) 3D graphics environment, which is more realistic than the 2D environment; disadvantages: (a) some knowledge of 3D graphics and animation is required from students, and (b) error messages are sometimes cryptic (as stated in [10]), particularly the errors that are caused by the students inability to make a difference between an Alice statement and a Python statement.
Trend: (a) support for various modern programming languages, which would enable students to learn real language syntax along with the concepts and (b) extension of built-in functions that would make the tool even more interesting for students.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The ArabicTutor tool [14] was created at the Qatar University in Qatar, through a project supported by the Qatar National Research Fund; it was published in 2012.

Purpose: The ArabicTutor tool is a multimedia m-learning system for teaching Arabic spelling and vocabulary, which uses interactive game-like teaching methods and the capabilities of modern mobile devices.

Structure: (a) the learning package editor, which is a desktop application that allows teachers to prepare teaching materials, (b) the ArabicTutor mobile app, which provides access to the prepared learning materials for students, (c) Web services for preparing learning contents: stemmer service (reduce a word to its root), dictionary service (provides a meaning for a word), text-to-speech service (converts written text into voice), diacritization service (adding diacritics to a word), and part-of-speech service (assigns a lexical class marker to a word), and (d) Web services for using learning contents: content service (enables access to prepared learning materials) and learning performance service.
Functionalities: (a) spelling test, students are asked to write down words to practice spelling, (b) MatchIt sentences game, users are asked to select the words to fill in the blanks in sentences, (c) MatchIt definitions game, users are asked to match the definition with the word, (d) sentence unscramble game, users are asked to reorder words in a sentence so it becomes meaningful, (e) which part of speech game, users are asked to select which part of speech is matched with the underlined word, (f) diacritizeIt activity, users are asked to add diacritics to a word.
Evaluation: advantages: (a) developed for mobile devices in order to make it available to users anytime anywhere, and (b) new games and activities can easily be added (as stated in [14]); disadvantages: (a) no predefined learning materials, and (b) no classification of learning materials based on the language knowledge level of users.
Trend: (a) introduce competitive dimension by keeping the best scores charts for all users and (b) allow users to create their own tests and then challenge each other to solve them.
Class: O[V:THI, A:V, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The BlueJ tool [26] was created jointly at the La Trobe University in Australia and the University of Kent in UK, through a project supported by SUN Microsystems, in the period of 1999 to 2011; the system is based on the Blue system, which was developed at the University of Sydney and the Monash University in Australia, in the period of 1997 to 1999; it is available for download from the Internet and it can be used for free.

Purpose: The BlueJ tool is an integrated Java development environment with a GUI designed for teaching the introductory object-oriented course at the university level.
Structure: (a) GUI environment, which shows a UML class diagram with application structure and enables users to interact with the objects, (b) standard Java compiler, and (c) standard Java virtual machine.
Functionalities: (a) interaction, which is done graphically by clicking the right mouse button on classes or objects and choosing from a menu to do some action with them, (b) visualization, which is done graphically in an UML class diagram manner, and (c) simplicity, in comparison with existing environments.
Evaluation: advantages (as stated in [26]): (a) its ease-of-use, which makes it appropriate for teaching and (b) interaction at an object level, where objects are represented graphically; disadvantages (as stated in [26]): (a) not a professional tool, students have to learn to work with professional tools before they leave the university, and (b) weaker understanding of traditional areas, students who use BlueJ have trouble learning traditional programming.
Trend: (a) support for group-work, which would enable students to work on a common project (as stated in [26]) and (b) support for Internet application programming that could be an extension used in courses at later years of studies.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPCD]; UM: PI.

The CSA (CPU Scheduling Algorithms) tool [48] was created at the National Institute of Development Administration in Thailand; it was published in 2013.

Purpose: The CSA tool is a visual and interactive eLearning tool for teaching CPU scheduling algorithms, which uses graphical animation to convey the concepts of various scheduling algorithms.
Structure: (a) a Java based simulator in simulation mode, which enables users to follow the execution of an algorithm as an animation or step by step, and (b) a Java based simulator in practice mode, which makes it possible for users to make their own decisions during the execution of the algorithm and test if those decisions were right.
Functionalities: (a) support for execution of six CPU scheduling algorithms including: first-come, first-served, round-robin, shortest-job-first, shortest-remaining-time-first, priority scheduling, and multilevel feedback queues, (b) predefined executions scenarios prepared, which enable users to watch the animation of an algorithm execution without the configuration, (c) possibility to create custom execution scenarios and configure the algorithm parameters, (d) state diagram view in the simulation mode only, and (e) an editable representation of an algorithm execution in the practice mode.
Evaluation: advantages (as stated in [48]): (a) practice mode in which the users can test their understanding of an algorithm, and (b) easy-to-use interface; disadvantages: (a) the number of processes is limited to four, and (b) in practice mode there are no precise step by step instructions for user.
Trend: (a) improving practice mode to include precise instructions for users instead of just leaving editable simulation and (b) removing the maximum number of processes limitation.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The CWRU (Case Western Reserve University) tool set [6] was created at the Case Western Reserve University in USA, through a project to support a course in Autonomous Robotics, in the period of 1995 to 1999.

Purpose: The CWRU tool set implies that students, from different disciplines, working in groups, design, build and program their own animal-like autonomous robots in order to compete with them in a public competition at the end of a semester, in a game of plastic egg collection.
Structure: (a) robot building kit, which includes over 1300 parts, among which, the most important component is the 6.270 microcontroller board, developed at MIT, (b) series of structured exercises designed to familiarize students with the components in the robot building kit, and (c) final egg hunt competition, which is designed to motivate students to build their robot, in several iterations, so it can meet the challenge in front of it.
Functionalities: (a) integration, students have to simultaneously apply the acquired knowledge from different areas to be able to build a robot, (b) real-world issues, unlike working with the simulators, building an actual robot confronts students with the real device problems, (c) interdisciplinary teamwork, teams are assembled by students on their own with limitations that aim to assemble multidisciplinary teams, and (d) critical thinking, which is accomplished by the final competition.
Evaluation: advantages (as stated in [6]): (a) final competition that is considerably more technically demanding and (b) a much broader set of educational goals; disadvantages: (a) investment in equipment, which is still not easily affordable at the universities of under developed countries, and (b) limitations in the number of students that are allowed to participate in the course due to equipment limitations.

Trend: (a) different type of competition every year, in order to keep the students interested and (b) making team robot competitions that would require even more integrated knowledge use from students.
Class: O[V:P, A:-, T:M]+I[V:-, A:-, T:TFMV]; UM: DM.

The Dictation program tool [45] was created at the School of Electrical Engineering, University of Belgrade in Serbia; it was published in 2011.

Purpose: The Dictation program tool is computer multimedia software designed for first grade elementary school pupils who are learning how to write; it helps them by creating a virtual classroom in which they can train writing and typing.
Structure: (a) the Editor application, which is used by the teacher for managing lessons and pupils' data, (b) the Trainer application, which is used by pupils for practicing writing and typing.
Functionalities: (a) the Editor application enables the teacher to create and manipulate lessons, (b) every lesson contains a sequence of lesson units, which represents pieces of text dictated at once, and the Editor application can be used to add, remove, or edit units or rearrange the order of units in a lesson, (c) units can contain recorded teacher's voice or pronunciation of units can be synthesized using speech synthesizer, (d) the Editor application can also be used to manage pupils, assign the next lesson for each of them, configure parameters needed for executing the next lesson and analyze pupils' results, (e) the Trainer application executes lessons designed by the teacher by dictating one unit at the time and allowing pupils to write down dictated text either by typing or by writing using optional graphics tablet, and (f) the Trainer application has three modes of operation: demo mode (for familiarization of pupils with the user interface), learning mode (which enables pupil to correct mistakes after every unit), and testing mode (which simulates real world classroom dictation and it is used for evaluating pupils' skills).
Evaluation: advantages: (a) the Dictation program system enables teachers to adapt lessons plan to each pupil individually according to the skill level (as stated in [45]), (b) the Trainer application helps teacher with the testing and evaluation process by doing it automatically according to the configured parameters (as stated in [45]), and (c) pupils are motivated to exercise their writing because of the interesting program that is in use; disadvantage: mistakes are not marked directly on the text written by hand.
Trend (as stated in [45]): (a) improvement in handwriting error detection and classification and (b) adding support for handwriting technique evaluation.
Class: O[V:TIA, A:V, T:-]+I[V:-, A:-, T:T]; UM: PI.

The Digital 3D Lego tool [54] was created at the University of North Carolina in USA, through a project supported by the Department of Energy (DOE) and the National Science Foundation (NSF) of USA; it was published in 2011.

Purpose: The 3D digital Lego tool is an eLearning system for teaching security protocols by applying pedagogical methods used in toy construction sets, treating security primitives as Lego pieces and security protocols as construction results.
Structure: (a) a module for automatic construction of Lego pieces, which enables teachers to automatically construct Lego pieces which will represent a primitive in the protocol for which the Lego set will be used, (b) the main rendering window, which consists of: the primitive panel that displays the current primitive design, the protocol panel that textually describes the protocol, the attack panel that textually describes the attack on a protocol, and the rendering panel that enables visualization and interaction with 3D Legos, (c) the

settings window, which allows users to adjust the rendering and interaction settings, and (d) the exercise control window, which makes it possible to control the execution of an exercise.
Functionalities: (a) rotating/moving/facing-to-viewer Legos, users can rotate/move/face-to-viewer individual or a group of Lego blocks, (b) displaying messages, message contained in a selected Lego block can be displayed, (c) merging, users can adjust the distance between Lego blocks and finally merge them like with real Legos, and (d) labeling, important primitives or protocol portions can be emphasized by adjusting their rendering parameters.
Evaluation: advantages (as stated in [54]): (a) digital Legos help students to identify individual security primitives and to understand the relationships among primitives and protocols, and (b) 3D digital Legos in addition to the text-based approach can increase the interest of students and improve their understanding of security protocols; disadvantage: students have to learn which primitives are associated with which Lego blocks.
Trend: (a) introducing standard Lego blocks designs for primitives and (b) including virtual reality equipment to enable students handling the digital Lego blocks as real Lego blocks.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPCD]; UM: PI.

The Digital Violin Tutor tool [53] was created at the National University of Singapore in Singapore, through a project to support beginning violin learners; it was published in 2005.

Purpose: Digital Violin Tutor is a computer multimedia tool designed for beginner violin students, which helps them tune the violin, indentify the mistakes in their play, and recognize the correct play.
Structure: (a) the transcriber, which transforms the recorded play into a note table with information about the played notes (pitch, loudness, duration, etc.), (b) the performance evaluator, which compares the transcribed student's play with the transcribed teacher's play, identifies mistakes and presents them visually, thus providing feedback to the student, (c) the tuner, which by using visualization and the transcriber helps the students to tune the violin, (d) the animator, which demonstrates the correct play by using 2D fingerboard animation and 3D avatar animation of the transcribed teacher's play, and (e) integrated video player, which shows the teacher's demonstration video.
Functionalities: (a) the transcriber is designed to be accurate (without this quality effectiveness of providing feedback is low), robust against noise (the system is meant to be used in a home environment with low quality microphones and that is why there is a lot of noise that has to be eliminated), and fast (the feedback should be almost instantaneous), (b) the tuner's pitch visualization shows a short history of the estimated pitch and not just the current estimate, which shortens the tuning time, (c) the performance evaluator recognizes three types of mistakes: wrong pitch of the note, playing of additional note that should not be played, not playing a note that should be played; the performance evaluator gives a simple visual representation of the comparison between the student's play and the teacher's play by using different colors to differentiate between the correct and incorrect play, and (d) for demonstrating the correct play the animator combines a 3D avatar animation, which is more interesting to students and, unlike a video, enables a certain amount of interaction (zoom, change of the viewing angle, etc.) and a 2D fingerboard animation, which is sometimes more convenient for detailed view of the played notes.
Evaluation: advantages (as stated in [53]): (a) no special hardware requirements, only PC and a simple microphone are needed and (b) multimodal feedback, which helps students practice and learn more efficiently; disadvantages (as stated in [53]): (a) limitations of 3D animation, which is still not realistic enough to generate natural looking human motion and (b) lack of audio feedback.

Trend (as stated in [53]): (a) adding of audio feedback along with visual feedback and (b) adding various avatar characters to make the system more entertaining.
Class: O[V:TIMA, A:M, T:-]+I[V:-, A:M, T:-]; UM: DM.

The EDCOMP tool [12] was created at the School of Electrical Engineering, University of Belgrade in Serbia; it was published in 2005; it is available for download from the Internet and it can be used for free.

Purpose: The EDCOMP tool is a Web-based, multimedia, educational computer system simulator designed to help students who are learning topics from computer architecture and organization courses.
Structure: (a) the educational computer system, which is designed to cover as many topics taught at the mentioned courses as possible and (b) the visual simulator, which is a Web-based software system developed to graphically simulate the educational computer system.
Functionalities: (a) the educational computer system contains a processor, a main memory, an I/O subsystem with a DMA and a non-DMA controller, six dummy peripheral controllers and an arbitrator, (b) the processor in the educational computer system represents a CISC architecture, (c) the visual simulator is run from a Web browser and it is used to configure and execute a simulation, (d) configuration of a simulation can be done automatically using prepared file or manually by setting certain parameters like clock rates, values of memory locations and registers of the processor, etc., (e) graphical representation of the educational computer system in visual simulator is hierarchical (block diagram is presented at the beginning and users can get detailed structural schemes for each block through the simulator GUI), and (f) the status and commands for control of simulation execution are available in a separate window, through text descriptions of the status and the command buttons used for control of the simulation execution (one clock, instruction or program ahead, etc.).
Evaluation: advantages (as stated in [12]): (a) instructive graphical representation which enables students to relate the material covered by lectures with the visual simulator used in the laboratory, (b) user interface which is easy to use, and (c) access to the visual simulator through the Internet; disadvantages: (a) absence of commands for execution of simulation in reverse (one clock and instruction backward) and (b) tool was developed as a Java applet and because of that it requires additional Web browser settings.
Trend: support for making changes in the educational computer system modules in the configuration part.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TC]; UM: PI.

The Explore! tool [3] was created at the University of Bari in Italy, through a project supported by Italian Ministry of University and Research, in the period of 2006 to 2008.

Purpose: The Explore! m-learning tool is an implementation of an excursion-game technique for eLearning with mobile technologies.
Structure: (a) Gaius' Day in Egnathia application, which is a computer game designed for mobile devices to make the visit to archaeological park of Egnathia more interesting to elementary school children, (b) a paper map of the park, (c) a backpack carrying a pair of loudspeakers, and (d) two mobile phones, of which, one is connected to the loudspeakers in the backpack and is in charge of providing contextual sounds, and the other one is in charge of running the game.
Functionalities: (a) game application, which relies on an XML file that describes the game content and is run on a mobile device, (b) hint application that provides the cues

also represented in XML and is also run on a mobile device, (c) debriefing application, which retrieves XML data from mobile devices and runs on a notebook, and (d) contextual sounds application, which runs on a mobile device that is connected to loudspeakers and generates contextual sound environment in outdoor settings.
Evaluation: advantages (as stated in [3]): (a) applications designed for mobile phones, so that visitors can use their own mobile phones, since the application is on a memory card, and no additional hardware is necessary and (b) applications that are easily adaptable to different archeological parks, since the descriptions are in XML files, so that history experts without knowledge in programming can adapt applications; disadvantages (as stated in [3]): (a) lack of a tool with user interface for adapting applications to other parks, and (b) limitations of mobile phones in 3D graphics representation, although new models overcome these limitations.
Trend: (a) improvement in graphical design of mobile device applications in accordance with the mobile phones recent development and (b) implementing a repository of students' activities that would be available to them at home through Internet access, so that they can revise what they learned.
Class: O[V:TIAP, A:A, T:-]+I[V:-, A:-, T:T]; UM: DM.

The eXspot tool [23] was created jointly at the University of Washington's Computer Science and Engineering Department, Intel Laboratories Seattle, and San Francisco Exploratorium in USA, through a project to support museum visitor's experience; it was published in 2005.

Purpose: EXspot is a RFID based tool, which aims to enhance a user's experience at the museum by enabling the user to record his visit and analyze it at home.
Structure: (a) museum (in this case San Francisco Exploratorium), which is educational environment for the system, (b) a small RFID reader package, for mounting on museum exhibits, which contains a Crossbow Mica2Dot mote, a low-power RFID reader, and LED indicators, (c) an RF tag, carried by visitors on a card or necklace, (d) a wireless network, for transmission of visitors RF tag ID from an RFID reader to the network base station where the information about the visit are recorded in a database, (e) a registration kiosk, which enables users to enter their email address to register their cards at the beginning of their visit, (f) dynamically generated Web pages, which are created based on the visitor's requests and are available to him at home.
Functionalities: (a) enables visitors to capture information about their visit to the museum and take pictures, by using their RFID cards to bookmark point of interest and trigger digital cameras to take pictures of themselves or the exhibit, and later they can access these information through a personalized Web pages, (b) the RFID reader package constantly queries for the presence of RF tags and when it reads a RF tag it sends its ID to a base station over Mote radio, then the ID is sent to a network base station wirelessly and there it is recorded to a database along with other basic information such as time and information about exhibit, and (c) the user accesses the personalized Web pages by his/hers RF tag ID and his/hers email address, and the pages contain information about user's experience at the museum (dates, exhibits they visited and photographs they took) and suggested links to additional teaching materials related to the exhibits.
Evaluation: advantages (as stated in [23]): (a) solution to the hurried-visitor problem, in museums with many exhibitions visitors can see only a small subset of the exhibits on display and usually they visit exhibits by rushing through a museum without a time to digest what they have seen and that is why using technologies like RFID to bookmark

visited exhibits and access the bookmarked information from home enhances visitors experience and (b) by recording information about a visitor's preferences during the visit, museum staff can analyze important data about visitors and adapt exhibits to be more interesting; disadvantages (as stated in [23]): (a) museum visitors poor understanding of RFID technology, which leads to mistakes in using RFID tags and complicates the visit, (b) their poor understanding of bookmarking concept, and (c) visitors impression about their personal data privacy, which makes the visitors suspicious about using RFID technology.
Trend (as stated in [23]): (a) education of visitor about proper use of new technology, like RFID, that is available to them at the museums and (b) improving the technology used for RFID reader to eliminate the problems that users have with proper reading of their RF tags.
Class: O[V:THP, A:-, T:-]+I[V:-, A:-, T:CV]; UM: DM.

The Family Ensemble tool [39] was created jointly at the ATR Media Information Science Laboratories and at the Japan Advanced Institute of Science and Technology in Japan, through a project supported by the National Institute of Information and Communications Technology (NICT), the Ministry of Education, Science, Sports and Culture, and the Hayao Nakayama Foundation for Science & Technology and Culture; it was published in 2004.

Purpose: The Family Ensemble tool represents a collaborative musical edutainment system, which enables a parent and a child to play piano duo at home, even if the parent has no knowledge of playing musical instruments, by correcting the parent's performance, thus making children more enthusiastic about practicing musical instrument playing.
Structure: (a) a piano keyboard, which is interface for playing music, (b) MIDI sound generator, which generates music, (c) a set of speakers, which reproduce music, (c) the score-tracking module, a software module that acquires the child's input and determines its current position in the score, (d) the note-number-acquisition module, a software module that gets the output of the score-tracking module as an input and determines the appropriate note for the parent, i.e. the current position in the original score, and (e) the note-number-replacement module, a software module that gets the output of the note-number- acquisition module as an input and replaces the played parent's note with the correct one, but preserves the other characteristics of the performed note (loudness, length, etc.).
Functionalities: (a) the score tracking algorithm, which takes in consideration four types of common mistakes: an extra note that does not match any notes in the score is performed, though a performed note matches a note in the score its pitch is incorrect, a note in the score is not performed, and an extra note sequence that matches a part of the score is performed and (b) there is a dependency between parent's and child's performance: if the parent stops playing, the child can continue undisturbed, but if the child stops playing the parent cannot play further than the position where child has stopped.
Evaluation: advantages (as stated in [39]): (a) by correcting only the parent's performance the Family Ensemble tool does not interfere with learning process of a child and at the same time enables the parent to concentrate on helping the child improve his/her/their performance, rather than concentrating on performing correct notes and (b) by implementing a good score tracking algorithm the Family Ensemble tool makes it possible for a child that makes many mistakes and a parent with no musical knowledge to play piano duo immediately, which helps motivating the child to practice; disadvantages: (a) only supported for a limited number of classical music compositions and (b) absence of visual representation.
Trend: (a) including different musical instruments in the Family Ensemble tool and (b) extending the number and the genre of available compositions in the Family Ensemble tool.
Class: O[V:T, A:M, T:-]+I[V:-, A:M, T:-]; UM: DM.

The Haptic/Aural tool [50] was created at the Vanderbilt University in USA, through a project supported by the National Science Foundation (NSF) of USA; it was published in 2011.

Purpose: The Haptic/Aural tool is a software application developed to work with a haptic touchscreen in order to make it possible for blind pupils to learn graphical mathematics in elementary schools.
Structure: (a) the haptic/aural software, which was developed in C++ using an API for a touchscreen and an open-source UI framework and (b) a haptic touchscreen, which has a possibility of providing a vibration feedback necessary for allowing users to recognize the graphical mathematics objects.
Functionalities: (a) exploration of the haptic touchscreen content using haptic and/or auditory feedback (Explore Mode) and (b) easy creation of new drawings using the haptic touchscreen (Sketch Mode).
Evaluation: advantages (as stated in [50]): (a) makes it easy for users to find and identify (determine coordinates for) a desired point in the grid representing coordinate system and (b) makes it easy for users to distinguish lines from shapes; disadvantages (as stated in [50]): (a) inability to conclude whether haptic or auditory feedback was more useful to users, and (b) lack of guidance for users on how to distinguish the different shapes from one another.
Trend: (a) creation of appropriate educational material for teaching mathematics using Haptic/Aural tool and (b) determination of which combination of haptic and auditory feedback gives the best results.
Class: O[V:I, A:E, T:R]+I[V:-, A:-, T:F]; UM: DM.

The HRITEH (Highly-Realistic, Immersive Training Environment for Hysteroscopy) tool set [21] was created jointly at the Computer Vision Lab, ETH Zurich, the University Hospital Zurich, and the Institut de Production et Robotique, EPF Lausanne, in Switzerland, through a project supported by the Swiss National Science Foundation; it was published in 2005.

Purpose: The HRITEH tool set represents a generic surgical training simulator for hysteroscopy, which enables users to train both basic manipulative skills and procedural skills.
Structure: (a) an OR (Operating Room) environment with real tools and equipment, which represents a realistic training environment, (b) a Limbs&Things model, which has been modified to be able to house the haptic device, (c) the haptic device, which provides 4 DOF (Deegrees-of-Freedom) for hysteroscopy, (d) an original resectoscope, which has been equipped with sensors to interact with the simulation, (e) valves for controlling in and out flow of the distension fluid, (f) the endoscopic camera, which is attached to the end of the tool, (g) the visual display, which displays a virtual scene, (h) the devices for auditory feedback, which has been recorded during a hysteroscopy intervention and is synthesized in real-time stereo during the simulation, and (i) software for creating individual training scenes, which makes it possible to create different scenarios based on the collected real data.
Functionalities: (a) entire procedure of a hysteroscopy intervention can be exercised, since the training environment is equipped like the real OR, (b) all typical manipulations of the original resectoscope can be performed during the simulation and also resectoscope can be completely disassembled so the trainee can get acquainted with the full complexity of the tool handling, and (c) during the simulation session, all gestures of the surgeon are tracked, which makes it possible to evaluate the recorded session.
Evaluation: advantages (as stated in [21]): (a) the use of the real medical tools in a real OR conditions, (b) the virtual scene starts automatically after the insertion of the tool, which permits a smooth transition into the scenario instead of the simulation on/off experience,

and (c) many different simulation scenarios, which have been created based on the real data, can be exercised; disadvantage: the price of the tool set.
Trend (as stated in [21]): (a) real surgical devices (like fluid pump, electrocardiogram, etc.) could be included in the tool set and integrated in the simulation to increase the realism and (b) extension of the setup to support team training should be considered.
Class: O[V:VP, A:A, T:M]+I[V:-, A:-, T:FM]; UM: DM.

The Humanoid Robots tool set [8] was created jointly at the National Central University and the Ching Yun University in Taiwan, through a project supported by the National Science Council of Taiwan, the Institute for Information Industry and the Ministry of Economic Affairs of Taiwan; it was published in 2010.

Purpose: The Humanoid Robots tool set recognizes possibilities of using humanoid robots in educational purposes and presents a study that discusses the use of robots for teaching second language in primary schools.
Structure: (a) a software controlling the robot, which enables various modes of operation for the robot and (b) robot partner for classroom teachers, a humanoid robot designed to help pupils in learning second language.
Functionalities: (a) storytelling mode of the robot, in which the robot can present stories in various voices and perform numerous sound effects, which makes the story more interesting to pupils, (b) oral reading mode of the robot, in which the robot leads the reading class and it can change the speed of its reading, which makes the pupils also to change it, (c) cheerleader mode of the robot, in which the robot encourages pupils to participate in the learning games, (d) action command mode of the robot, in which the robot obeys pupils instructions, and (e) question and answer mode of the robot, in which the robot communicates with pupils - it can be presented as a foreigner, which encourages pupils to use the foreign language to communicate.
Evaluation: advantages (as stated in [8]): (a) usage of the robot encouraged pupils to be more active in the classroom, to raise hands and ask questions, and to pay more attention during classes, (b) by using the robot, teachers can be relieved of routine tasks so that they can concentrate on being creative, and (c) while robot leads the class, teachers can focus their attention on individual work with pupils; disadvantages (as stated in [8]): (a) price of the robot, which is still too high, and (b) robot technologies, which are still in the research process and are not completely ready for commercial use.
Trend: (a) design of a better human-robot interface, which would enable teachers to use robots in the classroom easier and (b) improving robot technologies, which would help to improve humanoid robots that are used in the classroom.
Class: O[V:P, A:VA, T:-]+I[V:-, A:V, T:-]; UM: PI.

The Hyperscore tool [15] was created at the Massachusetts Institute of Technology in USA, through a project supported by MIT Media Laboratory, CSK, and Sega, in the period of 2000 to 2006; it is available for download from the Internet and it can be used by paying a commercial fee.

Purpose: The Hyperscore tool is a graphical computer-assisted composition system for users with no previous musical training or theoretical knowledge.
Structure: the basic component of the Hyperscore tool is its GUI that was written in C++ using DirectX and that contains: (a) canvas and (b) musical objects, which are created in a separate interactive window and can be placed anywhere on the canvas and interconnected to create a composition.

Functionalities: (a) graphically creating some melodic motives in "motive" windows, where vertical axis represents pitch (spanning two octaves) and horizontal axis represents time, by an expansive and zoom able canvas, which is used for graphical creation of compositions, (b) musical objects, adding colorful droplets (which represent notes) and blank spaces (which represent rests), (c) the user assigns a color for the created motive and then graphically composes a piece in a "sketch pad" window by using different colored pens (every color is a different melodic material) to draw colored lines thus creating a composition, and (d) influencing on the tonality of the motive by reshaping the lines (horizontal lines present motive repetition in the original tonality, but curves and bends in the line impose pitch envelope in the original motive).
Evaluation: advantages (as stated in [15]): (a) its appropriateness for novice users, unlike some of the other tools that are only appropriate for professional musicians and (b) ability to aid users in learning traditional composition, whereas some of the other tools only entertain users, but lack this ability; disadvantages (as stated in [15]): (a) lack of support for external input of melodic material and (b) no possibility of direct editing at the individual note level within the sketch pad window.
Trend (as stated in [15]): (a) support for reverse engineering that would allow a user to input a composition in some audio format and get a Hyperscore sketch for that composition, and (b) improving computer assistant role in the creation process of composing.
Class: O[V:TIA, A:M, T:-]+I[V:-, A:-, T:PCD]; UM: DM.

The Jeliot 3 tool [34] was developed at the University of Joensuu in Finland, in the period of 2003 to 2008; the tool is based on the Jeliot 2000 tool, which was developed at the Weizmann Institute of Science in Israel and previous versions Jeliot I and Eliot, which were developed at the University of Helsinki in Finland, in the period of 1994 to 2003; it is available for download from the Internet and it can be used for free.

Purpose: Jeliot 3 is a program visualization tool with ability of full or semi-automatic visualization of the data and control flows, aimed at teaching procedural and object-oriented programming to students of lower years at the university.
Structure: (a) GUI, used for interaction with the user, (b) DynamicJava, which is a Java interpreter used for interpretation of Java source code created by the user through GUI, (c) intermediate code interpreter, used to connect the GUI part of the system with the visualization engine, and (d) visualization engine, which was taken from the previous version, Jeliot 2000.
Functionalities: (a) user interface, designed to be appropriate for teaching novice students with graphical and classical textual representation of source code and menus for controlling the program visualization and (b) visualization, which was done in a manner that enables students to concentrate on learning programming and not wasting time on analyzing the environment (for example, all of the visualized components have their own area on the screen, etc.), thus reducing the cognitive load of the student.
Evaluation: advantages (as stated in [34]): (a) dynamic visualization of the program, which enables students to link the execution of the program with its visual representation and grasp the concepts with less difficulties and (b) novice level approach in visualization, compared to other similar tools that assume that the users are familiar with UML and the basics of programming; disadvantages: (a) not a standard environment, students have to learn to work with standard programming environments, which means they have to make transition from Jeliot 3 to standard environments and (b) only appropriate for beginners in programming, although there is a support for extensions.

Trend: (a) support for more modern programming languages, like C# and (b) set of prepared exercises with questions and answers for evaluating the progress of students learning with the Jeliot 3 tool.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPCD]; UM: PI.

The MLAUCS (Multimedia Learning Application for Undergraduates in Computer Science) tool [41] was created at the University Technology Mara in Malaysia; it was published in 2011.

Purpose: The MLAUCS tool is a multimedia eLearning application for teaching Wide Area Network (WAN) protocols in which cognitive and constructivist approaches from learning theories were applied.
Structure: (a) the tutorial part of the application, which has two parts: notes and animation and (b) the Q&A part of the application, which is used by the students to check how much they have learned, it consists of three parts: the objective question (multiple choice questions similar like the ones on the exam), cross word, and word search.
Functionalities: (a) the use of animation as a tool to aid students in understanding WAN protocols (switching network, circuit-switching network, X.25, frame relay, and ATM are the topics included in the application), (b) the use of narration as a method to improve the effect of the animation, and (c) the use of a metaphor 'a window to the new world' (includes images of the space, a space ship, astronauts, moon and stars), as a method to help students to better accept a user interface.
Evaluation: advantages (as stated in [41]): (a) the use of animation and narration gives better results than the use of animation and on-screen text, and (b) introduction of fun into learning through some educational games; disadvantages: (a) animations are static and therefore do not allow students to explore some situations by themselves, and (b) no easy way to add new topics in the application.
Trend: (a) design of a framework that would make it possible to add new topics to the application and (b) modifying the animations to allow users to control them.
Class: O[V:TIA, A:V, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The MLTIGS (Mobile Learning Tool for Improving Grammar Skills) tool [20] was created at the Universidad de Chile in Chile, through a project supported by the Chilean Fund for Science and Technology and the Latin American and Caribbean Collaborative ICT Research (LACCIR); it was published in 2010.

Purpose: The MLTIGS tool is a mobile software application that supports teaching grammar for Chilean elementary school children by combining individual work and face-to-face group work.
Structure: (a) a Web based user interface, which allows students to use the application through the Internet and (b) a PDAs based user interface, which allows students to use the application on their mobile devices.
Functionalities: (a) the first phase of the learning activity, during which every student is given individual text and grammar activities that he/she must complete (this is done asynchronously) and (b) the second phase of the learning activity, which begins when all students have completed the first phase, and includes online team assignment where each student's activities are marked with a different color in the text.
Evaluation: advantages (as stated in [20]): (a) version of the application for PDAs, which gives excellent support for the synchronous face-to-face group activity and (b) design of a collaborative learning activity; disadvantages: (a) the lack of multimedia contents that

could improve the application, and (b) the lack of educational games that could make the application more interesting to students.
Trend: (a) introduction of multimedia contents and (b) introduction of educational games.
Class: O[V:TI, A:-, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The MLVLS (Mobile Live Video Learning System) tool set [51] was created at the Shanghai Jiao Tong University in China; it was published in 2010.

Purpose: The MLVLS tool set is a mobile education system, which streams live lectures to mobile devices and allows students who use it a limited interaction with teachers during lectures.
Structure: (a) a classroom with instructor station which includes: teaching screen (contains the information shown to the students), feedback screen (contains text messages sent by the students and mirrored views of their mobile devices screens), and classroom recorder (camera records teacher, microphone records the audio information, and the teaching screen is also recorded), (b) central server, which includes: broadcasting server (receives compressed data from the classroom recorder and distributes it to the client viewers on their mobile devices) and the classroom management system (students use it to start live stream of a lecture and interact with the teacher by polls or SMS and teachers use it to monitor the students behavior during class), and (c) a mobile device with: client viewer module (three different views are available: slide-view, slide and teacher-view, and teacher-view) and interaction module (provides the polling and SMS feedback and transmits the mobile's screenshot to a teacher).
Functionalities: (a) the teaching screen is projected in the classroom, it is touch sensitive allowing the teacher to write on it freely, usually over previously prepared slides, (b) teacher can use feedback screen to respond to students questions by sending textual messages, view the results of previously prepared polls and monitor the behavior of students that are following classes on their mobile devices, and (c) classroom recorder makes it possible for students to chose to follow the lectures in one of the three possible views, depending on their needs.
Evaluation: advantages (as stated in [51]): (a) a pragmatic and cost-efficient solution, which enables more students to follow classes than in traditional classroom lectures, and (b) live broadcast that allows distant users to interact with teachers; disadvantages: (a) student monitoring system would have to be improved, since it only monitors the screen of their mobile device, and (b) there are still some technical issues (e.g. too many users simultaneously can overload the server) that need to be resolved (as stated in [51]).
Trend: (a) mobile devices have significantly advanced since this tool was published and the tool should be adapted to the new generation of mobile devices and (b) technological advances should be used to improve interaction between the students and the teacher.
Class: O[V:THIMA, A:V, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The MTM (More Than MindStorms) tool set [25] was created at the Villanova University in USA, through a project supported by National Science Foundation of USA, in the period of 2001 to 2003.

Purpose: The MTM tool set represents the collection of solutions for difficulties that prevent the use of the Lego MindStorms kit for building robots (the kit contains 750 building block pieces, among which, the centerpiece is the programmable control unit, called RCX, that contains a CPU, RAM and an IR transceiver) for teaching Computer Science at the university level in seven core areas of the ACM/IEEE computing curriculum [1]: Programming Fundamentals, Algorithms and Complexity, Programming Languages, Architecture, Operating Systems, Intelligent Systems, and Net-Centric Computing.

Structure: (a) Mnet firmware for RCX, which supports point-to-point communication and a bytecode for requesting the state information of an RCX, and is backward compatible with the standard Lego firmware, (b) a new API for developing in C or C++, which among other things, allows to transmit a vector of state information via IR with a single method, (c) a package of Common Lisp functions, (d) a Java programming package, which allows a desktop application to control the RCX without limitations on memory, and (e) Lego MindStorms robot building kit.
Functionalities: (a) resolving the limit of 32 KB of memory in the RCX by allowing to move most of the computation to desktop computer and to send commands as necessary to RCX and (b) enabling support for wireless point-to-point protocols over a built-in IR port.
Evaluation: advantages (as stated in [25]): (a) its firmware, which makes it appropriate for teaching by resolving some of the drawbacks of the original Lego firmware and (b) support for most of the programming languages that are usually taught at universities; disadvantages: (a) limitations inherited from Lego MindStorms kit that could not be overcome completely (as stated in [25]), and (b) investment in equipment which is still not easily affordable at universities of underdeveloped countries.
Trend: (a) support for modern programming languages, like C#, and (b) support for new areas of the computer science teaching.
Class: O[V:P, A:-, T:M]+I[V:-, A:-, T:TFM]; UM: DM.

The PathFinder tool [43] was created at the Technical University of Madrid in Spain, through a project supported by Technical University of Madrid; it was published in 2009.

Purpose: The PathFinder tool is an eLearning system for actively learning Dijkstra's algorithm, which provides an animated algorithm visualization panel showing the current step of the algorithm execution.
Structure: (a) the graph area of the window where the graph is displayed, (b) the algorithm area of the window where the algorithm execution code is displayed, (c) the messages area of the window where the messages during the execution of the algorithm are given, and (d) the framework area of the window where a table presenting the current state of the algorithm structures is displayed.
Functionalities: (a) editable graph, the users can create and edit nodes and weighted edges of the graph, (b) three execution modes: step by step (for every algorithm iteration user has to update the fixed and unfixed nodes, distances and predecessors), iteration verification (similar as previous but the verification of users input is done after performing an entire iteration) and direct execution (directly provides the final result), (c) in algorithm area of the window the current step of the algorithm is highlighted with blue, and when an error occurs in a step by step or iteration verification execution the step in which the error occurred is highlighted with red, and (d) when an error occurs while executing algorithm in the messages area of the window a message pointing out the problem and providing hints to resolve it is displayed.
Evaluation: advantages (as stated in [43]): (a) the algorithm visualization panel included in the tool, (b) the framework panel, which allows users to practice every algorithm step as if they were doing it manually on paper, and (c) the option to save and load graph; disadvantage: the tool is developed to teach only one algorithm.
Trend: (a) generalizing the tool to include teaching more graph related algorithms and (b) introducing assessment mode in which the students would be automatically graded.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPCD]; UM: PI.

The PRAR (Pattern Recognition and Augmented Reality) tool set [28] was created jointly at the Seoul National University and the Hanyang University in South Korea, through a project supported by ETRI (Electrons and Telecommunication Research Institute), Development of Elementary Technology for Promoting Digital Textbook and U-Learning Project; it was published in 2009.

Purpose: The PRAR tool set is an interactive eLearning system, which uses pattern recognition and augmented reality to help students while they are learning by providing them with realistic audio-video contents in addition to standard textbooks.
Structure: (a) a Web camera connected to a computer, which is focused on a textbook and provides input, (b) an image/object recognition module, which is enabled to identify the current text page and objects that the student is studying based on a database of images and objects in the textbook, (c) a polka-dot/color-band marker recognition module, which makes it possible to perform actions on the recognized images or objects, (d) an augmented reality engine, which is responsible to gather the input from recognition modules and produce output for students by adding appropriate audio-visual contents defined by a learning scenario, (e) audio-visual contents, which are associated with recognized images and objects, and (e) learning scenarios of the textbook, which are predefined steps that indicate when and where the contents should be augmented.
Functionalities: (a) polka-dot markers, which are put on the finger and can be used as a computer mouse to indicate their position in a video frame so that students can interact with the recognized objects, (b) color-band markers, which are used when more than one marker is needed simultaneously to manipulate multiple objects since the distinction between two polka-dot markers is difficult to recognize, and (c) interaction with the recognized objects, which includes selection from menu associated with object or moving objects, depending on the learning scenario.
Evaluation: advantages (as stated in [28]): (a) natural interface of the markers, because of which the students do not need to learn how to use the markers, and (b) interactive augmented reality, which increases students interest in learning, especially at the elementary school level; disadvantages (as stated in [28]): (a) there are still some recognition errors, and (b) there are no authoring tools which would make it possible for teachers to create learning scenarios by themselves.
Trend: (a) design of authoring tools for creating learning scenarios (as stated in [28]) and (b) including more interactions like interactive tests for example.
Class: O[V:TIAU, A:VM, T:-]+I[V:G, A:-, T:-]; UM: DM.

The Quest Atlantis tool [5] was created at the Indiana University in USA, through a project supported by the National Science Foundation (NSF), MacArthur Foundation, NASA, and Food Lion, in the period of 2002 to 2010.

Purpose: The Quest Atlantis tool is a 3D multiuser virtual game environment designed to immerse children, ages 9–15, in meaningful educational tasks.
Structure: (a) quests, which represent general curricular tasks, (b) missions, which are collections of concrete educational tasks and by solving the missions gamers acquire knowledge the quest is devoted to, and (c) units, which represent organized lesson plan of real-world and virtual activities that need to be completed to learn the material concerning certain matter.
Functionalities: (a) storyline states that there was a beautiful planet called Atlantis that was destroyed, and only the Arch of Wisdom, which contains all the wisdom and knowledge of the Atlantian people, was saved, but it is not working properly anymore and only way to fix it is to produce "lumins" (collect points) by solving quests and

missions in the game, (b) the 3D space contains different worlds that reflect various themes (water quality, weather, etc.) and include challenges (quests and missions), through which the students can learn about the theme, and (c) worlds create storylines and interactions such that students can use academic knowledge to solve problems.
Evaluation: advantages (as stated in [5]): (a) a triadic foundation, which means that the design of the game is based on education, entertainment, and social commitments, and (b) education component of the game is based on experiential learning, which implies that understandings are derived from experience, inquiry-based learning, and portfolio assessment; disadvantage: focus on online play, since there are many countries in the world where pupils and students do not have appropriate equipment.
Trend: (a) support for gaming consoles, which are more popular than PC for playing games and (b) new versions of the game with new storylines, which are essential in this type of games, since the players lose their interest in the game unless the scenario changes.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:PCD]; UM: DM.

The Robovie tool set [24] was created jointly at the ATR Intelligent Robotics and Communications Laboratories and the Osaka University in Japan, through a project supported in part by the National Institute of Information and Communications Technology of Japan, and also supported in part by the Ministry of Internal Affairs and Communications of Japan, in the period of 2000 to 2005.

Purpose: The Robovie tool set implies the use of the Robovie robot system, which is an interactive humanoid robot, for teaching elementary school children a foreign language as a peer tutor and establishing longitudinal relationships with children.
Structure: (a) Robovie robot system capable of human-like expressions with various actuators and sensors, (b) person identification with wireless ID tags, which enabled the robot system to show some human-like adaptation by recalling the interaction history of a given person, and (c) software architecture that enables the robot to simultaneously identify multiple persons and interact with them based on an individual memory for each person.
Functionalities: (a) situated modules, which are designed for certain types of action reaction pairs in a particular situations (for example, handshake), (b) person identification, which divides humans near robot into two groups: participants (persons in a distance less than 1.2 m) and observers (persons in a distance between 1.2 m and 3.5 m), and (c) module control, which selects the next situated module to be executed by looking up episodes that represent a sequence of situated modules executed in accordance with the interactive behaviors among humans.
Evaluation: advantages (as stated in [24]): (a) implemented interactive behaviors, which makes it interesting and appealing to children (100 interactive behaviors have been developed) and (b) design for long-term interaction, robot can call children's names and it shows more and more interactive behaviors as the time goes by; disadvantages (as stated in [24]): (a) limited interacting abilities, which makes it more appropriate to serve as a friend with children rather than a tutor and (b) limited sensing abilities in the real world environment.
Trend: (a) intelligent agents that can create interactive behavior patterns based on interaction with humans (learning ability) and (b) broadening of situated modules as a base for creating interactive behavior patterns.
Class: O[V:P, A:V, T:M]+I[V:G, A:V, T:FV]; UM: IC.

The SDLDS (System for Digital Logic Design and Simulation) tool [47] was created at the School of Electrical Engineering, University of Belgrade in Serbia, through a project supported by the Ministry of Education and Science of the Republic of Serbia; it was published in 2013.

Purpose: The SDLDS tool is a software system developed to support the teaching of digital logic through self-learning and laboratory work for students and automatic assessment and verification of student's work for teachers.
Structure: (a) the synthesis module, which allows users to follow the procedure for the synthesis of an arbitrary switching circuit, (b) the simulation module, which enables users to design and simulate a switching circuit, and (c) the verification module, which makes it possible to verify and assess the correctness of a switching circuit design.
Functionalities: (a) step by step formal procedure for the synthesis of an arbitrary combinational or sequential switching circuit can be followed by the users, (b) the result from the synthesis module can be used to automatically generate the switching circuit schema in the simulation module, allowing users to manually verify that result, (c) during the execution of the synthesis procedure a user can go back to some decision point at any time and observe how different decision choice will affect the result, and (d) in the simulation module standard combinational and sequential components are provided and users can design custom components, save them and use them in the same manner as standard components.
Evaluation: advantages (as stated in [47]): (a) step by step formal procedure execution, which is appropriate for self-learning, (b) possibility to verify the switching circuit design in the simulation module, and (c) automatic assessment and verification of student's work; disadvantages: (a) only sequential switching circuits that are based on the Huffman-Moor model are supported in the synthesis and the verification modules and (b) combinational switching circuits can only be assigned using truth tables and not by switching functions.
Trend: (a) improving the verification module to support sequential switching circuits that are not based on the Huffman-Moor model and (b) making it possible to assign combinational switching circuits using switching functions.
Class: O[V:TIA, A:-, T:-]+I[V:-, A:-, T:TPC]; UM: PI.

The Seeing Sound tool [16] was created at the University of Sydney in Australia, through a project supported by an Australian Postgraduate Award and a Department of Architectural and Design Science Supplementary Scholarship; it was published in 2005.

Purpose: Seeing Sound is a real-time sound visualization tool, which enables training of instrumental musicians by using visual feedback loops, thus replacing the usual iterative feedback loops that require the presence of a music instructor.
Structure: (a) the data filtering part, which uses Fourier transform based methods to extract parameters that describe specific aspects of the music stream, and (b) the visualization mapping part, which implements visual analogies to each of the extracted parameters.
Functionalities: (a) fine pitch represents discrepancy between the played note and the note in the western music scale and it is represented by the slant of the sphere group (the spheres are aligned vertically if the pitch is correct), (b) loudness represents the strength of the instrument's sound as perceived by the listener and it is represented by the overall height to which the group stretches, (c) the harmonic content of a note is represented by a set of equally distant spheres of different size, where each sphere represents a harmonic and the fundamental frequency is represented by the lowest sphere in a column, and (d) noisiness represents a ratio between periodic and random elements within the data stream and it is represented by a fountain of particles that are placed directly behind the spheres and originate from the same point as the sphere that represents the fundamental frequency.

Evaluation: advantages (as stated in [16]): (a) because this is a real-time visualization tool, it enables musicians to see the sound they just played and correct their technique without the need to rely on memory, as it would be the case with a tool that is not real-time, and (b) visualization methods that well correspond to a musicians mental visualization of the sound; disadvantages: (a) appropriate predominantly for musicians with deeper knowledge about music, and (b) limited number of parameters extracted from the sound and visually presented.
Trend (as stated in [16]): (a) support for multiple musicians playing in an ensemble and (b) extending the sound quality visual representation with more data extracted from the sound.
Class: O[V:IA, A:-, T:-]+I[V:-, A:M, T:-]; UM: DM.

The Smart Pen tool set [37] was created at the Gdansk University of Technology in Poland, through the project supported by the European regional development fund of the Polish State budget; it was published in 2010.

Purpose: The Smart Pen tool set is an eLearning system that supports the therapy of developmental dyslexia (problems with reading) and dysgraphia (problems with handwriting) by utilizing a display monitor equipped with touchpad and a specially designed writing tool.
Structure: (a) a LCD tablet that makes it possible for the tool to measure the pressure put on the surface, (b) the tablet pen, which is equipped with three pressure sensors that can monitor whether the users are holding it correctly, and (c) the software that offers different types of activities, monitors different significant parameters during an activity and stores the results in a database.
Functionalities: (a) the coloring activity, a picture should be colored without crossing its contours, (b) the squiggles activity, a shape should be copied without lifting the hand from the tablet surface, (c) the mazes activity, a path through the maze should be found, (d) the joining the dots activity, the dots should be connected according to the increasing numbers, (e) it is possible to listen to instructions how to complete the activity, and (f) new drawings for each activity can be prepared.
Evaluation: advantages (as stated in [37]): (a) the system can be expanded with new exercise modules, (b) the application can easily be configured in order to avoid that an activity becomes boring to the users, and (c) all parameters of all activities are stored in a database in order to observe therapy progress; disadvantage (as stated in [37]): different pen types for different tablets that are not compatible with each other.
Trend (as stated in [37]): design of new exercise modules that would increase the usability of the tool.
Class: O[V:TI, A:V, T:M]+I[V:-, A:-, T:F]; UM: DM.

The Tactile Thermal Display tool [22] was created at the Virginia Commonwealth University in USA, through a project supported by the National Science Foundation (NSF) of USA; it was published in 2011.

Purpose: Tactile Thermal Display tool represents a custom made hardware device designed to enable blind and visually impaired persons to gain better understanding of paintings in an art museum.
Structure: (a) the controlling software, which determines the location within the painting and changes tactile and thermal feedback in accordance with the location, (b) the tactile display that consists of: A Braille cell, which is equipped with a 2x4 pin array and an RF transmitter, (c) the thermal display is custom made device (among other it contains: A Peltier thermoelectric module and a temperature sensor), and (d) a graphics tablet.

Functionalities: (a) the tactile display conveys tactile texture information about brush-stroke size and orientation and (b) the thermal display is used to convey warm-cold color spectrum using temperature changes.
Evaluation: advantages (as stated in [22]): (a) this tool should provide deeper sense of the observed paintings to users, than the usual audio-description tools do and (b) device used in the tool is built on commercially available components; disadvantages: (a) lack of software component for conversion of a random picture in a form suitable for usage with this tool and (b) the tool is insufficiently tested and because of that its efficiency cannot be determined.
Trend: (a) support for usage of the tool in combination with the traditional audio-description tools and (b) creation of art courses material for blind and visually impaired persons, which would introduce this tool as an aid.
Class: O[V:I, A:-, T:RW]+I[V:-, A:-, T:F]; UM: DM.

The USIM (Ubiquitous Systems in Interactive Museum) tool set [17] was created jointly at the HP Laboratories in USA, as part of the Cooltown project, and at the San Francisco Exploratorium in USA, through a project supported by the National Science Foundation (NSF) of USA; it was published in 2002.

Purpose: The USIM tool set includes nomadic computing tools, which were designed and implemented to enhance visits to interactive museums, similarly to how acoustic guides have done that in classic museums.
Structure: (a) an interactive museum (Exploratorium in San Francisco), which is the educational environment for the approach, (b) personal digital assistants (PDAs) with appropriate sensors, which are mobile computers used for running applications, (c) an infrared beacon or a barcode or a radio frequency identification (RFID), which are used for tagging exhibits, (d) the Informer - an application that provides users with information about the exhibits, (e) the Suggester - an application that gives ideas about what interaction to try at an exhibit, and (f) the Rememberer - an application that enables users to build a record of their experiences.
Functionalities: (a) combining functions of informing, suggesting, and remembering in the form of Web pages, which users can access during the visit, at the place of exhibit by PDAs, or after the visit on any computer, (b) a personal scrapbook, which is created by allowing users bookmark pages and add comments (simulates writing stuff down on a conventional guidebooks), and (c) physical hyperlinks, the mechanism that enables users to get a given exhibit's homepage by pointing their PDAs at an object on the exhibit and reading its tag by appropriate sensor.
Evaluation: advantages (as stated in [17]): (a) physical hyperlinks, which are valuable at places like Exploratorium where navigation and identification are difficult and (b) ability to bookmark pages, which enables users to take another look after the exhibit at home or in a classroom environment; disadvantages (as stated in [17]): (a) interference with exploration, which comes from the robustness of handheld devices and makes it difficult for users to enjoy the interactivity of the exhibit and (b) application complexity, because three different functionalities were implemented it is possible to happen that users do not use them all, they only use the first two and completely forget the third.
Trend: (a) the ability to create custom notes (combining pictures from pages, inserting comments, making personal photographs) and (b) replacing PDAs with less robust devices like mobile phones.
Class: O[V:THIP, A:-, T:-]+I[V:-, A:-, T:TPCV]; UM: DM.

4 Analysis and discussion

This section presents an analysis of the presented tools based on the proposed classification and global trends in applying multimedia in eLearning tools, as well as our view of the future challenges in the area. Although the application of the criteria from the Section 3 to the selection of tools has eliminated a number of the analyzed tools, we believe that the resulting set of 30 tools is representative enough to allow deriving respectable conclusions.

Table 6 presents the distribution of the selected tools per natural (human) senses (VATOG-O coordinates) and appropriate multimedia content types. For each VATOG-O coordinate there is a row in the table containing the coordinate name, the number of tools that have the coordinate value different from "0", and then for each content type of that coordinate, there is a separate row containing the content type title, number of the selected tools that use that content, and references to the papers describing appropriate approaches.

It is common knowledge that humans receive most of the information using their eyes. Percentage goes from 80 % up to 90 % in favor of vision, while other senses remain underutilized. Since education is devoted to transmission of information to learners, it is expected that multimedia educational tools comply with this fact. Table 6 shows that 100 % of the selected tools use vision, 47 % of the selected tools use audio, and 23 % of the selected tools use touch to relay information to users.

Table 6 also shows that various content types are used for visualization and quite often combined. Text, image, and animation are used by most of the tools (53 % use all of these contents and 83 % use at least one of them). Text is traditionally used in education to provide explanations. It is used in 73 % of the selected tools. It is said that one image is worth more than a thousand words and therefore image is very useful in education when presented in a

Table 6 Distribution of tools per excited natural senses and content types

Natural sense (VATOG-O coordinate)	Number of tools per coordinate	Content type	Number of tools per content	References to approaches
Visus	30	Text	22	[3, 5, 10, 12, 14, 15, 17, 20, 23, 26, 28, 34, 37, 39, 41, 43, 45, 47, 48, 51, 53, 54]
		Hypertext	4	[14, 17, 23, 51]
		Image	23	[3, 5, 10, 12, 14–17, 20, 22, 26, 28, 34, 37, 41, 43, 45, 47, 48, 50, 51, 53, 54]
		Movie (video)	2	[51, 53]
		Animation	17	[3, 5, 10, 12, 15, 16, 26, 28, 34, 41, 43, 45, 47, 48, 51, 53, 54]
		Virtual reality	1	[21]
		Augmented reality	1	[28]
		Physical reality	8	[3, 6, 8, 17, 21, 23–25]
Auditus	14	Voice	8	[8, 14, 24, 28, 37, 41, 45, 51]
		Music	4	[15, 28, 39, 53]
		Ambient sound	3	[3, 8, 21],
		Electronic sound	1	[50]
Tactus	7	Roughness	2	[22, 50]
		Mechanical resistance	5	[6, 21, 24, 25, 37]
		Warmth	1	[22]

proper way. Image is used in 77 % of the selected tools. Animation is a bit more modern content used in education, which can make lecture more accessible to learners, as stated in [32]. If an image is worth more than thousand words, an animation, composed of series of images, is probably worth more than thousand images – literally and allegorically. Animation is used in 57 % of the selected tools. In the set of selected tools, other content types did not appear in as many tools as expected. Especially unusual is the lack of the tools that utilize movie, virtual reality, and augmented reality as content types. The reason for this is that we did not select for presentation all available and analyzed eLearning tools, because that would be practically impossible due to their number, but instead we only wanted to illustrate diversity of multimedia used in eLearning tools, as explained in Section 3. Regardless of that, we believe that movie, as a content type in educational tools, is especially suitable for self-learning at home. Augmented reality is an interesting content type [4] that is becoming more accessible as the equipment required for using it becomes less expensive and even available in modern mobile devices. We believe that this is one direction in which future eLearning tools could go. An additional reason why we did not include many tools that utilize virtual reality is that even though there is a large number of commercial tools there is a lack of scientific papers that describe the technology used in them. This content type is the preferred one in the areas where human lives could be in danger otherwise, like medical education, airplane pilots' education, spaceship crew education, etc. We believe that virtual reality will remain reserved for the mentioned areas, until a technological revolution appears that would enable simpler and cheaper use of this technology.

As we can see from Table 6, 47 % of the tools use audio contents to relay information. These contents are usually combined with visual contents (as suggested in [32], [29], and [31]) and are used to support the information that visual contents carry. Humans (except blind people) do not use full potential of their sense of hearing. Thanking to considerable advances in the voice synthesis and not expensive audio equipment available for home or school PC, as well as the mentioned fact of under-utilization of the sense of hearing, it could be expected that in the near future the number of eLearning tools that intensively exploit audio output will increase.

Touch is the least excited sense by the selected tools (23 % of the tools excite touch sense). It is used predominantly in the tools which have special target users (learners with disabilities). It has a potential, when used in combination with visual and audio (especially in some education areas that involve touch as its part, like driving or surgery).

Table 7 presents the distribution of the selected tools per artificial (computer) senses (VATOG-I coordinates) and appropriate user response types. For each VATOG-I coordinate there is a row in the table containing the coordinate name, the number of tools that have the coordinate value different from "0", and then for each user response type of that coordinate, there is a separate row containing the user response type title, number of tools that use that response type, and references to the papers describing appropriate approaches.

When we consider the distribution of the selected tools per artificial (computer) senses and appropriate user response types (Table 7), dominant computer sense is touch represented with 83 % of the selected tools, while audio and vision fall behind with 17 % and 7 %, respectively. This result is expected, since most of the tools are computer-based, and consequently response types correspond to those that are usually used in human-computer interaction by using mouse or keyboard.Typing, pointing, and clicking are the mostly used response types (all of them for 40 % of the selected tools and at least one of them for 67 % of the selected tools). Force (recognized by 23 % of the selected tools) is a user response type associated with the tools that use robots or with users that have a disability. Virtual connecting (used in 13 % of the selected tools) is a response type that is becoming more popular in recent years, since there are more and more ways to relay information contactless.

Table 7 Distribution of tools per excited computer senses and user's response types

Computer sense (VATOG-I coordinate)	Number of tools per coordinate	Recognized user's response types	Number of tools per response type	References to approaches
Visus	2	Scribing	0	-
		Drawing	0	-
		Eye tracking	0	-
		Mimics	0	-
		Gesture	2	[24, 28]
Auditus	5	Voice	2	[8, 24]
		Music	3	[16, 39, 53]
Tactus	25	Typing	17	[3, 6, 10, 12, 14, 17, 20, 25, 26, 34, 41, 43, 45, 47, 48, 51, 54]
		Pointing	14	[5, 10, 14, 15, 17, 20, 26, 34, 41, 43, 47, 48, 51, 54]
		Clicking	16	[5, 10, 12, 14, 15, 17, 20, 23, 26, 34, 41, 43, 47, 48, 51, 54]
		Dragging	6	[5, 15, 26, 34, 43, 54]
		Warmth	0	-
		Force	7	[6, 21, 22, 24, 25, 37, 50]
		Manual Manipulation	3	[6, 21, 25]
		Virtual Connecting	4	[6, 17, 23, 24]

Educational tools do not use audio response types as much as the technology allows. Today voice recognition software, especially command recognition software, has advanced to a stage that it can be successfully used, but impression is that educational tools failed to follow through this technology improvement. This is a direction that could be expected in the future to simulate classic education process.

The technology for utilizing vision as a computer sense is still maturing. We introduced into classification several response types that fall in this category, but we did not find eLearning tools that use these response types yet. We strongly believe that applying this kind of technology in eLearning tools would be very interesting from the students perspective.

Table 8 shows distribution of the selected tools among UM classification classes. For each UM class there is a row in the table containing the UM class name, the number of tools that belong to that UM class and references to the papers describing appropriate approaches.

We can see from Table 8 that direct manipulation is used in 50 % of the selected tools, precise instruction is used in 47 % of the selected tools and informal communication is used in only 3 % of the selected tools. This result is consistent with the observation that education slowly accepts new technologies and that is why informal communication is negligibly used in

Table 8 Distribution of tools per UM classes

UM Class	Number of tools per UM class	References to approaches
Direct manipulation	15	[3, 5, 6, 15–17, 21–23, 25, 28, 37, 39, 50, 53]
Precise instruction	14	[8, 10, 12, 14, 20, 26, 34, 41, 43, 45, 47, 48, 51, 54]
Informal communication	1	[24]

eLearning tools. On the other hand, this kind of communication is very challenging for eLearning tools purposed to preschool level, and especially for children with special needs in education. In order to use the technological advances in multimedia, new concepts in education will have to be devised.

Table 9 presents an overview of compliance of the selected tools with design principles defined in [31]. For each one of the tools in this group, there is a row in the table containing binary information about satisfaction of four out of the five design principles (*multiple representation*, *contiguity*, *split-attention*, and *coherence*).

In Table 9 the *multiple representation* principle is indicated, if the tool uses at least two different types of content. We can see that all tools satisfy the *multiple representation* principle, which makes them multimedia tools in the first place. The *contiguity* principle is indicated, if the tool uses different types of content simultaneously and not separately. The *split-attention*

Table 9 Overview of tool compliance with design principles

Title	Multiple representation	Contiguity	Split-attention	Coherence
Alice tool	+	+	-	+
ArabicTutor tool	+	+	+	-
BlueJ tool	+	-	-	+
CSA tool	+	+	-	+
CWRU tool set	+	-	-	+
Dictation program tool	+	+	+	+
Digital 3D Lego tool	+	+	-	+
Digital Violin Tutor tool	+	+	+	-
EDCOMP tool	+	+	-	+
Explore! tool	+	+	+	+
eXspot tool	+	+	+	-
Family Ensemble tool	+	+	+	+
Haptic/Aural tool	+	+	+	+
HRITEH tool set	+	+	+	+
Humanoid Robots tool set	+	+	+	+
Hyperscore tool	+	+	+	+
Jeliot 3 tool	+	+	-	+
MLAUCS tool	+	+	+	+
MLTIGS tool	+	+	-	+
MLVLS tool set	+	+	+	-
MTM tool set	+	-	-	+
PathFinder tool	+	+	-	+
PRAR tool set	+	+	+	-
Quest Atlantis tool	+	+	-	-
Robovie tool set	+	+	+	+
SDLDS tool	+	+	-	+
Seeing Sound tool	+	+	+	+
Smart Pen tool set	+	+	+	+
Tactile Thermal Display tool	+	+	-	+
USIM tool set	+	+	+	-

principle is indicated, if the tool engages more than one sense at the same time. Finally, the *coherence* principle is indicated, if it gives only necessary information without too broad details. We can see that most of the selected tools fulfill the requirements imposed by the described design principles. Tools that do not implement all of the design principles are usually targeted to the specific purposes that do not require all of them to be supported. We can observe that only the tools that have values for both vision and audio (VATOG-O/V and VATOG-O/A) fulfill the *split-attention* principle. Even though some of the tools that engage more than one user sense, they still do not apply this principle because they either do not carry the same information through different senses (like [6] and [25]) or they are designed for users with disabilities which can not use one of the presented contents (like [22]).

Table 10 Summary of the described tools according to each classification

Title	Ref.	VATOG-O			VATOG-I			UM classes		
		V	A	T	V	A	T	DM	PI	IC
Alice tool	[10]	TIA	-	-	-	-	TPC	-	+	-
ArabicTutor tool	[14]	THI	V	-	-	-	TPC	-	+	-
BlueJ tool	[26]	TIA	-	-	-	-	TPCD	-	+	-
CSA tool	[48]	TIA	-	-	-	-	TPC	-	+	-
CWRU tool set	[6]	P	-	M	-	-	TFMV	+	-	-
Dictation tool	[45]	TIA	V	-	-	-	T	-	+	-
Digital 3D Lego tool	[54]	TIA	-	-	-	-	TPCD	-	+	-
Digital Violin Tutor tool	[53]	TIMA	M	-	-	M	-	+	-	-
EDCOMP tool	[12]	TIA	-	-	-	-	TC	-	+	-
Explore! tool	[3]	TIAP	A	-	-	-	T	+	-	-
Exspot tool	[23]	THP	-	-	-	-	CV	+	-	-
Family Ensemble tool	[39]	T	M	-	-	M	-	+	-	-
Haptic/Aural tool	[50]	I	E	R	-	-	F	+	-	-
HRITEH tool set	[21]	VP	A	M	-	-	FM	+	-	-
Humanoid Robots tool set	[8]	P	VA	-	-	V	-	-	+	-
Hyperscore tool	[15]	TIA	M	-	-	-	PCD	+	-	-
Jeliot 3 tool	[34]	TIA	-	-	-	-	TPCD	-	+	-
MLAUCS tool	[41]	TIA	V	-	-	-	TPC	-	+	-
MLTIGS tool	[20]	TI	-	-	-	-	TPC	-	+	-
MLVLS tool set	[51]	THIMA	V	-	-	-	TPC	-	+	-
MTM tool set	[25]	P	-	M	-	-	TFM	+	-	-
PathFinder tool	[43]	TIA	-	-	-	-	TPCD	-	+	-
PRAR tool set	[28]	TIAU	VM	-	G	-	-	+	-	-
Quest Atlantis tool	[5]	TIA	-	-	-	-	PCD	+	-	-
Robovie tool set	[24]	P	V	M	G	V	FV	-	-	+
SDLDS tool	[47]	TIA	-	-	-	-	TPC	-	+	-
Seeing Sound tool	[16]	IA	-	-	-	M	-	+	-	-
Smart Pen tool set	[37]	TI	V	M	-	-	F	+	-	-
Tactile Thermal Display tool	[22]	I	-	RW	-	-	F	+	-	-
USIM tool set	[17]	THIP	-	-	-	-	TPCV	+	-	-

Table 10 sumarizes everything that we have analzyed in the selected tools. There is a separate row in the table for each tool. Columns represent title of the tool, reference to the appropriate approach, VATOG-O classification, VATOG-I classification, and UM classification.

We can make several observations from Table 10 and Table 5. First, tables show that 78 % of the tools that use the text, image, and animation (VATOG-O/V/TIA), the typing, pointing, and clicking (VATOG-I/T/TPC), and precise instruction (UM/PI) in combination are used in computer science or software engineering. On the other hand, tables show that 78 % of the tools in computer science or software engineering use the text, image, and animation (VATOG-O/V/TIA), the typing, pointing, and clicking (VATOG-I/T/TPC), and precise instruction (UM/PI) in combination. This indicates that the students in these fields respond well to this combination of content types, user responses, and precise instruction in eLearning tools. Second, the table shows that only 41 % of the tools that use the animation (VATOG-O/V/A) as a content type also use some audio content type (VATOG-O/A). This observation is not aligned with the suggestion from [32] to combine animation and audio contents. Third, we can see that there is only one tool [24] that combines computer senses, all other tools use only one of the computer senses to receive user's responses. We believe that the eLearning tools designers failed to consider the influence of allowing students to combine responses through different computer senses and that this could be potentially interesting area for research.

5 Conclusion

In this paper we have presented an overview of research efforts in the field of eLearning multimedia tools. We introduced a new classification and explained reasons behind the classification. Then we presented 30 selected tools in a uniform way and tried to answer on "7w" questions: who, when, whom, where, what, why, and how, and more for each one of them, try to indicate future trend for each one of them, and classified them according to the proposed classification. At the end, we have analyzed the distribution of the approaches among established classes and presented our opinion about the future trends in the area.

We have defined several goals that should have been fulfilled in this paper. The first goal was to create an easy-to-comprehend classification, which would show in which way multimedia is applied in eLearning tools. The second goal was to describe representative tools in a systematic way and give our suggestions for possible future development of these tools. The third goal was to identify potential directions for future development in the area.

When we analyzed the results of our survey, we noticed several gaps in the area based on different criteria. We consider these gaps to be possible new directions for development in the future. One of these gaps is the use of virtual reality tools in education. We have found that there are some such tools already in use, especially in medicine, but we believe that there is significant potential for the use of this technology in education. Another gap that is worth mentioning is the lack of tools that include smell and taste senses. There is a hint of technology being developed, which will allow these senses to be included in tools, but there is still no mention in which way this could help in tools for education. We can imagine that cooking education may benefit from the results of such a technology.

Upon analysis of the results from this paper, we came up with several ideas for future projects in the area and we hope that we will be able to realize some of them. The one that is the most notable is the idea for development of a controlled social network for pupils with a number of edutainment tools. Those tools would be designed to help elementary school pupils to acquire knowledge from different scientific areas through play and collaboration. There are several reasons that influenced our train of thought in arriving to this idea. First, we have noticed that technologies for development of Internet-based multimedia tools have matured. Second, we can see that social networks have become extremely popular in the last few years. Third, the most of educational areas serve facts and reasons which are difficult for understanding and adoption for majority of school pupils. And finally, we observed that similar tools, among those that we have analyzed in this paper, have shown significant results in a versatile set of areas of education.

We started our paper with famous Confucian wisdom and we believe that it is appropriate to finish with another one of Confucian, as well: “Learning without thought is labor lost; thought without learning is perilous”. Let this be a reminder about the importance of education in our lives.

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