Higher Education in the Twenty-first Century. The Chance of Adaptive Learning Environments

Antonella Poce
Department of Educational Design – DIPED –
Università degli Studi Roma Tre
Roma, Italia
E-mail: poce@uniroma3.it

Abstract

The keyword which describes in the most effective way Twenty-first century Higher education is suggested by Daniel et al. (2009)[1] and it is "expansion". More and more people will invest in their own education and in this process Higher Education is on the front line. The need for education and training, though, cannot be generic, what nowadays society wants cannot be identified in static knowledge. At the end of the learning path students should be able to employ the outcomes of learning in order to generate new learning. That is why new solutions and methods must be acquired and adopted. Being those the conditions, and having at disposal the undeniable chances that the Internet offers, a possible direction to be undertaken could be the one that drives us directly to the potentialities of distance education performed in adaptive environments. The present contribution aims at analyzing Higher Education present needs, offers a general highlight of adaptive and intelligent web based education systems and concentrates on examples which better respond to the needs previously highlighted.

Keywords: adaptive systems, higher education, technology, innovation.

I. Higher Education: a change of perspective

Daniel et al. (2009) *[2]* are to be quoted again in order to prospect which is the actual situation Higher Education is facing at the moment. The authors of the revealing article, *Breaking Higher Education's Iron Triangle: Access, Cost and Quality*, underline that by 2020, 40% of the global workforce will be knowledge workers with a need for tertiary qualifications. The world bank as well is now urging countries that have not yet done so to develop their higher education systems. Daniel et al. (2009) [1] specifies: *Already there are some 140 millions postsecondary students globally, if part-time enrolments are included. China and India have doubled enrolments in the past ten years, giving China the world's largest higher education system, with some 25 million students*."

This is an astounding trend but it must be supported by the Western Countries, because it means increasing prosperity of poorer countries, contribution to their political and economic stability and therefore expansion of their potential as markets for Western goods.

Highly skilled migrants should be welcomed in the western countries because they support development in the places where they go, as well as grow of the economy in their home countries when they will be back there.

The problem that arouses naturally, after the above brief account on the global state of the art of Higher Education, is that the outcomes of education required in such a situation need:

1. to show certain peculiarities and
2. cannot be reached in a traditional way.

As regards the first issue, it is widely recognized that to contribute to social progress, within higher education, both students and teachers need to use the knowledge available in order to create new knowledge. Certain abilities, therefore, must be supported by teachers and practiced by students. I refer, in particular, to creative and critical thinking skills.

Checkland (1999, p.154) [2] and Jupp (et al. 2001, p.6[3] agree that creativity is becoming a key resource for individuals and societies. It is needed *to make the most of new opportunities* and, being part of the knowledge society, we must be aware of the importance of enhancing creativity, especially in Higher Education.

The EUA –European University Association - in a report *[4]* on the project, entitled "Creativity in Higher Education 2005-2007"- stressing the value of creative skills at University and their influence on the welfare of society - states that we should learn to teach creativity if we want to live in a better society.

Moreover, in order to understand the direction to be undertaken by Higher Education Institutions it is vital to know what do we mean precisely when we speak about creativity.

Woolfolk (2008, p. 366) [5] defines creativity as "imaginative, original thinking or problem solving". She

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goes on to say t*o be creative the "invention" must be intended. An accidental spilling of paint that produces a novel design is not creative unless the artist recognizes the potential of the "accident" or uses the spilling technique intentionally to create new words (Weisberg, 1993). As we have mentioned before although we frequently associate the arts with creativity, any subject can be approached in a creative manner. […] creativity: often involves more than one person, happens when people apply their abilities as part of a helpful process in a supportive environment and results in an identifiable product that is new and useful in a particular culture or situation.*

If creativity can be associated with group work in particular situations where an innovative solution is needed, it means that a higher level of critical thinking skills must be employed. Woolfolk et al. (2008, p.427) [5] again offers a definition of the above abilities as those of *evaluating conclusions by logically and systematically examining the problem, the evidence and the solution.*

The key issue resides in the definition of critical thinking abilities reported above and it is not by chance that it is the core content of the so called *Dublin Descriptors, conceived* by EU representatives after the Conference held in Dublin in 2004.

The descriptors recommend which abilities should be fostered at levels 2 and 3 of Higher Education. Some of those are the following:

Ability to make judgments …	*[through] critical analysis, evaluation and synthesis of new and complex ideas…*
Ability to communicate …	*…with their peers, the larger scholarly community and with society in general about their areas of expertise*
Learning skills ….	*... expected to be able to promote, within academic and professional contexts, technological, social or cultural advancement*

At the end of a Higher Education learning path students should be able to find solutions to the various problems they will be facing immediately after having celebrated for the degree they acquired.

This means that students should be constantly supported and tutored.

A dilemma arouses: how to cope with the growing number of students and at same time with the need of almost one-to-one tutoring?

Traditional teaching is no longer and answer and financial resources have been constantly reduced.

Starting new private Higher Education institutions cannot be a solution because low-cost public provision is still essential, especially in poorer countries.

Distance Learning and E-Learning, in particular, are increasingly seen as key to providing access to the wider student population now seeking higher education, especially working adults.

What the present contribution would like to point out is that, in order to allow a larger public benefit from valuable Higher Education teaching, even in distance education, it is necessary to look for environments where it is the addressee of the message of communication, and not communication itself, at the centre of the matter. Systems where individualized learning is possible are the ones to be preferred to the others. In a time when technology allows possibilities not even thinkable some decades ago, it would be an unforgivable waste to miss such opportunities.

To have a better knowledge of what is the state of the art, the following paragraph is dedicated to the description of the main peculiarities of Adaptive and Intelligent Web-based Education Systems, which are at the moment the ones that show more than others the requirements innovative Higher Education teaching should boast.

II. Adaptive and Intelligent Web-based Education Systems

As Paramythis and Loidl – Reisinger (2004, p. 182) [6] point out speaking of adaptive systems can be misleading if the meaning of the terms employed is not clearly stated. According to them, for instance, a learning environment is considered "adaptive" *if it is capable of monitoring the activities of its users; interpreting these on the basis of domain specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models and finally acting upon the available knowledge on its users and the specific matter at hand, to dynamically facilitate the learning process*. It can be argued therefore that adaptation does not mean only flexibility, it refers also to the possibility offered by the system of intelligently understand the "nature" of the learner and offer him/her an individualized teaching offer.

Paramythis and Loidl – Reisinger (2004, p.182) [6] distinguish different categories of adaptation in learning environments and they are the following:

- *Adaptive interaction*. In this case the adaptation consists in facilitating students interaction with the system. Examples can be

identified in the employment of alternative graphical or colour schemes, font sizes etc. to respond to user preferences, different abilities at lexical level of interaction.

- *Adaptive course delivery*. The most common way of adaptation, it refers to the possibility of tailoring the course according to the individual learner characteristics. With regard to this option, advantages are for instance: compensation for the lack of human tutoring, improvement of self-assessment activities by the learner himself/herself. In the above context, it will be possible to encounter: dynamic course re-structuring; adaptive navigation support and adaptive selection of alternative course material as highlighted also by Brusilovsky (2001) [7].
- *Content discovery and assembly*. Here the possibility is wider because adaptation is carried out "assembling" course material from distribute resources or repositories. The innovation here lies on the fact that adaptation-oriented models and knowledge about users is derived from monitoring. This situation implies the different perspective of the individual learner who has to locate relevant material within a corpus and the author who has to put together a course from existing materials, targeting a specific audience. Both the situations are possible within adaptive environments.
- *Adaptive collaboration support*. This category is intended to capture adaptive support in learning processes that involve communication among a group of people.

To define adaptive system Brusilovsky and Peylo (2003) [8] point out a different distinction. They separate *adaptive web-based* systems from *intelligent web based* ones. In fact, in the former the stress is on the different approach that these systems can customize on the single or group/s of learners, by taking into account information accumulated from the individual/group/groups model. Most of the systems in use show characteristics from both intelligent intelligent and adaptive environments but, anyway, they are very diverse, offering various kinds of support for both students and teachers involved in the process of web-enhanced education. According to Brusilovky and Peylo (2003) [8], it is possible, in fact, to identify 3 groups:

1. *Adaptive technologies*. Technologies used in this area are mainly adaptive hypertext and hypermedia systems. The goal of the first one is to adapt the content presented in each page to student objectives and knowledge. In this sort of system, pages are not static but adaptively generated or assembled for each user. Adaptive navigation support assist the student in the hyperspace orientation and navigation by changing the appearance of visible links. It helps the student to find the "optimal path" through the learning material. Adaptive information filtering is a classic technology from the field of information retrieval. The aim here is to find a few items that are relevant to user interests in a large corpus.

2. *Intelligent class monitoring* is provided by the following technologies: curriculum sequencing, intelligent solution analysis and problem solving support. Curriculum sequencing provides the student with the most suitable individually planned sequence of topics to learn. Intelligence solution analysis deals with student solutions of educational problems and it is able to tell what is wrong or incomplete and which missing or incorrect pieces of knowledge may be responsible for the error. Interactive problem solving support is to provide the student with intelligent help on each step of problem solving.

3. *Intelligent collaboration support* represents a group of technologies developed from two fields: computer supported collaboration learning and ITS. The advent of web-enhanced development and the interaction of the above two areas stimulated the increasing demand of those technologies.

The cases described below represent meaningful examples of how technologies can be "service-oriented" and how "the services interplay with the domain semantics (mathematics) and the pedagogical semantics used, e.g., for course generation", as Ullrich and Libbrecht state (2008) [9]. In particular, ActiveMath reflects the above architecture and can be seen as a valuable practice to be considered in view of enhancing personalization of e-learning tools.

III. The case of ActiveMath

ActiveMath is an example of high technology education tool, which combines features from adaptive and intelligent systems. It is able to support both interactive problem solving and up-to-date adaptive presentation navigation.

The need for such a system derived from the observation that in colleges and universities the same subject is taught differently to different groups of users and it is set in different contexts as well (e.g. statistics for math, economy, medicine, etc.). The choice of content is therefore of key importance.

As the authors of the system highlight (Melis et al. 2001) [10], web-based systems can be used in several learning contexts: long-distance learning, home work, teacher –assisted learning etc. *ActiveMath* was

therefore the solution to the above requirements foreseeing adaptive content, adaptive presentation features and adaptive appearance.

ActiveMath general learning objective is, of course, mathematics and is the consequence of the ascertainment by the subject pedagogy community that students learn more effectively, if traditional learning of formulas and procedures is supplemented by the possibility to explore a broad range of problems and problem situations.

A. Semantic Services in *ActiveMath*

As Ullrich and Libbrecht (2008) [9]describe in their work on the functionalities of *ActiveMath*, the system uses semantics to represent the domain, mathematics, and to represent the pedagogical knowledge needed to generate the course. Different services operate on these semantics. The system is supported by an important database and is endowed with a fuzzy and semantic search engine.

A generic semantic markup language has been chosen to keep the encoded content reusable and interoperable by other, even non-educational, mathematical applications. With this regard the authors [9] specify: *Activemath content is represented by a collection of typed items called "learning objects" annotated with metadata. The semantic information includes types, relations, and other mathematical and educational metadata. The type indicates a characterization of the items as collection theory, concept or satellite items.*

The authors in fact designed an Ontology of Instructional Objects (OIO) developed to characterize educational resources. The OIO, as the authors calls it, describes resources in such a way that pedagogically complex functionalities, like course generation, can be performed precisely. The above ontology, in fact, has a specific scope: instead of describing the authoring process during which the educational resources are developed, it is focused on describing the resources themselves. Essential seems to be the distinction between "fundamental "and "auxiliary" elements. "Fundamental " is referred to the instructional objects that describe the central pieces of domain knowledge, while "auxiliary" ones include those objects which contain additional indications about the fundamental and the learning experience as well.

B. How does *ActiveMath* work?

In order to generate a course the system takes into account different kinds of information:

- ✓ the concepts the learner wants to learn;
- ✓ the setting the user chooses: exam, exam preparation, overview, detailed overview, guided tour and detailed guided tour;
- ✓ the user's knowledge mastery and action history;
- ✓ the user's capabilities to work with one of the external systems integrated into *ActiveMath*;
- ✓ pedagogical rules.

The course generator employs pedagogical rules to determine when and which items should be presented and in which order. Since employing an external system when working on exercises and examples requires a certain minimal familiarity with the systems themselves, *ActiveMath* presents those exercises only if the capability is confirmed. In addition, pedagogical information may restrict the available features of an external system.

The result of the generation is a linearized collection of Identities adapted to the user's needs, preferences and knowledge that can be transformed to pages.

C. *ActiveMath* in Europe

The studies conducted by the research group that worked to the creation of *ActiveMath* developed also the *LEActiveMath* project (*Language Enhanced User-Adaptive, Interactive eLearning for Mathematics*). The above project is one of the three Specific Targeted Research projects selected in the first call of the *6th Framework Programme Information Society Technologie*s, key action *Technology-Enhanced eLearning*. The project ran from January 2004 to December 2006.

As it described on the website of the project (http://www.leactivemath.org), The design and development of *LeActiveMath* learning content aims at advancing e-learning at universities by taking a user centred approach, fitting content into existing courses, and managing interactions with the learner so that the adaptive *LeActiveMath* engine can provide appropriate support.

Moreover it is defined as *an innovative third generation e-learning system for educational institutions that can also be used in informal contexts such as revising. LeActiveMath is designed for a wide variety of university students. The learning content currently available for university students is calculus and is offered in three languages:*

- *German*
- *English*
- *Spanish*

The learning content is primarily designed for first year mathematics students, but the content should also

be suitable for second year engineering/science students.

What is worth noticing, analyzing the studies conducted on *ActiveMath*, is the interest that the European Scientific community showed toward its technology, because another project connected to the previous one has been funded.

I refer to *Active Math-EU* that is a project to disseminate the results of *LeActiveMath.* Information on the website (http://www.activemath.org/eu/) reveal:

Since the analysis of LeActiveMath' exploitation potential by Klett-Verlag has shown that an opensource distribution is a key exploitation measure, the services to be developed by ActiveMath-EU include: user mailing list, uploading facilities, integration into open-source LMS, integration into portals, manual for users, web-site with wiki, etc. Services for installation and documentation will be developed that can be refined by the spin-off e-Tell to serve schools, universities and independent users after the project has concluded.

Another development carried in this new project is the translation to more languages of *ActiveMath* content (Czech, Hungarian, Dutch, French), the production of new types of exercises produced and the integration of contents from other projects (Combien, Komma).

On the website, the authors of the project state: *The European dimension will be strengthened by making ActiveMath available in more languages and for a larger geographical coverage, by disseminating to European networks, and by including representatives of new countries in the user community and in the consortium. The open-source community does not stop at country-boarders anyway.*

The path of exploitation of such a product, as *ActiveMath* is, should suggest how to approach new ways to innovate Higher Education teaching.

It is not just a matter of finding new tools it is necessary to put those new tools and their possibilities of employment at disposal of the whole community, over passing national and even continental borders.

IV. Assessing outcomes: the example of *TestMaker*

TestMaker is an innovative software able to measure reading comprehension abilities. It is the product of a three year FIRB project, *Fund for the Enhancement of Basic Research*, funded by the Ministry for Education and Research in 2003 at the University Roma Tre.

The research group, that worked to finalize the project, a paid a great attention to the linguistic aspects of the communication message. A balance, in fact, was to be identified between the learner's alleged ability of understanding and the actual one.

At first the competence of the virtual learner has been considered equal to that needed to understand the message of communication.

This was necessary in order to have a reference to measure the actual competencies.

Differences between the real competences and the virtual ones would reveal the area where intervention is due.

According to the authors (Vertecchi, Agrusti, 2007) [11], assessing linguistic competences on the basis of lexical repositories is surely a simplification, because syntactical and semantical aspects are skipped, but it allows the production of a teaching offer coming, even if partly, from the analysis of the actual characteristics of learners.

The above reasons drove the research group to design a tool able to define the profile of each learner. This was possible starting from reading comprehension tests which allowed measurement in situation of real use of lexical competences. Solutions were to be found out to have a continuous availability of tests arousing within the same teaching module. *TestMaker* is, therefore, the product of such a need. It is an automatic solution to create reading comprehension tests of different nature: cloze, multiple choice and matching.

The idea of building a tool based exclusively on statistical analysis, without considering artificial intelligence instruments, facilitates replicability of results. This software has been conceived to build objective tests, trying to limit at the most human intervention, during their definition process.

Up-to-now, the system is able to create cloze tests from an archive of tests available.

A. How does *Testmaker* work?

TestMaker is able to identify the frequency of terms within a certain text. Once the source to build the test on has been identified, *TestMaker* shows the path of creation:

1. choice of the level of difficulty;
2. display of the list of "empty words" to show the ones that cannot be singled out for the test;
3. display of the list of possible solutions of the test.

At this stage a further check is made between the "eligible" words and those present in the frequency list already mentioned.

TestMaker is then able to give out a cloze test, having removed, from the text, some words that will constitute the list of solutions at the end of the page shown on the learner's screen, while taking the exam.

From the brief description above it is clear that adaptable tests can be created without losing assessment objectivity.

What emerges from the analysis of the potentiality of tools such as *TestMake*r is that benefit is both side: it supports the teacher who needs to produce tests according to the peculiar nature of each of his/her students and , at the same time, it is precious to the learner who knows that his teaching could not be more individualized.

Possible developments of *TestMaker* are under study and the research group based in Rome obtained further funding by the Italian Ministry for Education and Research (2006) in order to investigate different forms of use of TestMaker as a tool for texts analysis. In particular the project *Am Learning. Online learning (individualisation) of learning in a compliant environment* coordinated by DIPED-Università Roma Tre and carried out together with University Roma La Sapienza and the University of Modena and Reggio Emilia.

The major aim of the project is to introduce innovations within online education, *moving the emphasis away from speed of delivery towards the end users individual needs.*

The key elements of the strategy to be engaged are solutions:

a) for the evaluation of comprehension skills during the learning process where it is necessary to draw a dynamic profile of the learner in order to individualise the message;
b) for shaping the message to fit the learner profile;
c) for the adjustment of the learning difficulty, considering the difference between the competence required for understanding the message in its own original formulation and the actual learner skills.

The research group working on this further project stresses the importance of research on online education. Thus far the only solutions which have been adopted have been inspired by direct interaction between teacher and student. The only progress made in online research has been invariably linked to technological advances. In order to achieve a substantial improvement in the quality of education attention must be focused on both structure and formulation of the message: if a message can be personalised with regard to the needs of each learner the ways of its dissemination should vary in accordance to technical evolution. Technological advances should not be allowed to hinder new approaches in education.

Another aim of the project is to identify a method of assessment which is specific to online education; this method incorporates two elements of originality: one, it is computer based and two, the interaction which happens during the learning process provides the bases for the evaluation. It is worth mentioning that the methods of assessment currently in use have not been modified, if not marginally, by the new technological opportunities.

V. Conclusions

Diana Laurillard[1], expert in the field of the impact of technology in Higher Education teaching, in a recent publication of hers (Laurillard, 2008) [12] states:[…] *never before has there been such a clear link between the needs and requirements of education, and the capability of technology to meet them*. She goes on identifying the essential needs of present education, which are:

- ✓ personalization (relevant to all the stages of the learner's path);
- ✓ flexibility (enabling learners to study where and when is best for them, and to the choice of the curriculum, which should be learner-oriented);
- ✓ inclusion (requiring a form of personalization to diagnose or identify learner's needs and to provide study conditions and teaching methods that meet them);

As Laurillard (2008, p. 8) [12] reminds us capabilities of digital technologies are diverse and extensive and for each stage of the learning path it is possible to find useful combinations of technology options that could satisfy every specific need.

Laurillard (2008) [12] quotes the cycle of learning which can be summarized as goal-action-feedback-reflection-adaptation-feedback-reflection as a reference point from which to start to determine the adequate use of technology, which, properly adopted is able to respond the needs we are facing.

Products of research like *ActiveMath* and *TestMaker* are important milestones because they represent technology which serve education and not the other way round as it frequently happens. If the ever growing needs of Higher Education are the ones highlighted above, the possibilities offered by advanced technologies cannot be neglected, but supported and facilitated. Both *ActiveMath* and *TestMaker* put the student at the centre of the process of learning and are factual instances of the direction to take if the aim is the one of finding proper solutions for the renewal of present Higher Education.

[1] Diana Laurillard is Professor of Educational Technology and Pro-Vice Chancellor for Learning Technologies and Teaching at The Open University.

Experiments on the use of such devices are in progress and objective data on their impact on learning will be produced soon.

It is important, though, to underline that the way in which such tools have been built respond to the most recent needs knowledge society showed so loudly. Starting to disseminate the evidence of such good examples among the scientific community is, anyway, essential in order to start experimentations and consequently improve. Laurillard (2008, p.21) [12] has something to say again with this respect: *one of the challenges to the technology is productivity. Digital technologies are well adapted to achieving economies of scale, so we should aim to take advantage of that by migrating the lessons learned, the success stories, and the technologies themselves across as many institutions as possible*.

The keyword to be kept in mind and put in practice is, therefore, dissemination, considering that sharing of results can only bring further development and growth.

VI. References

[1] Daniel J., A. Kanwar, S. Uvalic-Trumbic, "Breaking Higher Education's Iron Triangle: Access, Cost and Quality" in *Change. The Magazine of Higher Education*, March_April 2009, available at http://www.changemag.org, last access 21.05.09)

[2] Checkland P., *Systems Thinking, Systems Practice*, Wiley, London, 1999.

[3] Jupp R. et al., *What learning needs: the Challenge for a Creative Nation*, Demos/Design Council, 2001. Available at www.demos.co.uk/catalogue/learningneeds, last access: 21.05.09)

[4] *Creativity In Higher Education, Report on The EUA Creativity Project 2006-2007*, European University Association, Brussels, 2007.

[5] Woolfolk A., M.Hughes, V.Walkup, Psychology in Education, Pearson Longman, Harlow (Uk), 2008.

[6] Paramythis A, S. Loidl-Reisinger, "Adaptive Learning Environments and e-Learning Standards" in *Electronic Journal on e-Learning*, vol. 2, Issue 1, February 2004, pp.181-194.

[7] Brusilovsky P. and P. Miller, "Course delivery Systems for the Virtual University" in T.Schang et al., *Access to Knowledge: New Information Technologies and the Emergence of the Virtual University*, Elsevier Science, Amsterdam, pp. 167-206.

[8] Brusilovsky P. and Peylo C., "Adaptive and Intelligent Web-based Educational Systems" in *International Journal of Artificial Intelligence in Education,* 13, 2003, pp.156-169.

[9] Ullrich C. and Libbrecht P., "Educational Services in the ActiveMath Learning Environment" in S. Salerno et al. (eds), *The Learning Grid Handbook*, IOS Press, Amsterdam, 2008.

[10] Melis E. et al., "ActiveMath: A Generic and Adaptive Web-based Learning Environment" in *International Journal of Artificial Intelligence in Education*, 2001, 12, pp.385 – 407.

[11] Vertecchi B. and F.Agrusti, "TestMaker. Un programma per migliorare la capacità di comprensione della lettura" in *Cadmo*, XV, 1, 2007, pp.118-122.

[12] Laurillard D., *Digital technologies and their role in Achieving our Ambitions for Education*, Institute of Education, University of London, London, 2008.