

ENGINEERING EDUCATION: DENSE TEACHING FOR LIFE-LONG LEARNING

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The trouble with our times is that the future is not what it used to be.
PAUL VALERY

ABSTRACT: The paper starts from the conclusions of a paper on innovating engineering education, but it is only partially its extension, since moving from targets ("*what* needs innovating") to methods ("*how* should be innovated") entails a triple shift of focus: the *perspective* is rather academic than managerial, the *echelon* is rather tactical than strategic, the *granularity* is rather fine than coarse (however, specific – mainly debatable but crucial – Information Technology issues are dealt with in line with new paradigms in a paper to be presented in a section). After reviewing contextually the chief (but well-known) challenges (e.g., risk taking vs. continuity, technological innovation vs. academic inertia, exploration vs. exploitation) the paper investigates a less studied paradox of andragogy: how organise institutional teaching, clearly limited in both time (in line with the Bologna framework) and objectives (in line with the curricula) to meet expectations in a free, dynamic, and indistinct environment, as involved by life-long learning. The proposed solution is based on the concept of "*e-maieutics*". Among the conclusions: a) Teaching focus must move from knowledge to skills. b) Educator profiles must move from teacher, to trainer, to tutor, to moderator, to catalyst.

1. INTRODUCTION

The paper is the fourth of a succession, as stated in the preceding one: "in the conceptual and temporal environment of this conference, there are five interconnected papers, corresponding somehow to five stages of a long-term endeavour" [22]. This paper starts from the conclusions of [22], but is only partially its extension, since moving from targets ("*what* needs innovating") to methods ("*how* should be innovated") entails a triple shift of focus: the *perspective* is rather academic than managerial, the *echelon* is rather tactical than strategic, the *granularity* is rather fine than coarse (however, specific – mainly debatable but crucial – Information Technology (IT) issues are dealt with in line with new paradigms in the fifth paper (to be presented in another section).

Thus, the conclusions of [22] reformulated as premises are: a) Innovating engineering education (EE) is of paramount significance to any university and it becomes urgent to deal with. b) EE environments are open, uncertain, and intensely dynamic. c) EE should be based on advanced concepts like anthropocentric systems; cognitive ergonomics; life-long learning (3L). d) EE should be approached architecturally, basically holistic, top-down, and based on transdisciplinary research merging synergistically two vital strands explored before: quality management and agent-orientation.

Accordingly, the objectives are: a) To identify and investigate the main contradiction entailing difficulties in adapting to the Knowledge Society (KS). b) To delineate the profile of a "KS-end-user" of higher education services and to adjust it to EE.) c) As a result, to propose a kind of "KS-oriented learning methodology" starting from the outdated existing pedagogy. d) To explore thoroughly the intrinsic "temporal contradiction" asserted in [20] and [22], regarding the settings of teaching and of learning. e) On this groundwork, to propose an experimental model of a solution.

Since the blend of "research-and-position-paper" of the first papers is not necessary any longer, this paper is organised similarly to an applied exploratory-research paper: After reviewing *related work* in Section 2, the main contradiction entailing difficulties in adapting to KS is elaborated upon in Section 3, namely the impressive "*speed of change*" vs. the much slower "*change of needs*". On this groundwork, EE can be approached delineating both the "*robot-portrait of an post-industrial engineer*" (Section 4) and "*the long way from pedagogy to andragogy to heutagogy*" (Section 5). Now, the *hurdle* created by the fact that *teacher and learner live in different times* (Section 6) can be analysed and dismantled, so that a solution based on "*e-maieutics*" (a concept launched in [4]), sustained by a *virtual Socrates* (modelled in [3]), could be proposed (Section 7). *Conclusions and intentions* (Section 8) close the paper.

2. RELATED WORK

To be relevant, related work must be sorted out because of five reasons: a) the paper is the penultimate from a series of five; b) the undertaking is inclusive and – as regards some topics, for instance, agent-orientation applied to 3L – extends over more than eight years; c) regarding the most innovative aspects of this research, prior work of the authors has been presented already at this conference (in Section 3 "*History*. Merging Two Research Strands" of [22]); d) significant related work was reviewed very recently (in 2008 in [4] and in 2009 in [8]; e) the focus in [3] [4] [5] and [8] is on keywords pertaining to four of the five objectives set up above (the objective regarding the "temporal contradiction" is new, hence no directly related work was found;). Accordingly, related work reviewed below is divided in four subsections, in line with the paper objectives (of course, recent papers review also work in closely related sub-domains):

a) The major contradiction between speedily advancing technology and slowly changing social needs is dealt with in [5] and the 22 papers referred to there. As regards the badly needed paradigm shift, a "lot of fundamental scientific concepts – inside and outside IT – changed dramatically their intension since IT begun to be the dominant "Novum Organon" of post-industrial technological development. [...] The paradigm shift "from Kelvin to Zadeh" becomes urgent to keep pace with a rapidly changing e-world" [8].
b) The key concept for profiling any end-user of education services within KS is obviously *e-learning* as method and – less obviously – *bounded rationality* as content restriction. Current e-learning is largely based on *L*earning *O*bjects *R*epositories (LORs): "a digital object that is used in order to achieve the desired learning outcomes or educational objectives [...] Although the term, "learning object" originated from the notion of "object-oriented" computing and programming, which suggests that ideal way to build a computer program or anything digital is to assemble it from standardized, small, interchangeable chunks of code, the approach is somewhat different in an e-learning setting. In this case, learning management systems […] could be considered large meta-objects, that contain spaces for the incorporation of granular objects […]. Large repositories of learning objects are now available […]. Although this tactic offers greater access and availability, they are not always easily navigated, nor is there a uniform system for classifying them" [28].

Similar ideas about the problems of LORs: "the combination of prior knowledge analysis and a personal recommender system has a high potential to bridge the gap between the distributed resources and distributed self-directed learners who have the burden to choose suited learning activities and resources" [15]. "Globalization amounts to a massive downgrading of local context and offers the prospects of an unbounded, pervasive knowledge domain. Learning, however, if it is not restricted to professional training, consists in social processes, developing in multiple formats and channels of instruction and feed-back. Such events require a given location and a specific horizon of expectations. Learning objects may become the substitutes of text books, but this does not resolve the central challenge of education: mediating abstract knowledge and embodied, contingent patterns of expertise" [13]. "Change in the area of distance learning is rapid, and without a solid connection with underlying learning theories, the use of learning objects quickly becomes a function of the technology rather than the desired learning outcome" [28].

An essential work for this paper is [7], where the following quotations come from: "E-learning will be considered any pedagogy (andragogy) that utilizes the Internet for communication". "E-learning should not be confused with distance education. Distance education is a program format in which the learners and instructors are geographically separate. While E-learning can be used in this format, it can also be used in an onsite program. Some programs allow learners the flexibility of moving in and out of f2f, distance education and E-learning through out their academic career". "Another form of E-learning is independent study". "The main theoretical bases upon which E-learning revolves are andragogy and constructivism. Andragogy is a term that refers to the teaching methodology that best facilitates learning in the adult. Constructivism refers to the belief that learning occurs as a result of the learner thinking about and interacting with the subject matter". Another recent comment in a specialised journal: "In the modern knowledge-intensive era, life-long competence development has become a major challenge to our educational systems that have not changed their educational policies and pedagogical models to support life-long learning. There is an increasing demand for new approaches towards fostering life-long learning perspectives" [16].

Such methods are criticised mildly in [24]: "While institutions are recognizing the value of online education, perceptions have been slower to change. Unfortunately, […] poor attempts at online education have sometimes tended to engulf the learner, causing frustration and defeat. Studies indicate that nearly 85 percent of learners involved in […] e-learning quit before finishing their program (2002)" [24]. In [3] (quoting also some comments in [13]), the evaluation is much more severe (mainly for the particular case of nursing).

As regards bounded rationality, it is comprehensively dealt with in [6], based on the determining work in [14] [17] [25] [27]. Likewise, more reviewed work will be in the fifth paper, in the context of agent-orientation applied to 3L.)

c) While work quoted above criticises e-learning as *method*, here is mentioned – and in Section 5 is investigated in detail – work questioning the very essence of learning: "as regards the *learning process* as such – prefixed with "*e*-" or not – the viewpoint is that human learning is best described by the information-processing approach in cognitive psychology" [4]. Thus: "Most modern information-processing theories are "learning-by-doing" theories which imply that learning would occur best with a combination of abstract instruction and concrete illustrations […] combining abstract instruction with specific concrete examples […] is better than either one alone" [1]. Moreover, "Higher order thinking is nonalgorithmic" [23] (the path of action is not fully specified in advance). Thus, even in the rather deductive and apodictic cognitive environment of college-level mathematics, non-ductive reasoning is vital: "The primary goal […] is to define the skill threshold necessary […]. We have discovered two salient themes in the literature concerning what this means precisely. The first is the knowledge […]. The second theme concerns the skills and abilities […]. Abilities are attributes that affect the ability to perform a task, such as manual dexterity and inductive and deductive reasoning" [11].

"Learning is not restricted to the classroom and to formal learning inside learning institutions, it […] happens throughout life, at work, play and home. In the modern knowledge-intensive era, life-long competence development has become a major challenge to our educational systems that have not changed their educational policies and pedagogical models to support life-long learning. There is an increasing demand for new approaches towards fostering life-long learning perspectives" [16].

A very recent collection of basic papers in this field is [18]. One of them asserts [9]: "We define remote in terms of geography, culture, language and telecommunications. One might think that the growing availability of 'open content' would make this an easy task, however our initial trials show this to be incorrect. Many of the current models for open content are not flexible enough to meet the demands of supporting 'meaningful learning'[…] In order to investigate the individual's learning environment we undertook a very brief review of the current technology tools available on the desktop, that could assist learners in their tasks associated with personal knowledge management. There was nothing available that

offered integrated support for knowledge management within a learner's personal domain that was available for use online and offline".

On the other hand, Aristotle is modern again: "What we have to learn to do, we learn by doing". (Mark Twain asserted the same idea even more convincingly: "If you hold a cat by the tail you learn things you cannot learn any other way".) Indeed, "Among the processes that have been shown by recent research to have considerable power in speeding the learning process and encouraging the learner to achieve deeper levels of understanding are learning from examples and learning by doing. Computer tutors, using these and other methods, are beginning to show impressive effectiveness [...] There is almost universal consensus that only the active learner is a successful learner. Proponents of situated learning and constructivism have proposed a number of modes of instruction that are aimed at encouraging initiative from students and interaction among them" [1].

d) Since the proposed solution is based on e-Maieutics, a concept defended extensively in [4] – taking advantage of the length of an invited paper –, related work is mirrored in the 44 references in [4] (because the concept is still new, new concept and this undertaking as a whole is unconventional, related work *proprio sensu* does not exist; the only papers concerning it describe prior work of the authors).

3. "SPEED OF CHANGE" VS. "CHANGE OF NEEDS"

The notebook used to prepare and present this paper has a computing power 40,000 time greater than that of the Computing Centre of the Sibiu County, less than forty years ago. Perhaps the size difference between a massive medieval cathedral clock and a tiny lady wristwatch is similarly impressive but there is still a huge distinction: shrinking a clock needed almost a millennium while the "digital revolution" took less than a human lifetime. Indeed, the section title is taken from a akin section in a paper trying "to explain the widening gap between the views technologists and social scientists have about using broad-band technologies, opposing the increasing "*speed of change*" to the much slower "*change of needs*"" [5]. Section 2 of [5] is abridged below:

"Time is Money" becomes an obsolete slogan, while adapting to the overwhelming "e-rhythm" is even more difficult in the last twenty years. Among the context-related reasons: globalization, modern enterprise paradigms [...], intense (mainly positive) feedback. The main IT-related reason is "*Moore's Law*" and its most vigorous consequences: Internet [...], agent technology, semantic Web, Google, and so on. [...] "Over time, the amount of transistors that could be put on a circuit for the same price doubled every 18th month! So for the same price you can buy something which can store twice as much information, every 18th month! This is Moore's Law. The implications are enormous! If the price/performance ratio doubles in 18 months… And then doubles again in 18 months… And then doubles again in 18 months… Then the price /performance is 8 times higher in only 4.5 years! 16 times higher in 6 years!" [slideshare.net/Christiansandstrom/no-technology-has-been-more-disruptive-presentation]. Moreover, this amazingly increasing computing power entails that "remembering" is almost not anymore needed, since the computer remembers much better and faster (and the "e-World" never forgets). Hence, the focus is on *understanding* (as aim) and on *involving* (as means).

On the other hand, it is unthinkable that user needs could evolve in a comparable pace. Thus, the gap between *problem* (real-world requirements) and *solution* (ICT offer) is widening because users can neither adapt nor resist to such a technological innovation rate. There are three convergent factors, supporting each other in a vicious circle manner: First, humans are inclined to reject – and even be afraid of – what they do not understand: "micro-miniaturization" (due to Moore's law) reduces radically most perceptible effects of the digital basis of information processing (you could look into a radio, but not into an integrated circuit). Secondly, no genuine need for a "better" (more complex, smaller, faster, cheaper, etc.) tool could emerge when users were disappointed by the previous, simpler tool; though, the new ICTs will go on, proposing (or forging) applications for rather artificial needs. Thirdly, when instead of focusing on "what *feature* do we need?" the problem becomes "what *technology* do we choose?", the confusion is spreading and the very language/jargon impairs communication.

From a general standpoint, asserting that we are migrating towards a "civilization of illiteracy" because we entered an era of non-linear development, whereas "the experience of self-constitution in language preserves linearity", Nadin [19] writes: "The new pragmatic framework requires skills related not only to language and literacy, but also to images, sounds, […] motion, and virtual space and time".

In short: user's disillusionments with technology stem – at least for the most part – from the fact that technology changes very quickly while user interests/motivations/needs change much more slowly. IT changes expressed by *Moore's Law*, engender not only the huge psychological difficulty to adapt to an unprecedented speed of change but explain also some known side effects [8]: instability, complexity (mainly, cognitive), distortion, and frustration.

4. ROBOT-PORTRAIT OF AN POSTINDUSTRIAL ENGINEER

To be able to innovate here and now *engineering education* it is necessary to define the target: how would look like an *educated engineer* in the future KS. (Bizarre designations of subfields become common: after "*system*" and "*genetic*" engineering in the XXth century, now "*memetic*" is added too.) To boost relevance, the main features of the KS engineering profession will be stated standing out against their counterparts in customary, traditional, engineering; to emphasise the change – mostly paradigmatic shifts – the features are expressed as "From …to". (Many of them are rephrased from [8] and will be investigated in the fifth paper.) However, why the two appellations in the title?

Postindustrial. Since KS accelerates the shift from products to services, the "postindustrial" features will be much weightier:

a) From *deterministic* (closed, static, known) to *nondeterministic* (open, dynamic, partially unknown) environment.
b) From *well*-defined *problem* (general, all-purpose, based on *quantity*, precision, certainty) to *fuzzy*-defined *situation* (limited, based on *quality*, imprecision, uncertainty).
c) From *solving* (atemporally) the *problems* (based on stability, efficiency, and reliability) to *managing* ("Just In Time") the *situations* (based on effectiveness, flexibility and robustness).
d) From (lasting, optimal, apodictic) *solutions* to (temporary, suboptimal, revisable) *answers*.

e) From *technocentric* design (based on efficiency, accurate, with complex functionality) to *anthropocentric* design (based on value theory, user-friendly, with simple interface).
f) From conventional *e-learning* with *programs* as software entities (*objects* devised as *tools*) to innovative *e-training* with *agents* as software entities (*processes* devised as *interactants*). This major shift from photo to movie will be scrutinised in the fifth paper, from an IT perspective.

In short, it is a paradigmatic shift from the "*Producer-Consumer*" paradigm of the industrial era to the – much more dynamic – "*Client-Server*" paradigm of the postindustrial one. (It is a telling undertone in the order of the two entities: in line with the still reigning paradigm, the beneficiary is the second, whereas in the arising one, he/she is the first. Remark: in the fifth paper it will be shown that for IT even the "*Client-Server*" paradigm becomes obsolete.)

Robot-Portrait. There are two insinuations here: a) the target is *elusive* (the engineering line of work in KS is yet ethereal; its profile is "wanted"); b) the target is *moving* (the profile of a KS engineer is – at least – as dynamic, uncertain, and unpredictable as the working environments the engineer acts in). Whereas the features above regarded rather KS *engineering* as activity and challenge, the features below regard rather KS *engineers* as behaviour and approach.

g) From *know* to *know-how*. The (more than forty years old) lengthy shift from data-driven static knowledge towards event-driven dynamic knowledge (i.e. skills) is a corollary of the six features stated above and could be seen as the foundation any higher education in the KS (it is also a pillar of the fifth paper). The more general feature, i.e., "education in the Knowledge Society would focus rather on *skills* than on *knowledge*" [20] [22] was comprehensively dealt with in the foregoing papers. Thus, the next features are in some way particular components, adapted strategies, working examples, or a kind of "metaskills", namely "skills to acquire skills". In short, "how to know how"
h) From *reductionist*, analytic, algorithmic, apodictic reasoning to *holistic*, synthetic, non-algorithmic, revisable reasoning. (In other words, from solely *left*-brain inference chains to a blend of reasoning tactics from *both* brain hemispheres. Otherwise, why do we have both of them?)
i) From numeric (mathematical) precision to textual (semiotic) vagueness.
j) From building bottom-up structures based on objects to devising top-down architectures based on processes.
k) From the serenity offered by *testing* (based on design specifications) to the worry involved by *validating* (based on end-user satisfaction).

In [8] the paradigm shift is labelled as a whole: from "Kelvin-Number-Oriented" to "Zadeh-Word-Oriented". In the fifth paper examples will be given from engineering curricula regarding mathematics, physics, chemistry, economy (based on "Just In Time" and on bounded rationality).

In short, the postindustrial engineer is immersed in a "Continuum of Learning".

5. THE LONG WAY FROM PEDAGOGY TO ANDRAGOGY TO HEUTAGOGY

Since the three concepts are used in the title as landmarks, before examining them through the filter of their (in)adequacy to 3L, at least some simple working definitions should help. Thus *pedagogy* stands for children education and has its usual connotation; *andragogy*, is the "process of engaging adult learners in the structure of the learning experience" [en.wikipedia.org/wiki/Andragogy]; *heutagogy* is "the principle of teaching based upon the concept of truly self-determined learning" (http://en.wikipedia.org/wiki/Heutagogy). All three are rooted in ancient Greek education and are well known in the history of culture (examples: teaching in schools, training in battles, "learning to be old"). It seems too simplistic to mix them together, to obtain 3L; on the other hand, it is obvious that 3L is a constant of human civilization – perhaps its engine.

Pedagogy. Since it refers to children and is the oldest of the three concepts, it is the starting point to be quitted as soon as possible, to meet he requirements od 3L.

Andragogy. At first sight, andragogy seems synonym to 3L but the two terms are slightly different. "Andragogy, initially defined as "the art and science of helping adults learn," has taken on a broader meaning since Knowles' first edition. The term currently defines an alternative to pedagogy and refers to learner-focused education for people of all ages. The andragogic model asserts that five issues be considered and addressed in formal learning. They include (1) letting learners know why something is important to learn, (2) showing learners how to direct themselves through information, and (3) relating the topic to the learners' experiences. In addition, (4) people will not learn until they are ready and motivated to learn. Often this (5) requires helping them overcome inhibitions, behaviors, and beliefs about learning" [7]. Andragogy is "changing perceptions of adult learning theory and changing minds in academia" [16].

Specific for andragogy is that: "Adult learners tend to be self-directed in their learning and desire situations in which they can control their own education. The adult learner brings certain life experiences to the classroom that should be acknowledged as a frame of reference. They also require relevance in the content being studied. The information needs to be relevant for the adult to fully appreciate the need for the learning. These characteristics result in motivation for the adult learner to continue in their academic pursuits". "Constructivism focuses on the concept of knowledge construction versus knowledge transmission […]. The basic focus of constructivism is that the learner interacts with the content being learned. This allows the learner to develop meaning about the content being learned within an environment that is/represents reality. In essence, the learner may acquire an understanding of basic principles and concepts by examining them within their natural environment" [7].

Heutagogy. "It is suggested that heutagogy is appropriate to the needs of learners in the twenty-first century, particularly in the development of individual capability, individualised learning and independent learning using the internet-based systems including multimedia, virtual learning environments, online assessments and social software" [en.wikipedia.org/wiki/Heutagogy]. "While Malcolm Knowles contributed greatly to our understanding of the limitations of pedagogy when it came to adult learning by defining andragogy, […] andragogy did not go far enough. Any examination of learning experiences and curricula designed around andragogical principles certainly demonstrated the capacity for linking into the adult experience and recognised the advantages of self-directed learning. However, curricula were still very much teacher-centric with little opportunity for any real involvement […] by the learner. […] Action research allows experimentation with real world

experience where learning is in the hands of the participants. […] This is as close to real world learning as one can get in a controlled setting […] doctoral students undertaking action research theses have progressed from pedagogical, then andragogical to heutagogical learning" [12].

Consequently, was this long way towards heutagogy necessary to accomplish 3L? Yes. Was it also sufficient? No, because the way is blocked by *time*. Indeed, it seems impossible to organise *teaching*, intrinsically *finite* in human life-time to meet the requirements of the "Continuum of Learning", practically *infinite* in (active) human life-time.

As always, to defeat that old and powerful enemy, which is time, we must convert it in an ally.

6. THE HURDLE: TEACHER AND LEARNER LIVE IN DIFFERENT TIMES

"Marshall McLuhan first noted the tendency to use new technologies in the model of the old. We have seen early examples (especially with remote classrooms) of teaching and learning that has hardly changed despite the investment of large sums of money and effort in new technology. Perhaps what is missing is new pedagogy that drives the development of new learning and assessment activities. In this topic we explore connectivism, heutagogy, e-Learning 2.0, and other ideas about formal and informal learning in the net-infused era" [1].

"It sounds familiar: no e-technology could solve the inherent problems of formal education, staying anchored in the old way of thinking. Worse, LORs inherited from their software objectual model the technocentric stance (focusing on "reuse") instead of the anthropocentric one (focusing on the very "use"). This unfortunate approach can be easily proved through a Google search: {"learning objects repositories" "adult learning"} returns about 91 results, whereas replacing "adult learning" with "andragogy", returns 9 results, and replacing it with "reuse", returns 1060 results. Hence, the old paradigm is more than ten times stronger!" [4]. (The Google search above was made in April 2008. Repeating the search in September 2009, it returned about 304, 99, and 780 results respectively. Hence, the old paradigm is now only about 2.5 times stronger.)

Returning to the instance of "time as obstacle", the problem is even more complex and was pointed out in the first two papers as "baffling paradox" of a "temporal contradiction": "how to organize institutional *teaching*, clearly limited in both time (corresponding to the Bologna degree framework) and objectives (corresponding to the focused curricula) to meet the expectations of a dynamic and indistinct environment, as implied by the concept of life-long *learning*. The inconsistency is deeply rooted in traditional perceptions about the educational process itself, seen as requiring a face-to-face relationship between teacher and student. Since it is obvious that the processes of teaching and learning cannot be anymore synchronous, with the student and teacher sharing knowledge in the same space and time, a totally new [...] approach is needed" [20]. Indeed, "Our present object of work (teaching) is neither *present* nor *object*, since it aims at a *future*, quite far away, *process* (learning). Why should the teacher focus on *solving* (predictable) *problems*, when the learner should focus on *managing* (unpredictable) *situations*?" [22].

Accordingly, to circumvent the hindrance, e-learning must be substituted by a method based on four ideas: a) Keep the *e-* (IT means are unavoidable because a lasting face-to-face relationship is out of question). b) Replace learning with "*metalearning*" – having the meaning of "being aware of and taking control of one's own learning" [en.wikipedia.org/wiki/Meta_learning] (because learners are most of their life without their teachers). c) Find a way to quit "the 3rd Order Ignorance" in the meaning of Armour [2]. d) Academics as educators should shift from the role of teacher to the much more subtle role of catalyst.

7. A SOLUTION: E-MAIEUTICS OR THE VIRTUAL SOCRATES

In this section title a most significant word is the article "*A*" because the solution proposed here –being anthropocentric and yet innovative – cannot be declared as "*the* solution", since it was not validated *in vivo*. (As asserted in [21], "validating anthropocentric applications is done exclusively by the end-user and has three stages: *in ovo* (conceptual validation of the interface [...]); *in vitro* (the interface is evaluated in detail while the functionality behind it is considered in principle); *in vivo* (ecological validation, i.e., in actual operation".)

The strategic decision to apply research results first only to real-world toy problems was defended in [22] (citing also [20] and [21]) "since a key thesis of the entire undertaking is affordability – in the meaning implied by the first two papers". This approach "offers to less advanced universities the chance to "take a shortcut" (in French it sounds stronger: "brûler les étapes"), avoiding inefficient incremental research and focusing instead on exploratory, trans-disciplinary research niches for learning" [20]. In contrast, some "mechanisms [...] have [...] a double vulnerability: they are either incremental as regards the "Kelvin way of thinking" or too loosely linked to new paradigms. Thus, what is their relevance? To break the vicious circle – since there is no "methodology for paradigm shift " –" [8] we have to consider software to be "not a product, but rather a medium for the storage of knowledge. […] The other knowledge storage media being, in historical order: DNA, brains, hardware, and books. […] Software development is not a product-producing activity, it is a knowledge-acquiring activity" [2].

To impair redundancy with [3] [4] [5] [6] [8] [20] [21] [22] and mainly with the fifth paper, the following subtopics are here skipped: a) Practically, all "*e-*"aspects. b) Architectural features regarding the interfaces of experimental models based on maieutical agents (for instance: nurse, disc jockey, guitar teacher). c) Skill-oriented learning (implying a fine-tuning of the shift from teacher to catalyst, mentioned above, by passing through trainer, tutor, and moderator). d) KS- oriented total quality management (above all, qualitative validation).

However, to preserve the autonomy of this paper, some key ideas are abridged below:

Maieutics revisited. After two and a half millennia Socratic maieutics is again in vogue because: a) "The activity of a teacher is relevant to the extent that it causes students to engage in activities they would not otherwise engage in" [1]. b) "One hallmark of Socratic questioning is that typically there is more than one "correct" answer, and more often, no clear answer at all. […] The Socratic method has been adapted for psychotherapy, most prominently in Classical Adlerian psychotherapy and Cognitive therapy. It can be used to clarify meaning, feeling, and consequences, as well as to gradually unfold insight, or explore alternative actions" [en.wikipedia.org/wiki/Socratic_method]. c) It is still a kind of skill-oriented metalearning. d) It is andragogical *par excellence* and has some heutagogical features too.

E-Maieutics. The concept was introduced in [4] "as (essentially nonalgorithmic) alternative to conventional e-Learning, suited to both *content* (specific to life-long learning) and *setting* (dynamic and uncertain environments, hosting most nontrivial interactive applications) [...] where *maieutics* is action-oriented and highly personalised, while "*e-*" is carried out through virtual entities interacting with the learner as interface agents" [4]. Its two key design-space dimensions follow.

Bounded rationality. "The term is used as defined, explained and endorsed in [10] [25] [27] [...]: time is gained giving up the "force of perfection". That means to acknowledge that in real-world applications, it is illusory to hope for well-defined [...] problems, complete information, accurate data, acceptable time restrictions, low risk, conventional business, etc. and for being able to give optimal solutions through scores of exact data (if possible, output offline and sequential). On the contrary, most problems are multicriterial, online, and distributed, supplied with incomplete, fuzzy, and/or uncertain information – arriving in parallel, in huge amounts and in unpredictable moments –, in the context of critical response time, high risk, virtual enterprises, etc. [...] The solution must arrive "just in time" and be acceptable suboptimal" [3].

Simon-Learning. "Learning should be considered – in both humans and agents – as a process where most effectiveness is reached through a blend of symbolic ("left-hemisphere"-like) and subsymbolic ("right-hemisphere"-like) modi operandi. Nowadays, the approach is much closer to "by rote learning". Thus, the balance has to be redressed, favouring right hemisphere tactic" [3]. That means that learning should be assessed holistically. Thus, the performance metrics proposed is based on action-oriented "Simon-type machine learning" [26] [1], namely, the diminishing duration of task completion (evaluated through a simple time derivative of task duration).

Experimental models. The design space for virtual Socratic educators was drafted [3] [4] but only some of its dimensions have been implemented in interfaces. The less primitive Socratic agent is now a virtual guitar teacher (details in the fifth paper).

8. CONCLUSIONS AND INTENTIONS

The conclusions match up with the paper objectives and are presented in the same order:

a) The main contradiction entailing difficulties in adapting to the KS is the widening gap between *problem* (real-world requirements expressed as user needs) and *solution* (ICT offers evolve in an amazingly fast and nonlinear pace). Users can neither adapt nor resist to such an accelerating technological innovation rate.

b) The postindustrial engineer – as "KS-end-user" of higher education services – will be immersed in a "Continuum of Learning". Focus moves from *static* general knowledge to *dynamic* personalised knowledge. The quantity of information is replaced by the quality of skill.

c) As a result, a "KS-oriented learning methodology" was outlined based on andragogical and heutagogical principles. Educator profiles must move from teacher, to trainer, to tutor, to moderator, to catalyst.

d) Since teacher and learner could be synchronised for only short periods, it is very difficult to organise *teaching*, intrinsically *finite* in human life-time to meet the requirements of 3L, practically *infinite* in (active) human life-time. To explore thoroughly the intrinsic "temporal contradiction" asserted in [20] and [22], regarding the settings of teaching and of learning.

e) On the groundwork of this intrinsic "temporal contradiction", a solution model for 3L was proposed starting from e-maieutics, an innovative concept launched in 2008, where learning is action-oriented, highly personalised, and catalysed through virtual maieuts interacting with the learner as interface agents.

Intentions. The keyword is *affordability*. Specific steps will be set up in line with the proposals for interbalkan cooperation in engineering education, presented in the third paper.

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