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EDUCATIONAL TECHNOLOGIES FOR E-LEARNING AND STEM EDUCATION

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***Abstract**: At the outset of innovating Vocational Education and Training (VET), we ask ourselves: What directions of innovation look promising in terms of 'perceived needs' and 'meeting endemic values'. From the pure scientific point of view, operationalizing "Quality of Learning" is one of the hardest nuts to crack; Once listing all relevant dimensions of learning processes and outcomes, there is no end. Similarly, to listing qualities in fashion, gastronomy, music, every new trend in socio-economic era, brings its own new desires and ideologies.*

PREFACE

The list of quantifiers for qualities of learning: the speed of it, easiness for the student and the teacher, endurance of what is learnt, the depth of it, its flexibility, its authenticity, its pedagogical soundness, self-efficacy and ……. Indeed, the student's capacity to become a successful entrepreneur. For those Higher Education teachers who admit that entrepreneurship is key to future societies, there might still be hurdles before arriving at confirmation on how to nurture entrepreneurship: "Are there dependencies between pure knowledge, craftsmanship and entrepreneurial mindset?" First of all, as it implies that these two excel in its innovative effects. But also, as they pretend to be feasible candidates in terms of its adaption by Higher Education stakeholders (incl. the students and their potential clients, their business partners, etc.). The best way to label gamification and story-telling is "catalytical" to the ongoing evolution of Higher Education and its surrounding society. Gamification and Storytelling seem to be strong triggers for changing the school-culture in Higher Education towards breeding ground for young entrepreneurs. Is the traditional teacher-student paradigm in conflict with the entrepreneurial - oriented Higher Education? We think not; a large part of the entrepreneurial mindset relies on the apprentice's eagerness to learn from anybody

who can demonstrate competencies that may lead to solutions for unexpected problems. However, this very 'transfer-paradigm' (from teacher to student), though very much needed, is not enough as students in a receptive attitude are slow and even averse to 'changing themselves'. The classical teaching-learning paradigm is that students are supposed to adapt in order to comply with the assessment criteria. In order to create a life-long entrepreneurial learner it is more the 'willingness to change oneself', in order to grow where your customers are going to. In this sense Entrepreneurial is more than adapting your competences; it is developing a sharp eye for 'what is needed by others' rather than obeying your superior. A good entrepreneur does not follow what his/her customers want now. It is a matter of narrating to your potential customer in order to create his/her need of tomorrow. Here is where gamification and nitrification come in: It helps students to open an additional mindset. The real job for us now is to find effective design rationales on how to weave gamification and storytelling in existing curricula. Rather than delivering hard-core recipes, we claim that teachers need to go through a set of experiences how gaming and telling opens additional genres for our mentor roles in entrepreneurial stages of Higher Education.

Three main questions were posed. The essentials have been formulated below.
The three main questions are:

A. From your current good practices, does the choice for PBL (Problem-Based Learning) as a framework for gaming, storytelling and simulations look as an appropriate one?

B. What do you see as the most important steps to be undertaken before PBL can be integrated in courses throughout your organization?

C. What additional elements would you like to be articulated sharper in the years to come?

Experts' responses to the three main questions can be found below. Its overall tendency is that the techniques like storytelling, gamification, creative problem solving and problem-based learning have been already recognized as valuable ingredients of instruction and students' project work. Most of the teachers do not see them as obligatory formats for vocational education, however, firstly, the subject matter, secondly, the students' stage of socio-/cognitive skills and thirdly, development and fourthly, the mentor's actual pragmatic preferences should have a need for them in that particular situation. This overall conclusion leads us to the common-sense criterion of "fit for purpose"; It implies that the diversity of learning/teaching processes needs diversity in applied methods and tools as well. Throughout recent research it has been admitted that the proposed new methods/tools need to be integrated as candidate ingredients in an overall instructional design approach as generally endemic to Higher Education in general.

Keywords: Educational Technologies, E-Learning, Virtual Reality, Immersion, STEM Education.

INTRODUCTION

Entrepreneurship is the core target for future Higher education. As will be elaborated further in this article, entrepreneurial-oriented learning is as multi-facetted as business itself. However, it is worth to see a common denominator of an "entrepreneurial mindset" that may serve as a more generic driver for Higher Education and even for middle and higher education in general. In order to make the entrepreneurial-oriented Higher Education tangible, a subset of the recent didactic repertoire will be highlighted. There are many avenues for innovating Higher Education that have not been fully exploited yet: 1. Gamification, 2. Playing, 3. Collaborative Learning, 4. Storytelling and 5. Simulations are just the most obvious ones. However, also Mobile Learning, Virtual Reality and the many more techno-driven innovations to come are essentially promising candidates for the future of Higher Education. In order to make learning in Higher Education more effective, efficient and sustainable we need a strong foundation for its embedding in the actual educational situations and further consolidation. Having seen the recent scientific literature and good practice examples, this envelope is PBL (Problem-Based Learning): The method to place the apprentice at the very core of his/her learning process; (s)he (re)gains full ownership of the start of a life-long learning process. For the sake of innovative Higher Education it means that apprentices who typically have a less favourable earlier school experience, they need to be encouraged by being welcomed and empowered through a student-centred pedagogy. Problem-Based Learning should not be confused by Project-Based Learning. The essence of the PBL approach is to learn about a subject through the experience of solving open-ended problems found in trigger material; prototypical questions that orient the learner towards understanding what PBL questions ideally are. The PBL process does not focus on problem solving with a defined solution, but it allows for the development of other desirable skills and attributes. This includes knowledge acquisition, enhanced group collaboration and communication. As overall recommendation: Motivate Higher Education trainers to see the elegance and sustainability of PBL; (Smyrnova-Trybulska et al., 2017). It is a powerful paradigm before adopting and integrating the new ICT-based tools as presented before. The main driver behind the integration of PBL in Higher Education is that it fit very well with the type of motivation of young apprentices "to make a difference" and "find a job" or "start a company". More in general, we see a recent policy towards preparing Higher Education students for "Smart Jobs"; (Issa et al., 2017). It preludes a more active learning approach and ready for the post-industrial era where men and machine face new complementary skills and autonomous life-long learning. This inherent trend not only holds for including ICT skills; it is a much more

intricate shift from technical-, via communicative- to conceptual skills. According to "Balance-Careers" the Top-Five conceptual skills are: Analysis, Communication, Creative Thinking, Leadership and Problem-Solving. According to "Business-Directory," conceptual skills can be delineated as: The ability to think creatively about, analyse and understand complicated and abstract ideas. Using a well-developed conceptual skill set, top level business managers need to be able to look at their company as a holistic entity, to see the interrelationships between its divisions, and to understand how the firm fits into and affects its overall environment. Until very recently these 'conceptual skills' were supposed to belong to the repertoire of corporate leaders and top managers. We see now that very rapidly these skills are seen as essential for labour force throughout the enterprise pyramid.

1. GAMING ELEMENTS IN EDUCATION

Before exploring the potential of Gaming and Storytelling it is useful to provide two main reasons for our searching in the next directions. The first is that, complementary to our day-to-day classroom efforts for converting students into better learners, the main question is to make educational systems better by rephrasing Kenneth Dunn (Kaufman et.al. 1997): "If students don't learn the way we teach them, let's teach them the way they learn". The second one is the notion that Higher Education faces a moving target; enterprises and economies are shifting due to globalization and new technologies. The third direction is that employees face more and more demand for strategic thinking. Though the term "conceptual skills" may suggest that it belongs to high level managers, there is a growing understanding that for a large class of jobs conceptual thinking is needed in order to promote problem solving and creative approaches. This trend goes together with the growing need for knowledge - rather than industrial workers. Conceptual skills are the next step after we mastered factual and procedural knowledge. Both knowledge and skills are consolidations after good practice has found an optimum;

As our surrounding world evolves, new Higher Education needs to be developed: Its goal is to prevent a group of youngsters to become obsolete. We hope to illustrate that gamification, storytelling and many more are indispensable in this continuous process. **Definition**: Gamification is the application of game-design elements and game principles in non-game contexts (Werbach, 2014). The main reason for defining gamification as a process is that it provides a scale for gamification and not an absolute category. Gamification commonly employs game design elements to improve user engagement, organizational productivity, flow, learning, employee recruitment and evaluation, physical exercise, traffic violations, voter apathy, and more. Werbach and Hunter (2015) identified five game dynamics used in gamification:

- **Constraints** are about balancing limitations and freedom for a player as well as integrating forced trade-offs in the design of a gamified solution.
- **Emotions** aim to produce enduring player engagement and appear during an activity.
- **Narrative** is represented for a player through either an explicit or implicit storyline having its own consistent inner logic and following a certain context.
- **Progression** reports the player's growth and development when navigating through a game and the possibilities to do so.
- **Relationships** consider the social interactions of players in a game which can create feelings of camaraderie, status and altruism.

A number of studies on gamification show that it has positive effects on individuals in terms of cognitive flexibility, changing role perspectives, etc. However, individual and contextual differences exist. Gamification can improve an individual's ability to comprehend digital content and understand a certain area of study such as music. Research into the use of gaming for learning shows that gamification penetrates all sectors of life where awareness, latent ambitions and mental growth are at stake. As such, gaming may not only increase the effectiveness of traditional learning goals like memorization and skill routinization; It may help learners to refresh their concept of what learning is about. In its deepest sense, learning can be seen as one's developing willingness to change him/herself; (Kommers, 2004). The contrast between single- versus double-loop learning is that single-loop learning can be compared with a thermostat that learns to switch-off the heating when a certain temperature is reached, whereas double-loop learning occurs when a device (or a person) learns to monitor a wide set of parameters and becomes keen on which of them are the best first-order predictors for anticipation when heating or cooling is needed. Games as we typically know for increasing speed and precision have already proven its value for learning. Its overall metaphor is "beat your peer student or your own score in the past". Double-loop learning games place the learner at the core of a realistic situation and ask to discover 'hidden' relationships in a certain domain. Where gaming aims at winning, playing aims at conquering new levels of understanding, self-awareness and self-efficacy. In terms of VET, it is the learner who attempts to become his/her own coach.

The relations Learning-Working and Playing-Working have been extensively explored in educational practice before. The intersection Playing-Working seems to be underexploited yet; See Figure 1. Its goal is to make apprentices better new colleagues who dare to question and help to transform into new business models. As Steve Jobs claimed: "Traditionally we, as Apple, scout and hire the best people around the globe, pay them highest fees, and subsequently tell them what to do..."; It reflects the growing notion that in the post-industrial era, working is the efforts

to exceed earlier expectations and survive in an ever more competitive market. The notion of 'double-loop' learning confirms the manifold efforts in the last four decades to equip the learner with ever more autonomy, self-regulation and metacognition, in order to start the process of a life-long learning attitude as early as possible.

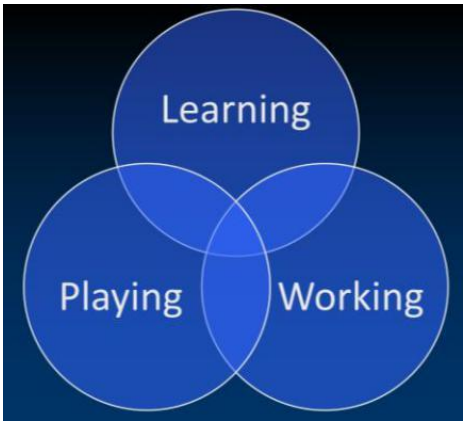

Figure 1: Synergy between Learning, Working and Playing.
Source: Bonanno & Kommers, 2008

2. WHY PLAY-BASED LEARNING? METHODOLOGIES AND APPROACH

Play-based learning as a research topic has been presented as a method for pre-school learning mainly. In this IO5 an effort is made to position the playing-working combination as a new prospect for VET. In the triangle learning-playing-working the phase of learning is traditionally seen as mitigation between work and play, in which play is unnecessarily seen as 'leisure time', 'divertissement' and 'digression'. The essence of playing is the immediacy between actual interest, affordance and try-out. There is no other agenda than "follow your interest" and "see how far you can go". So, though the improvisation and impulsiveness may look as "unfocussed" and "senseless", the optimal sense-making occurs in the playing attitude as it completely absorbs the person. In terms of the net learning (understanding a complex of variables through experiencing direct-and indirect side effects of an earlier intervention) one can say that playing is one of the very few activities with a minimal of cognitive overload; no prescriptive agenda, no extrinsic motivations and a one-to-one match between cognitive repertoire and intuitive horizon. Just like virtual and vicarious allow the learning to take freedom and fully focus on the proximate zone of achievement, so is a situation of playing the de-facto match between momentary intention, imagination and cognitive operation. It is now a matter of finding complementary arrangements for Higher Education

mentors to convey such a process and find adequate scenarios for progressively integrating its learning outcomes in meaningful segments of the job performance.

3. GAMIFICATION OF LEARNING: PRINCIPLES AND MECHANISMS FOR ENGAGEMENT

Gamification of learning is a much broader process than finding appropriate game templates and integrate them in curricular and instructional contexts. One of the recent efforts has been to classify better what element of gaming would contribute to the learning process. The prefix “serious” has been chosen to narrow the spectrum of diverse gaming genres. Critics came along that gaming for the gamer is always a serious matter. On the other hand game ambassadors claim that an explicit serious connotation may squeeze out the attraction of game-experience soon.

1. One of the drivers of game-based learning is Engagement; Learners feel immersed and sometimes even obsessed while playing in a virtual reality where a certain number of performance parameters are continuously measured and displayed.
2. The second driver is Flow; Its effects increase the learners’ strength of experience, concentration and endurance. In particular, for VET, gamification in learning has the extra effect of “Breaking the Yoke of Seriousness”; As “Work” is inextricably bound to serious business, the novice might easily get too much infatuated with “avoiding mistakes” so that “risk avoidance” easily emerges and hampers mindset for learning and understanding.

4. DIGITAL STORYTELLING FOR LEARNING

Definition: Storytelling describes the social and cultural activity of sharing stories, sometimes with improvisation, theatrics, or embellishment. Every culture has its own stories or narratives, which are shared as a means of entertainment, education, cultural preservation or instilling moral values. Crucial elements of stories and storytelling include plot, characters and narrative point of view. The term "storytelling" can refer in a narrow sense specifically to oral storytelling and also in a looser sense to techniques used in other media to unfold or disclose the narrative of a story. Research into the use of story-telling for learning can be found here. Its main lessons are that both the teacher and the learner have larger repertoires of earlier experiences and imagination than we typically rely on. A story is an existential (how do I experience a certain fact or event?) rather than epistemic (how things are). The term ‘Digital’ storytelling reflects that the face-to-face format is powerful, however not necessarily the only one. For instance, the option of letting people build their stories on top of earlier stories

by others, or even simultaneously build parallel stories have been explored in the "Woven Stories" project; Harviainen et al., 1999 and Nuutinen et al., 2010. Connected, interlinked stories are a good candidate to promote collaborative understanding and constructivist in addition to instruction-based learning. The revaluing of story-telling can partly be attributed to the earlier technical virtues of hyperlinking, compartmentalized paragraphs and hypertext as decontextualized information; (Kommers, 1988). Narrative methods for revitalizing teaching and learning can be seen as compensation for the step-by-step "cleaning" of rhetoric; definitional purity and the wish to make texts tractable had the price of losing episodic lines and losing the persona (the imagined concrete person who the listener/reader can identify with). Marketing campaigns have already picked up this need for 'Personal Templates'. In tutorials and manuals, we see the trend to articulate "the user" of "the customer" as vignette character: a fictitious flat character who serves as a simplification of the manifold persons who the apprentice may meet in the near future. In terms of scaffolding, the initial simplification like posing the customer as 'caricature' first and allowing an increasing realism of the customer as a more complete person later, might be a good heuristic for the design and pacing of the narrative approach. Once the apprentice becomes involved in virtual presence, the avatar is a comfortable way to represent oneself without disclosing his/her identity. An epitome of narrative format is TED Talks, amongst the ones by Sir Ted Robinson have a major message on creativity for both regular education and VET.

5. INTRODUCING CHARACTERS / AVATARS

Characters or its representatives allow the audience / reader to identify with the story. The most compact guidelines for the introduction of characters can be found in film-script guidelines. Crucial in establishing characters are the features of what we call 'a personality'. Let the listener immediately know who (s)he is via exposé of (trans)actions and contrast with the other players on stage. Make clear that (s)he is going to play a decisive role in the coming adventure. Typically, the listener should be able to identify with the main character, but at some essential point there needs to be ambiguity: 'strange' behaviour that cannot be explained or could not be recognized before. Overwhelm the listener very soon with typical bloopers ('big mistakes') by the main character. Keep your story compact so that the main line can easily be remembered. Insert looking back and forth as mental perspective; The listener is supposed to 'create' his/her own interpretation. In case of more abstract concepts in the knowledge domain, elaborations are needed; encourage the listener to interweave prior and final understanding and keep this discrepancy until the very end of the story. The elaboration of Story-Mapping, Hero's Journey and the available multimedia tools for web-authoring can be found in the next link to David Mamet's message triggers your mind on storytelling:

6. SIMULATIONS: DEFINITION OF THE CONTEXT, TEAM WORKS, SKILLS, PATHWAYS, E-TOOLS, MANAGEMENT

Both gamification and narrative discourse for learning can be seen in the many simulation programs that have been integrated in various levels from early regular unto the highest levels in corporate and civil training in everyday life already. Since computers became multimedia (Multi Modal), its potential contribution to let people explore almost any context, inclusively 3D spatial environments with stereopsis for surgical training, kinematic and proprioceptive sensations for vehicle control and haptic experience for training manipulation feedback; See Figure 2. The instructional context and the apprentice's prior knowledge and skills is decisive for what is actually learnt from a simulation model. The underlying photo of an expert surgeon who calibrates a haptic device before the students start working with it; (Kommers et. al. 2004). A typical phenomenon is that after a few hours of practicing, the novice will perform better than the expert. This is the moment that the students need to go to the more realistic context so that many more parameters like the total constitution of the patient, the smell, heart functioning etc. should be considered. As many competences imply social interaction and teamwork, also a large proportion of didactic simulations demand collaborative tasks; See Figures 3a, 3b and 3c. In the context of Utrecht University, a numberof collaborative group tasks have been developed for the sake of observation and later analysis. In terms of didactic context, it is important to discern the training of the individual pure job performance and the goals in terms of socio-cognitive development.

The Teams-Games-Tournament format (Ke, F., & Grabowski, B., 2007) originally defined by Bob Slavin (1977), prescribes an overall sequence of cooperative- and competitive group work. Skills progress through simulations has been described by Luursema et al. (2008). Its conclusion is that stereopsis only makes a positive difference when the novice has a limited capacity in spatial imagination.

Monitoring pathways of skills: One critical factor in the success of learning with simulations is the overview of students' partial successes/failures in the targeted skill domain. The underlying diagrams allow trainers to quickly analyse novices' learning performances. It is an example on how e-tools allow the human factor to survive and even excel, compared to the f2f classroom situation.

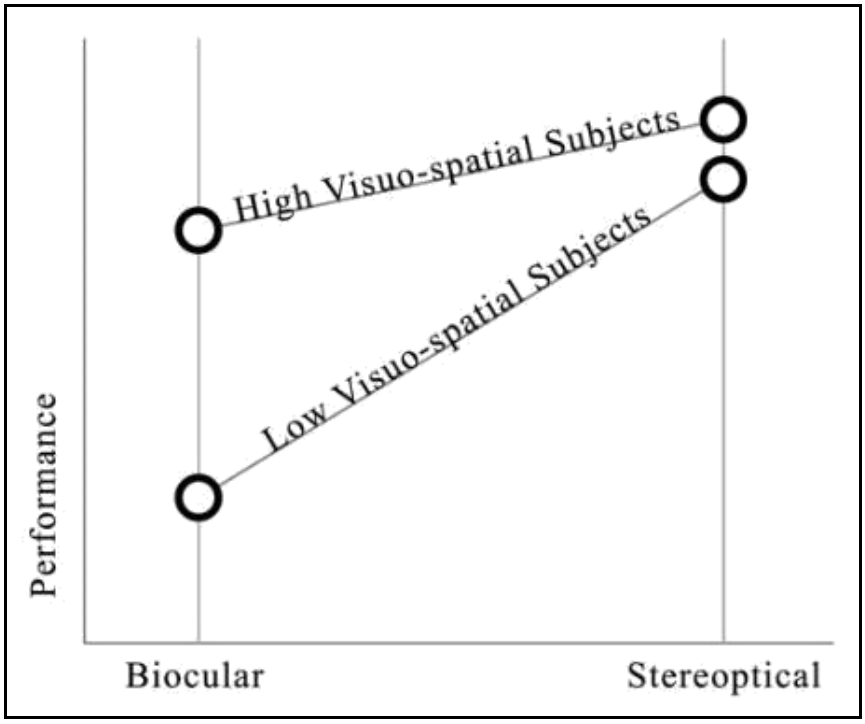

Figure 2: Luursema's finding that the added value of the heavier 3D stereoptic goggles emerges more in case of a weaker visual imagination
Source: Kommers, Luursema, Rodel, Geelkerken, Kunst, 2004

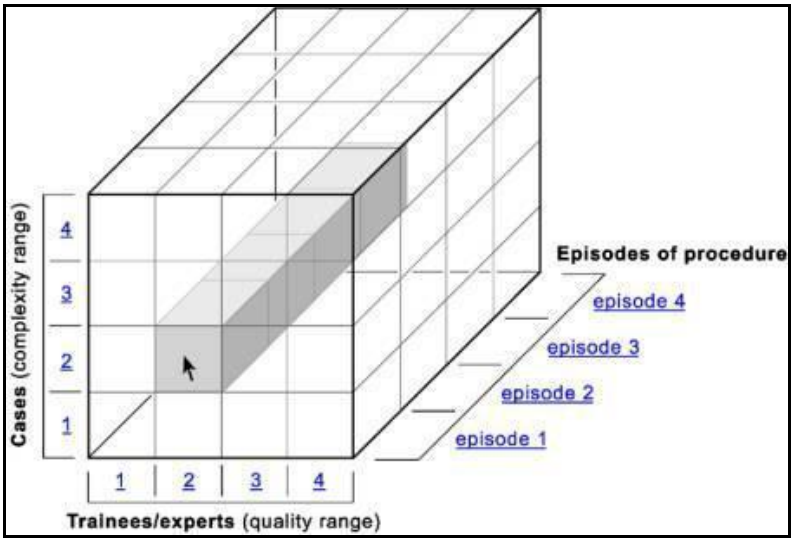

Figure 3A: Selecting a particular intervention episode across all trainees for one particular patient

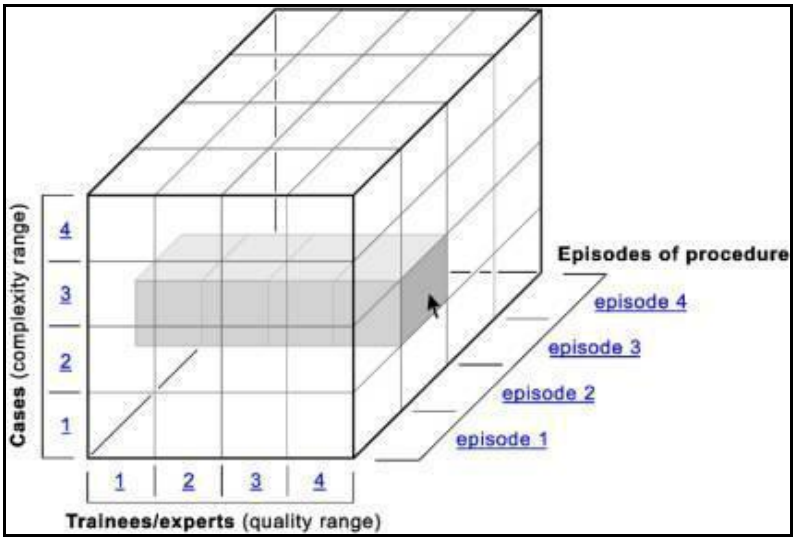

Figure 3B: Selecting a Trainee / Patient intervention history

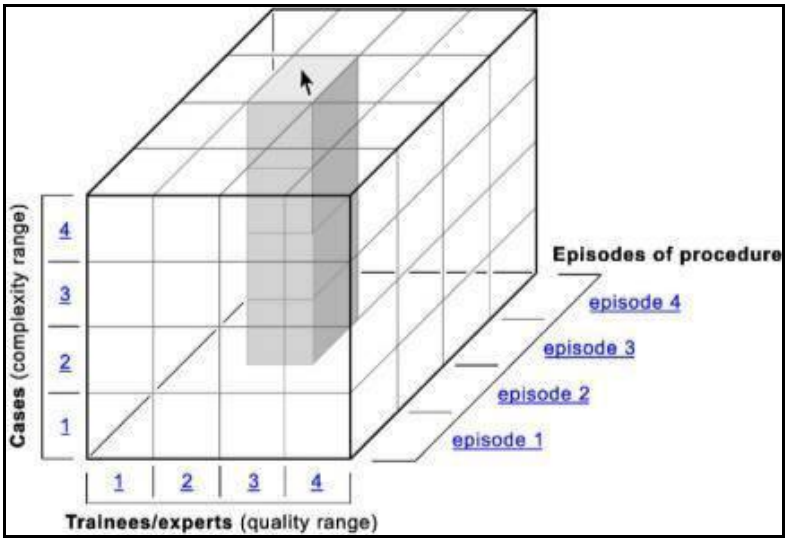

Figure 3C: Selecting a particular intervention episode across all patients for one particular trainee

Source: Kommers, Luursema, Rodel, Geelkerken, Kunst, 2004

The study by Kommers et al. (2003) revealed that though virtual reality is one of the prime candidates in vitalizing learning by its realism and direct appeal to the students' natural affordance to act upon urgencies rather than to "know" what experts are saying; VR in itself is not enough to make the learning more effective. Obviously, the realism in VR cannot exceed the real situation it self. As the experiences with Link Trainers for airplane pilots has shown,

we know that the simulation can be more effective, once it elicits the novice to go into critically complex situations; exactly those situations that we never hope to meet in reality. The added value is not just that the learner's reflexes are trained to survive in the panic of preciously decisive seconds. The value is also that learners can best understand the foundations of complex mechanisms when they are forced to work on the edge of what is a success versus a failure. Training through real-patient interventions are not allowed to approach this area. That is why the VR-based medical intervention is an even better preparation to the first clinical steps compared to witnessing dozens of impeccable operations performed by the master.

Young delinquents in prison have been exposed to in the tradition of Seymour Papert's 'Mind Storms' project at Media Lab MIT. "Climbing steep slopes" was one of the typical exercises. Finally leading to the understandable challenge to "even climb back hanging walls" as a common dream in prisons.

6.1 Contexts for simulations

Simulations have been developed in industrial projects in order to prepare better for the unforeseen complexity during calamities. Its main effect was that engineers and decision makers became better prepared compared to those who just concentrated on formal models with a high degree of precision. As simulations became easier to emulate more complex realities, education has gathered more than only interest and got more and more convinced that a reduced reality had advantages for gaining understanding compared to the situation with full reality and scale. Simulation has even become a metaphor for education at large: If the real setting cannot absorb novices' presence and contributions, it is needed to build a reduced version of a particular enterprise. Not only to increase safety and flexibility for the time of learning, also for breaking-out when no urgent maintenance or trouble shooting was needed. For example, Hewlett-Packard's inkjet cartridge filling factory in Dublin had a mini factory where employees could exercise in fault-finding so that they reached a shorter downtime in case of failure. In other words, simulations have a wide potential scale of functions. Its use for learning purposes can be focused on tackling renowned problems like flight pilots who need to practice emergency landings that they would never voluntarily undertake in reality. But also, simulations allow novices to explore and experiment configurations in order to develop a better. What-If thinking for the cases that fresh reasoning is needed in a future break-down.

CONCLUSIONS

Entrepreneurship-oriented learning like gamification, storytelling, simulations etc. can only be adopted and effectively integrated if an overall pedagogical framework has been articulated. Problem-Based Learning seems the best candidate as it places

the learner at the very core of the life-long learning process. (and subsequently fading) is seen as a safe way to make learners less dependent on the teacher and institutional guidance. The same is true for the initial and further (in-service) training of Higher Education teachers. The choice of "narration" is a clever choice to let existing Higher Education trainers build upon their prior traditions and reflexes; (Kommers & Simmerling, 2015). At the same time, they need an appropriate didactic framework that allows all the upcoming ICT tools to be integrated by the learners themselves. At the moment it is gamification and simulations. In the near future it will be a wealth of MOOCs, Big Data applications, Learning Analytics, Artificial Intelligence, etc. The chosen didactic framework is Problem-Based Learning with an ever-stronger focus on the existential factors of the learner with his/her unique talents.

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