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PROCEEDINGS

Resource Efficiency for Global Competitiveness

27 – 29 January 2016
Stellenbosch, South Africa

Organised by
Department of Industrial Engineering
Stellenbosch University

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International Academy of Production Engineering

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Gamification: Teaching Within Learning Factories

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Abstract
Gamification, the use of game elements for non-gaming purposes, may just make a huge impact on education, a contribution the world in general and South Africa in particular, desperately needs. In today's fast-paced work environment, there is not only a severe skills shortage, but also a great need for graduates with practical knowledge - students that are not purely "book smart". Didactic teaching habits have created an education realm in which reciting facts is more often than not what gets students to pass. Learning factories are physical, operational factories that serve as exemplary and realistic hands-on learning environments and provide an important step towards more industry-prepared graduates. Top universities around the world are establishing such environments and are showing superb results. This paper explores the potential benefit of applying gamification in such a setting to enhance the learning environment even further, and provide opportunities for training otherwise difficult to teach topics, such as shop floor management.

Keywords
Gamification, learning factory, shop floor management

1 INTRODUCTION

"The direction in which education starts a man will determine his future in life." ~ Plato

In South Arica, approximately 50% of all students who start school, drop out before reaching matric [1], resulting in a real pass rate of only 36% for 2014. Of these high school graduates, less than 10% enrol for tertiary education, at which the average graduation rate of 15% [2] results in only 1 in every 100 youth in South Africa having an undergraduate degree. To add to the problem, business leaders have expressed concerns that graduates lack skills in problem solving and self-directed learning [3]. The direction in which we are sending our youth, is undeniably dismal. This paper aims to identify the problems and challenges faced in the current education system and analyses a new approach for learning as a possible solution.

2 HOW PEOPLE LEARN

2.1 Approaches to learning

[4] Discusses three distinctive approaches to learning, namely a surface-, strategic-, and deep approach. The surface approach relies on rote learning with the sole purpose of meeting the minimum course requirements. Students who are entirely outcome-orientated, motivated only by studying what is necessary to achieve high marks, follow the strategic approach to learning. A deep approach is followed by those students whose intent is to gain a deeper understanding of the material. The deep approach is the desired approach since only when a student understands the work material, can he/she apply it effectively in practice.

2.2 Principles of learning

According to [5], learning is based on the following four principles:

- Learning occurs in context.
- Learning is active.
- Learning is social.
- Learning is reflective.

These principles suggest that in order for learning to be successful, it should be based on real-world situations and contexts, involve the student actively, be provided in a social environment with interaction amongst students and educators as well as facilitate feedback that allows for reflection and reworking of ideas to improve understanding.

2.3 Learning theories

The main learning models discussed in the literature are the behaviourist-, cognitivist-, and constructivist learning theories. Cognitive learning environments are the traditional, purely theoretical and instructive ones [6], whereas behavioural methods incorporate purely practical training in an attempt to provide a more hands-on experience. Both theories are based on instruction, where the educator tells students what to learn or do. Over the past decade, there has been a shift in emphasis from behaviourist and cognitivist learning to a more learner-centred approach known as constructivism [3, 4]. Constructivism is based on the assumption that self-learning is developed when the student is actively engaged and attempts to gain an in-depth understanding of the environment [3]. The principles of constructivism are, active learner engagement, knowledge construction, collaboration and contextualisation [4]. These principles are directly aligned with the principles of learning discussed previously and would suggest that such an approach will result in the most successful knowledge transfer. The two most commonly discussed learning theories built on constructivism are Problem Based Learning (PBL) and Experiential Learning Theory (ELT).

2.3.1 Problem Based Learning

PBL is a learner-centred approach in which learning is driven by problems as opposed to facts or information [3]. It further allows for students to participate in a more real world context than traditional learning methods. PBL has been found to not only develop effective problem-solving skills, enhance the retention and application of knowledge, and provide opportunities for interdisciplinary skills and knowledge transfer, but also to promote active, lifelong learning and strengthen the recipient's motivation to learn [3].

2.3.2 Experiential Learning Theory

ELT is based on the idea that learning should be undertaken as a holistic process and not in terms of singular outcomes, as it has been done in the past [7]. An important distinction from PBL is that in ELT, learning is best facilitated by a process that includes feedback and allows for the reworking and relearning of ideas and knowledge, through experience. The learning process is modelled as a cycle where observations and reflections are based on actual experiences. These reflections lead to the abstract conceptualisation of knowledge, which in turn leads to active experimentation from which new experiences are drawn. [8] Describes ELT as a collaborative, hands-on, self-directed learning process that engages learners in a social learning environment.

Regardless of the method or theory, experts seem to agree that learners have a much higher and effective degree of knowledge retention when all their senses are actively engaged [9].

2.4 Technology based training/teaching (TBT)

Due to globalisation, economic pressures and work-life concerns, companies and academic institutions are looking toward technology for innovative and flexible training and education solutions [6, 10]. [10] Breaks TBT down into three levels namely basic, middle and high-end sophistication. On the basic level, technology such as CD-ROM, DVD, interactive video systems and e-learning are used for training. The next level includes electronic performance support systems and intelligent tutoring systems, which have the added capability of tailoring the training to the individual. At the high end of the continuum are technologies such as distributed interactive simulations, distributed mission training as well as game-based environments. Such highly sophisticated systems place learners or employees in simulated, realistic situations applicable to the job.

2.4.1 The shift to TBT

An initial and most common application of TBT is Information and Communications Technology (ICT). There has been a large degree of interest in ICT in recent years, as it is believed to improve educational efficiencies and to be useful in addressing educational shortcomings often found in developing countries such as South Africa [11]. The 2003 white paper on education, stipulated that by 2013 every South African learner in tertiary education should be ICT capable [12]. Furthermore an e-education policy was formulated in 2004 to equip all schools with ICT [11], in an attempt to improve the quality of education in South Africa.

Other than reducing costs and training times, TBT has the ability to surpass the standard classroom experience since it can be used to provide a personalised learning experience and monitoring of progress [10]. With so many advances in educational theory and clear advantages of TBT, it is at first not clear why the results are still so poor. It is thus important to identify why the education system in South Africa (as well as in many other countries) is underperforming.

3 WHAT IS WRONG WITH THE CURRENT SYSTEM?

In South African higher education institutions, 41% of students drop out, with between 50% and 60% of them dropping out in their first year. Of the 59% who remain, not all pass, as suggested by the university graduation rate of 15% [13]. The resulting questions raised are therefore: Why are so many of our students dropping out, and secondly; why are those who do not drop out, struggling to pass and not prepared for the practical work in industry?

3.1 Reasons for high dropout rates

A study done in America reported that 47% of respondents listed classes being boring as their main reason for dropping out, while 69% of respondents also admitted that they did not feel motivated to work harder [14]. When asked how the education system could be improved, the top two suggestions made, each with a convincing 81%, were that there should be more experiential learning and opportunities for real-world learning, and secondly, better teachers who actually make classes interesting. Very similar comments echoed in the classrooms of South African institutions such as Stellenbosch University.

3.2 Stuck in their old ways

The positive projections for ICT in South Africa in the 2003 white paper did not materialise. Despite the move toward a more student-centred, constructivist learning approach incorporating TBT (more specifically ICT), many educators have stuck to their traditional ways of teaching. In a study on ICT use in South Africa, educators were asked why they were not implementing TBT into their lessons [12]. 75% of respondents gave "[the] necessary computers were not available" as one of their reasons for not having implemented TBT. 36.8% noted that they did not have sufficient preparation time, while 25% admitted to not being confident enough with technology, and 17.9% said that integrating technology into lessons is simply too difficult. In the same study however, 93% of educators indicated that they did have access to computers, although mostly in a designated computer room. Interestingly, educators with more than 21 computers available per class were the least willing to integrate it into their teaching, raising questions about the validity of the excuse of computers not being available. Regardless of the reasons, experts are in agreement that instruction alone, is simply inadequate to prepare students for today's competitive environment [3, 9].

3.2.1 Instruction's inability to adequately prepare learners

The problem with an instruction-based approach to teaching is that it incorrectly assumes that knowledge can be directly transferred by means of facts [8]. The assessment methods implemented in such an approach are usually summative (i.e. writing a test or exam at the end of the module) and do not allow for feedback and rework to take place [4]. The student has one, sometimes two opportunities to demonstrate his/her knowledge and pass the module. This theoretical rote learning does not stimulate the student's problem solving ability, nor does it prepare learners for a world in which practical knowledge is a necessity [15]. Instead, it leads to students adopting the attitude of "Will this be in the exam? Otherwise I do not need to know it".

3.3 Getting TBT wrong

A study conducted in 2000 on the use of ICT in South African schools, concluded that it is not always that the technology is not available, but rather that the educators do not know how to use it [16]. A common misconception of TBT is that it is simply the use of some form of technology in a classroom environment [16]. Many educators use technology as add-ons and replace existing manual methods without actually providing any useful interaction [4, 5, 9, 16]. [16] Explains this problem in relation to the South African Teacher Development Framework provided by the Department of Education. In education, there are five teacher capacities as depicted in Figure 1. The lowest levels are the entry and adoption levels, in which educators are only capable of limited use of ICT due to lack of resources or more often, technological skills. These stages relate to the basic level of TBT sophistication discussed in Section 2.4. The adaption and appropriation levels include educators who are able to adapt technology and apply it in manners in which the student's education is enriched, and thus relate to the middle level of TBT use. The highest and desired level is that of innovation, in which an educator is able to develop an entirely new environment in which the flexible use of ICT allows for interactive and collaborative learning. This in turn relates to the high end sophistication level of TBT use.

Figure 1 – The teacher development framework

Due to reasons ranging from lack of technical experience to unwillingness to change, South African education is struggling with the successful adoption of ICT [12]. Replacing blackboard notes with PowerPoints and written tests with online tests, the majority of educators are stuck in the lower levels of the framework. Where technology is being used for such purposes, it is redundant and of no benefit to the learner [16].

3.3.1 Learner perceptions of ICT

Although seldom applied effectively, the appeal of ICT to students is clear. In a South African schools study conducted, 94% of learners reported that they felt more motivated, and 83% that they obtained a more in-depth understanding when learning with ICT [12]. Other benefits of ICT use included that it:

- accommodates different skills levels (85%);
- gives more, more relevant and faster feedback (92%);
- allows for collaboration (88%); and
- provides for more creative thinking (88%).

3.4 Information overload

Regardless of whether or not technology is being used instead of manual methods, education in South Africa remains too didactic [17]. Excessive amounts of information, combined with the lack of constructive feedback, leads to a shallow understanding of the work, and encourages only surface learning [4]. Students become bored and whilst many drop out, others graduate having made no attempt to understand the work material, and enter the workplace hopelessly ill-prepared.

The question that can be raised becomes: how can we teach people in a way that will motivate and engage them, whilst equiping them with the problem solving and innovative skills they require in a real working environment?

4 A POSSIBLE SOLUTION

Other than reducing costs and training times, TBT exceeds the standard classroom experience since it can provide a personalised learning experience, monitoring of progress, increased engagement and facilitate more active PBL [4, 8, 10, 18], if applied effectively. These advantages, along with the increasing availability of technology provide for a strong support that it should be used to improve education.

In order for TBT to be effective, it should engage and motivate students, encourage self-learning and provide opportunities for collaboration and social interaction [4]. The feasibility and potential impact of TBT is clear, but how to implement it practically or innovatively, is less so.

4.1 Learning factories as an innovative approach for competence development

As a result of the growing interest in practical and experiential teaching or learning environments, as well as the use of technology in teaching [10], leading universities and colleges have reacted by establishing learning factories [22, 23, 24]. These physical, operational factories usually cover the whole creation process of a product selected in accordance with didactical criteria and serve as exemplary and realistic hands-on learning environments. The concept of learning factories integrates self-directed and action-oriented learning in heterogeneous groups to encourage implied experiential knowledge, integrated into a formal didactical concept. This enables the trainer to address the intended competences systematically by guiding the learners through the processes necessary to acquire the intended knowledge and professional and/or vocational competencies. This symbiotic combination of teaching professional expertise, methodical and individual competencies as well as some soft skills can be achieved by combing traditional, instructor-based teaching methods with hands-on sessions held in teamwork to improve social and group work competencies [25, 26]. The tasks or problems students get confronted with are inspired by issues of high practical relevance and designed openly to avoid predefined solutions or approaches. By using mostly commercially available technologies in learning factories, a very authentic learning environment can be created, resulting in a highly immersive experience for the learners [27]. Additionally, higher learning success is achieved by including the own actions of and the interactions between the learners into the learning experience compared to conventional teaching and learning methods [28, 29].

4.1.1 Qualification procedure in learning factories

To achieve the given objective of providing the learner with the relevant skills and competences a multi-staged qualification concept is used (Figure 2). This concept contains phases of self-study, instruction, practice and the self-dependent action and experience oriented application of methods within a comprehensive and complex task in the learning factory. The self-directed reactivation of basic knowledge helps to ensure that all participants have the same entry-level of knowledge, which improves time-efficiency of the actual training. To transfer new knowledge and methods, different teaching methods such as instructive and constructive learning are combined. This qualification part already takes place in the actual learning factory to familiarise participants with the digital and physical infrastructure used. The role of the trainer is becoming more and more passive, shifting from a pure instructor to a moderator or coach. Instead of providing learners with direct instructions as in the traditional teaching, a coach provides guidance but allows students to create and learn from their own experiences. Ultimately, the learners are confronted with a final qualification scenario. An example of such a scenario is where they receive all required information such as product and order data. Based on this information, the learners plan and design their individual operational, collaborative production system. The trainers are only assisting the learners in case of questions regarding the used technical assistance systems at this stage of the qualification procedure. During the actual operation of the factory the trainer may introduce turbulences, forcing the learners to reconfigure the work system.

An objective evaluation of the execution of the given task can be conducted based on specific indicators such as the capacity utilization, throughput times, quality performance indicators, on-time delivery or other relevant measures depending on the learning goals. Even more important than these objective criteria is the final reflection of the learner group regarding the methods learnt, decisions made and the exchange of individual experiences in accordance with the adopted role within the team.

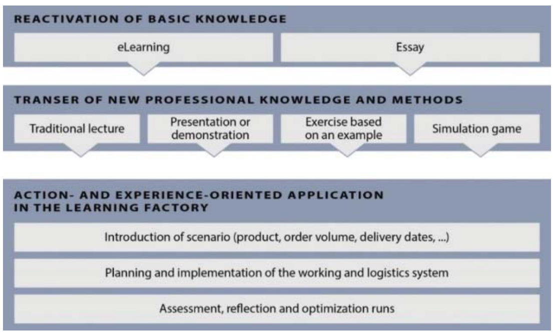

Figure 2 - Qualification procedure [30]

4.2 Potential to surpass the current learning factory experience

A learning factory provides students with a more interesting, real world, experiential learning environment than purely instructive teaching. It also involves students actively and allows for a high level of social interaction. It therefore satisfies the first three principles for successful learning that were discussed in Section 2.2. The final principle is that the environment must provide adequate feedback and allow for the reworking and improvement of ideas. Although the qualification procedure does provide for reflection, this only occurs at the final stage along with the assessment. The problem identified with assessment methods in traditional teaching was that they are summative, and do not allow for the reworking of ideas [4]. The learning factory therefore teaches students valuable lessons, but does not provide iterative opportunities to learn from experience, rework ideas and relearn.

4.2.1 Gamification

Whilst high end technologies as discussed are far better than traditional training, they still do not allow for a lot of interaction and communication between trainees, nor do they allow for adequate feedback loops [10]. A new and improved branch of game-based training is gamification, which is largely dependent on the interaction and cooperation of trainees. Gamification takes aspects from games, and places them into the actual job environment, taking advantage of the high levels of engagement games have to offer, and implementing this into the workplace. [28] Looks at how gamification can offer a fun and engaging learning environment and provide the user with constant feedback regarding their work, allowing for continuous rework. Another benefit of gamification is that it can be adapted to each learner's capabilities – the task at hand is always perfectly balanced so as to be challenging, yet never be above the player's current abilities, which provides high levels of motivation.

4.2.2 Feasibility of gamification and TBT

The generation born between the 1980s and the early 2000s, known as generation Y or the millennials, are the group of young adults who will be entering the higher education system as well as the workforce in the years to come. It is therefore important to assess the potential that game-based learning has for this generation. [19] Provide an interesting view on this, describing a generation they call the game generation. The game generation is the combination of generation X (born between the 1960s and 1980s) and generation Y. This is the group of people who grew up in a world where games have, so to say, defined their lives. Games and technology are everywhere and people from this game generation will have a very difficult time trying to picture a world without it. The use of TBT shows great promise for such a generation, where gaming is simply the norm. [19] Go further to suggest that growing up with games has shaped the game generation into being very capable employees and even top managers.

In South Africa specifically, the gaming industry holds a very bright future. Although poor broadband limits online gaming in South Africa, the mobile gaming industry is expected to contribute to 39% of South Africa's gaming industry by 2017, in comparison to a mere 8% on a global level [20]. A study in 2013 showed that despite the high poverty rate, over 75% of South Africans classified into the low income group and above the age of 15, own mobile phones [21]. Gamification thus shows great potential, leaving only the task of how it can be incorporated into a teaching/training environment.

4.2.3 A training need in South Africa

In South Africa, a topic that is continuously found in headlines, is the corporative attitudes between business employers and labour unions. There is no working together, but instead, the high levels of confrontation lead to frequent strikes and lost production which eventually result in large scale retrenchment due to financial strains. The Workplace Challenge (WPC) is a South African government initiative to support the introduction of employee participation programs in South Africa [32]. Its aim is to incorporate employees in the business, and develop good relationships between business and labour unions. Team-based work organisation (TBWO) was introduced into 12 sections of 5 small and medium sized manufacturing firms. TBWO, more commonly known as shop floor management, addresses lean principles as well as soft skills within a business, as portrayed in Figure 3.

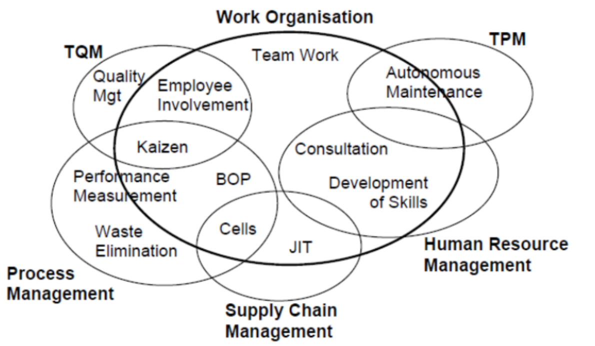

Figure 3 - Practices associated with TBWO [32]

Teamwork and decentralised decision making has been adopted in many companies and has shown to improve overall efficiencies as well as employee motivation. The WPC was conducted over a very short time span of 2 years, and whilst not all participating firms had clear cut results, the potential impact of shop floor management in South Africa is undeniable [32].

4.2.4 CIRP Conference

The topic of learning factories in South Africa was addressed in the 2015 CIRP conference held in Cape Town in August 2015. A large group of researchers, industry experts, government representatives, as well as academics were present from around the world. In a workshop led by Prof. Dr.-Ing. Hummel, attendants were asked which concepts they believe should be demonstrated in a learning factory. Whilst concepts such as manufacturing and logistics were also listed, an overwhelming number of attendants reported that they would like to see more of the softer skills addressed in such an environment, as it is crucial for the business world but difficult to teach otherwise. Another theme which was very prominent in the feedback was that of lean basics. A learning factory generally consists of a model production line in which physical, mechanical and logistics systems are evident. Lean basics such as 5S and Kaizen are generally incorporated directly into the production line, but students never fully grasp the impact of not employing such concepts. Soft skills such as project management, communication, multicultural interaction, and leadership, are less prominent. Although the learning factory does involve teamwork and project management, the inadequate feedback does not allow students to fully realise the impact of e.g. bad attitudes and miscommunication on the company. These skills are not as easy to conceptualise and teach, since they cannot be taught by instruction and human behaviour is almost impossible to model accurately.

4.3 Gamification's potential in learning factories

In such a case where instruction is inadequate, one should look to more innovative solutions such as gamification. Games could be used to accurately simulate real world interactions in the work place, the impact of clean workstations and reduced waste, the effect of human error and poor communication, as well as inter-racial and –linguistic conflicts. They would also provide a more motivating and stimulating learning environment, for topics which many students may find boring and obvious, yet lack the definite skills in. Learning factories already provide the practical skills, but adding this dimension of games and simulations provides the opportunity to teach shop floor management (including lean basics and the softer skills) that form a crucial part of any business today, in a fun and innovative way that keeps students motivated and engaged.

5 CONCLUSIONS

Stellenbosch University is currently in the initial planning phase of developing a learning factory in the Department of Industrial Engineering. The potential for gamification is clear, but whether or not it has a lasting effect remains to be seen although the trends suggest so.

To assess the effect of gamification within the learning factory, a learning module will be developed for the addition of gamification into the Stellenbosch learning factory. The still conceptual plan is to design a gamified module for "Shop floor management" to teach lean basics as well as soft skills. The game will be designed and implemented into the module by means of scientific or experimental validation. In such a validation procedure, one has a control group and a test group. In this case, the control group will be a group of students who partake in the module in the basic learning factory without gamification. The test group will partake in the gamified version of the module, still within the learning factory. The two groups will then be assessed to determine whether the addition of gamification had any impact on their understanding and results.

The full potential of a more constructivist teaching approach can only be reached if both teaching and assessment methods are redesigned. It is the aim of this project to assess the potential of gamification in the learning factory, and contribute to the redesign of the learning environment at Stellenbosch University.

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7 BIOGRAPHY

Tanja von Leipzig obtained her B.Eng degree in Industrial Engineering from Stellenbosch University in 2014. She is currently a Masters student in the Department of Industrial Engineering, with her specific area of focus and research being that of gamification: the use of games and game thinking to motivate and engage learners to enhance their learning.

Konrad von Leipzig obtained both his B.Eng and M.Eng degrees in Industrial Engineering from Stellenbosch University. He later also completed a B.Comm degree. He has been a lecturer at the Department of Industrial Engineering at Stellenbosch University since 1987. He forms part of the team undertaking the initialisation and realisation of the Learning Factory in Stellenbosch. His research areas include process management, supply chain management, logistics and financial management.

Vera Hummel, Prof. Dr.-Ing., Dipl.-Ing., has been a professor at the ESB Business School, Reutlingen University since 2010. Previously she held leading positions at the Fraunhofer IPA in Stuttgart, the working area Industrial Engineering, and the Graduate School of Advanced Manufacturing Engineering at the University of Stuttgart. She is currently leading the expert group in logistics at Reutlingen University. She is a founding member of the “Initiative of European Learning Factories” founded in May 2011 at the TU Darmstadt and the initiator of the “ESB Logistics Learning Factory” at Reutlingen University.