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A framework of innovative learning for skill development in complex operational tasks

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ABSTRACT

As today's oil and gas projects are becoming larger and more complex, project managers are constantly faced with a number of concerns about schedules, budgets, productivity and safety. Operating an oil and gas facility is a process where workers refer to technical specifications to obtain the right information, identify the components, and then make a decision as to the adjustment or correctness. This entire process is iterative and triggers a learning process which may lead to improved proficiency as the cycle is repeated. The inability to find the right information or sequence within a cycle can contribute to efficiency losses. Jobsite training offered by qualified organisations and associations for the oil and gas industry is very limited, and the relevant training facilities and centres that have been established or considered in the construction agenda are far from sufficient to the growing standard of operators and industry expansion. This paper, underpinned by advanced innovative visualisation technologies, proposes a framework to improve efficiency and expedite the process of developing the complex procedural skills in operating and maintaining oil and gas facilities, through identifying scientific principles of enabling complex procedural learning approaches, developing proficiency-based learning approaches and corresponding learning curricula, and appraising learning outcomes according to developed skillset taxonomy. The proposed framework is tested under the development of an innovative and immersive Augmented Reality/ Virtual Reality training system, which reveals significantly pragmatic benefits in terms of boosting up workforce productivity while bringing down rework. It is also demonstrated that embedding paradigms of transformative learning process while pedagogically adopting Information Communication Technologies (ICT) in curricula development and assessment regimes can help the sector significantly improve workforce safety.

1. Introduction

The rapid expansion of worldwide oil and gas industry has resulted in construction of a large number of Liquefied Natural Gas (LNG) projects since the last decade [1,2,3,4]. Within a couple of years, the current number of LNG training facilities will be far too few to handle the industry's increasing demands for skilled labour; further exacerbating the problem [5]. On the other hand, as maintaining and operating complex LNG facilities is hazardous work, industry is highly concerned about workplace health and safety. Although the oil and gas industry enjoys an excellent reputation for workplace health and safety, there are often major consequences of committing even a small error during the construction or operational phases, as indicated by the accident statistics [6,7]. It is therefore important that employees are aware of safety protocols within a workplace and know how to achieve a safe and productive operational environment [8]. However, it has been observed that industry has a very limited ability to analyse and understand the impact of different task settings with regards to productivity and safety issues [9].

To gain hands-on skills and practical experience in a recognised qualification in such sector, traineeships should usually be task-oriented or entitled to both off and on the job options [10]. For instance, as safety experience is often acquired through on-the-job experience [11], without jobsite training settings, some of the inherently dangerous factors cannot be readily identified. The efficacy of off-the-job approach is critically subject to a series of factors [12], for instance:

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whether companies open sufficient training facilities; are those training facilities with restrictions on time and space allowance, investment, and expert knowledge. On-the-job training options though, are relevantly impractical, given that a real field scenario may be logically difficult and dangerous to be operated by a less well-trained worker, or unduly expensive to shut down a part of the site as part of a learning course. The fact, unfortunately, is that there is still a lack of established training facilities and effective training approaches across the industry. On the other hand, given the large and complex amount of assets to operate and maintain the resources and efforts allocated to developing an advanced and organized training program could be significantly massive. In this sense, the industry-specific needs, for example, compliance with health, safety, environmental and operational standards, require a high level of understanding on what training metaphors are required for delivering effective learning outcomes. However, it is still ambiguous for the entire sector to justify what training metaphors can facilitate effective knowledge acquisition.

2. Literature review

To foster efficient skill development through training, there are vast amounts of research work demonstrating very promising approaches [13,14]. Among these approaches, the mixed-reality technologies, such as Virtual Reality (VR) and Augmented Reality (AR), offer unique new viewpoints on the core goals of training and education [15,16,17]. What distinguishes VR and AR from all preceding training technologies is the sense of immediacy and control created by immersion: the feeling of “being there” or presence that comes from a changing visual display dependent on individual's movements [18]. A brief overview of existing mixed-reality research on training, skill transfer, education, and procedural and cognitive learning vastly demonstrates the promising facts of mixed-reality paradigms [19].

Operation and maintenance of oil and gas facilities, however, is a more complex process which refers to an operational iteration to fulfil the function of equipment. In an oil and gas context, this process requires high-demanding manipulative skills, creative problem solving strategies, risk taking, decision-making, consciousness of occupational health and safety, and is normally conducted in dispersive positions in different climates [20]. Although visualisation-supported learning has been shown to be an effective way to reduce cognitive load and enhance learning outcomes [21], the antecedent research has not bridged a critical research gap, which is how to apply such an approach to facilitate complex procedural skills learning, given the difference between complex procedural training and generic training. Prior research has vastly shown that VR and AR scenarios are effective for learning basic skills in the practice of construction, engineering and medical science [22,23,24], however, principles derived from simple skills training do not necessarily generalise to more complex skills such as identifying risk factors and troubleshooting complex faults. Therefore, the commitment to the utilization of mixed-reality technologies is still relatively infantile in complex procedural training and skill development realms such as oil and gas operation and maintenance.

Generic training that aims at teaching easily transferable skills values a realistic experience through simulating real-task scenarios (technological advancement of developing a training system) [25]. However, in more complex procedural task training, devising appropriate curricula with underlying valuable human factor insights is so important because it underlines the fact that individuals perceive and interpret the same circumstances differently depending on their personal attributes and how they cognitively make sense of their surroundings. This comes up with another research gap: although studies have demonstrated the beneficial effects of novice training using VR and AR simulators, there is still no consensus regarding optimal training curricula and underpinned human factors for complex procedural training. In an oil and gas context, primary principles for productive and safe operation and maintenance are concerned about a variety of factors such as task proficiency, time consumption, error rate, motivation, mental workload and so on [26]. As these factors are of significant relevance to human behaviours, this project needs to derive a proficiency-based “mixed-reality scenario to real-world scenario” cognitive learning model. For example, when an operator is asked to behave someway, the investigator will apply “espoused theory” and “theories-in-use” [27] to interpret the action he plans to do under certain circumstances and account for his subsequent actual behaviour. If inconsistency occurs, a number of contributors from human factor perspectives will be adduced, as the focal point of inquiry, to expound this inconsistency. To this end, a cognitive learning model that accounts for level of alertness, awareness of hazards and other distractions will be explored to develop proficiency-based learning approaches, where the amount of immersion which stretches from mixed-reality displays to a completely synthetic world (with haptic and sensory feedback) will mimic same factors of the real-world. The proposed training curricula will accordingly highlight the need to determine unsafe working conditions and acts associated to an activity, and identify areas where prevention efforts should be made for more effective accident prevention skill development. Therefore, this paper will establish and validate structured mixed-reality curricula to provide evidence-based learning approaches for improving efficiency, effectiveness, and safety through complex procedural training programs.

Given enormous complexity of an oil and gas context, developing mixed-reality training programs and curricula requires comprehensive knowledge and understanding on oil and gas operation and maintenance and mapping of practical task settings to mixed-reality learning environments. Bring these two areas more closely together is another research gap that the proposed framework must address in order to effectively design and utilize these learning environments. A feasible approach is forming a collaborative design team (researchers, industrial practitioners and game developers) to synchronize the designing process of complex procedural tasks, task environments, human factor issues and pertinent mixed-reality systems. To illustrate, complex procedural skill development from mixed-reality environments leans heavily on trials and allow for risks and errors, therefore, the design team will structure learning environments that learners are offered the opportunity to engage with contents based on real world issues, to test learning outcomes, and to develop greater expertise through addressing complex procedural problems. Last but not least, there is also a need for the proposed framework to scientifically validate the learning outcomes in this relatively new research area. Without strong performance measures, the outcome in terms of knowledge learned and ability to transfer newly acquired skills to the real world practice is unknown.

3. Framework development outline

The ways in which the training communities define procedural skills of the targeted industry are fundamental to understanding how the learners form their learning mechanisms. In this regard, the framework proposed will investigate varied human factor and learning related theories, including procedural learning, visual-spatial skills development, and generic decision-making mechanisms. To this end, this paper aims to contribute towards the development of new learning approaches to significantly improve the productivity and safety of oil and gas workforce, which ultimately provide paradigms of transformative learning process of pedagogically adopting technologies in national curricula development and assessment regimes. Based on the above-mentioned research gaps, the focus of this framework is therefore on what strengths will be well matched to the capability development of operators for complex procedural activities, and what training and learning settings are appropriate for a trainee to develop particular skills. Understanding these questions has great significance in training novice operators who are supposed to apprehend the knowledge of what and why to do (domain knowledge), how to decide what to do and when (strategic learning), and how to do (procedural knowledge) [28].