Technological University for Dublin

Re-imagining our curriculum

Consolidating the First Year Experience

Prototype Project Updates:

January 2016

General Details	
Project Title	**Realisation and implementation of a testable prototype of a web-based stimulating learning system for construction engineering**
Name of Main Applicant	Garrett Keenaghan
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Signed	
Date	28-01-2016

TU4D Theme (Please tick)

- ☐ **Induction/early orientation**
- ☐ **Peer mentoring**
- ☐ **Graduate Attributes**
- × **Learning spaces – virtual & physical**
- ☐ **First 5,6 or 7 weeks;**
- ☐ **Assessment and feedback;**
- ☐ **Students/ autonomous self-directed learners,**
- ☐ **Alternative Curriculum models**

Summary of Prototype project (max 200 words)	This project is based on the implementation of a testable prototype of a web-based stimulating learning system (WB-SLS). The multi-enabler-based WB-SLS addresses the current pedagogical and technological challenges of self-managed socialised on-line learning of construction engineering and intends to reproduce an immersive environment and to offer a student-centred knowledge and skills acquisition approach.
Project dates	September 2015 to June 2015
Main proposed original project outputs for the TU4D (max 100 words)	This project proposes to identify innovative digital game and 3D modeling software to provide visualisation of semantic information in a 3D virtual world. It is this researchers intention to provide an online learning space that allows construction engineering learners to develop higher level problem solving skills through virtual environments scenarios equal to existing face to face training.
Project outputs including any evaluation data (max 300 words, data to be included in an appendix but can be summarised here)	As a result of the time and energy digital learners devote to engaging with technological enablers it is appropriate to explore the power technological, social and cognitive enablers have to motivate and engage students. Research literature that linked engagement and motivation to effective learning has led us to explore the use of technological enablers in the form of game engine and 3D modelling software as a potential means for blending with social and cognitive enablers. This is not to be confused with using game theories as a means of providing motivation and engagement but rather it is about using the technological enablers (game engine and 3D modelling software) as a means to provide digital savvy dislocated and co-located users the ability to practice and achieve (i) goal setting tasks, (ii) interpersonal relationships and (iii) problem solving when blended with

	social and cognitive enablers.
Lessons Learned (max 200 words)	The overarching feedback included comments relating to (i) visuals, (ii) interpersonal networking, (iii) design framework and (iv) identify other disciplines that can benefit from the WBS-LS design. In general it was felt that the visual graphics are good requiring little need for improvement. The interpersonal networking seems overly complicated and may require a set of help tools. There is a need for a clear design framework such as workflow diagrams which will assist others develop other learning scenarios in subjects such as levelling and surveying.
Next stage(max (max 200 words)	The objective of this ongoing research is to create a novel web-based education system that: (i) reflects real world procedural actions, (ii) provides a mechanism to encourage the development of higher level problem solving knowledge gain, and (iii) enables learners dislocated in multiple locations to experience perceptive, immersive, and pervasive learning.
	The next phase of this research is the challenge of testing the prototype WB-SLS. The aspirations for the design are to engage students in complex problem-solving in a multi-level, scenario-based WB-SLS. The process will begin by presenting users with alternative scenarios for real life operations and events in the refrigeration process (i.e. list the basic elements of the system or show operation process) and then integrating the context of those scenarios into constructing a set of real classroom instruction. A learning scenario design is based on a learning module in refrigeration engineering. The learning module scenario will then be tested by volunteer users and validated under a controlled set of scientific criteria to determine if we have met our stated objectives and satisfied the research hypothesis.

Research Background

A review of literature as far back as 1938, uncovers the ongoing debate about traditional versus progressive education [1]. How to design and deliver progressive education is exercising the minds of educationalist, students, parents and policy makers. The motivation is twofold, (i) the generation divide, and (ii) the need for improved performance of mankind. The objective of this research will indirectly contribute to the current debate on how technology use and current student interactions with same leads to progressive education. The origins of this investigations stems from the need to keep dislocated construction engineering students engaged in procedural activities normally carried out on site by their co-located peers.

Game research is a rapidly growing area in education. One specific area of game research has been devoted to examining (i) whether, (ii) how, and (ii) what, students learn from entertainment games (e.g., SimCity, World of Warcraft). Entertainment games offer virtual simulated environments that enable the application of cognitive knowledge and practice of psychomotor skills in an interactive way [2]. They simultaneously remove the potential to expose participants to a high risk process [3]. Computer technology is increasingly using game engine platforms to simulate real life scenarios. The high level of interactivity is promoted both through social and work based virtual encounters. 21st century students are more and more being referred to as digital learners. The evidence indicates the main gap is that 20 century educators think and use technology as tool while digital learners use technology as a foundation base of everything they do.

There is also growing research evidence demonstrating that, with the advancement of visualisation and virtual reality (VR) technologies, comes the provision for cognitive stimulated learning to enhance the digital learner's experience [4]. Teaching and training for construction engineering (CEE) using computer simulations of buildings although recently developed is not new. Established evidence based theories of learning are now recognised as central to the development of learning practice across all fields of learning activity [5]. Computer technology is increasingly using game engine platforms to simulate real life scenarios. The high level of interactivity is promoted through social and work based virtual encounters. The challenge for CEE is to provide a framework for the delivery of the underpinning knowledge that enables both the co-located and dis-located students to become trained in real world work practices and procedural skills.

Today's advancement in VR technologies has resulted in the practice of virtual construction becoming a widely accepted planning and design technic in the AEC industry [6]. CEE has been researching the concept of using VR for a number of decades. The past few years has seen an explosion of data in the applications domain and theories concerning the human factor [7]. With high investment by industry, technology is now providing very realistic models for almost every real life scenario further enhancing the benefits game engine technology brings to CEE [7]. For the moment, a relatively small minority of CEE professionals (human users) are using VR technology. VR technology provides "a connection between theory and practice on site" and is used as a practical tool on construction sites to: improve collaboration, co-ordinate and plan future activities, reduce lead time and speed up information flow [8]. Virtual construction of a project provides a greater understanding of the multidisciplinary design decisions and how these affect each other. As a result of advances in mobile technology and ubiquitous network connections the construction process has become more intelligent and is utilising VR technology [9]. The changes in how the AEC conduct business have come about as a result of (i) the need for sustainable construction technics, (ii) Government regulation, (iii) competition to provide efficient and quality products and services, (iv) requirements for a knowledge economy and (v) energy conscious end-users/stakeholders [9].

Gamification of education happens for two reasons: (i) presentation of educational content, and (ii) facilitation and delivery of educational process. The accepted definition for gamification is applying game like operations to existing content. This manifests itself in the addition of a scoring system, varied levels of difficulties, leader boards and points to make the content interactive and improve user experience. Video games and virtual worlds excel at engagement [10]. The overarching evidence indicates that both the AEC industry and the CEE sectors are experimenting with a wide range of computer supported technology. There is evidence on the effects advanced computer systems are having on both the education sector and the practicing industry sector. Initial surface findings have concluded that research into what are the optimal computer support systems for CEE is lacking and warrants some focused investigation.

Specification of research problem

The aim of the research project is to aggregate knowledge for and to develop an effective web-based personalized system for distributed construction engineering education using technological, cognitive and social enablers. This is pursued to enhance real life learning experience in a construction discipline using virtual environment stimulation. The motivation for doing the presented research and initiating the development of a novel web-based system came about as a result of the challenges, problems and issues experienced in relation to a construction engineering discipline, refrigeration maintenance, which requires learners to develop higher level problem solving skills and to demonstrate their knowledge through procedural actions.

1.1 Overall research objective

The overall objective is to answer the following question:
Can 3D learning application be further developed to become complex edugame?

This leads to a number of sub-questions as follows:

1. Can such a developed edugame provide multiple, unpredictable scenarios?
2. Can such an edugame also engage the students both cognitively and affectively?
3. Can such an edugame enhance the problem-solving skills of learners within procedural action based disciplines of construction engineering (which require higher level problem solving thinking)?

Therefore, the concrete objectives for this research are;

1. To learn more about the observed phenomena and to explain its relationships and behaviour.
2. To conceptualize an approach and a framework for a novel support system/
3. To create a novel web-based education system that reflects the procedural actions of a real world construction engineering discipline (refrigeration maintenance).
4. To provide a mechanism that will encourage the development of higher level problem solving knowledge gain.
5. To enable learners dislocated at multiple locations to experience perceptive immersive pervasive learning.

1.2. Knowledge exploration, conceptualisation and research assumptions

The focus of knowledge exploration and conceptualisation of this research is on how to develop 3D learning applications for construction engineering disciplines that rely on: (i) procedural actions, and (ii) higher level problem solving thinking into complex edugames. The literature review revealed how virtual learning environments created to mirror procedural actions, enable the application of cognitive knowledge and practice of psychomotor skills [11]. The first assumption about the use of virtual reality (VR) environments for learning construction related procedural actions is; (i) the user can be exposed to high risk processes, (ii) maintain visual stimulation and (iii) eliminate all of the real world associated personal risk. In other words VR simultaneously removes the potential to expose participants to a high risk process associated with construction engineering disciplines [12]. The second assumption is that game engine software development kits (SDK) provide computer programmers with the means to (i) simulate real life scenarios and (ii) promote a high level of interactivity both through social and cognitive based virtual encounters. As a result today's learners are now known as digital learners. Therefore the third assumption is that digital learners use technology as a foundation base for everything they do, such as (i) read larger volumes of web page content and digital social media content compared to the amount of both text book and hard copy content. (ii) They are natural multitaskers when using multiple software platforms concurrently with interacting in real world activities.

1.3. The overall research design.

To obtain a more in-depth knowledge the following research approaches apply; (i) research in design (RID) context based on literature studies and critical analysis exploration, (ii) design inclusive research (DIR) based on tangible theories and concepts and (iii) Operative design research (ODR) based on prototype design and real world application for testing and validation.

1.3.1 Research cycle 1 (Aggregating knowledge about the studied phenomenon)

The studied phenomenon has been defined as:

> Integration of technical aspects of learning with cognitive and social aspects of learning is underexploited in current systems and practices.

The main focus of this cycle is to descriptive knowledge about what this phenomenon is, what forms it manifests itself in, and what its main characteristics are?

This involves identifying data from the following sources:

1. A state of the art literature review concerning the application of VR technologies in construction engineering education (CEE).
2. An analysis of the current trends and developments in current virtual reality technologies and systems.
3. An evaluation of their educational usability and effectiveness

1.3.2 Research cycle 2 (Investigation of influential factors and causalities)

The past few years has seen an explosion of data in the applications domain and theories concerning the human factor [13]. There is strong evidence that the practice of virtual construction is fast becoming widely accepted in the AEC industry [14]. The findings from this data also formulated the following assumption:

1. Researchers are investigating the concept of using VR for a number of decades
2. It is now possible to simulate real life scenarios
3. VR can now promote a high level of interactivity both through social and cognitive based virtual encounters.
4. Digital learners use technology as a foundation base for everything they do.
5. They read web page content and digital social media content more frequently than they read from hard copy text media and books
6. They have to be multitaskers and use multiple software platforms to interact between the real and the digital world.

The question of learning and how people learn best has been at the forefront of educators minds since learning and teaching began [15]. Information technology has forced users to take another look at learning space.

1.3.3 Research cycle 3 (Conceptualisation of an approach and support system)

Based on the theories deduced and validated in research cycles 1 and 2, a conceptual proposition to apply a conceptual theoretical design framework that involves the blending of the following theory sets was explored:

1. cognitive enablers theory,
2. technological enablers theory,
3. social enabler's theory.

The theoretical design framework was presented for testing to a group of experts. The design questions posed for the focus groups utilised the reasoning model from RC1 and presented in our state of the art review paper [16]. The research data from RC1 and RC2 provided evidence that current technology driven simulated education for CEE tends to be overly bias towards the technology platform [17]. The vision to develop a complex edugame stimulator consisting of multiple unpredictable events that both engages the users' cognitively and affectively, while enhancing their problem-solving skills within the construction engineering discipline of refrigeration, was proven to be novel.

1.3.4 Research cycle 4 (Prototype level implementation of the support system)

For research cycle 4 the focus was on the development of a testable prototype. The multi-enabler-based WB-SLS is designed to address the current pedagogical and technological challenges of self-managed socialised on-line learning of construction engineering students and intends to reproduce an immersive environment that offers a student-centred knowledge and skills acquisition approach. In order to test the effectiveness of our conceptual WBS-LS design we built a 3D learning application which virtually replicated the content and process of learning the procedural actions for the construction engineering discipline of refrigeration. Included in the design is the enabler design framework which assists learners to develop problem-solving and higher level thinking skills when presented with unfamiliar scenario problems. At the heart of this enabler design framework is a complex edugame with multiple, unpredictable scenarios which now needs to be tested in RC 5.

1.3.5 Research cycle 5 (Testing the prototype support system in real life context)

Research cycle 5 will focus on a field situated experimental study, a real student cohort studying the discipline of refrigeration in construction engineering education, will be selected. RC5 will conclude the entire research. At this point the theoretical expectations will be compared with the empirical observations and the influencing factors evaluated. This practical justification process will be conducted through the experimentation which requires the real-life implementation of the simulated virtual learning experience. This will make it possible to test the impacts of the proposed system and methodology. The dual objectives of this part of the study are to test performance of the system and overall user satisfaction.

2. Research Methodology

2.1 Framing of the research

Though logically connected, each and every research cycle is a separate operational unit with its own objectives [18], the evaluation of the output from each cycle provided the opportunity to test the quality of the results and determine if the gap between the required and implemented characteristics of the cycle met with the stated objectives. In order to publish the results obtained through the whole research project a PhD thesis will be written. This thesis will provide an accurate account of the research data, summarise all the results and procedures of the research and present for analysis and grading to a group of jurors. Journal articles and conference papers have been written to share the main findings of the project. The presented methodological approach substantiates all design decisions with documented theories. The bringing together of references to theories in design inclusive research (DIR) enabled the researcher to anticipate the characteristics of the design. Analysing and evaluating aggregated knowledge simulated theory development and also provides a link between DIR and theoretical research. Figure 1 demonstrates how the research cycles afforded the opportunity to trace, revise and enhance design decisions throughout each of the research cycles.

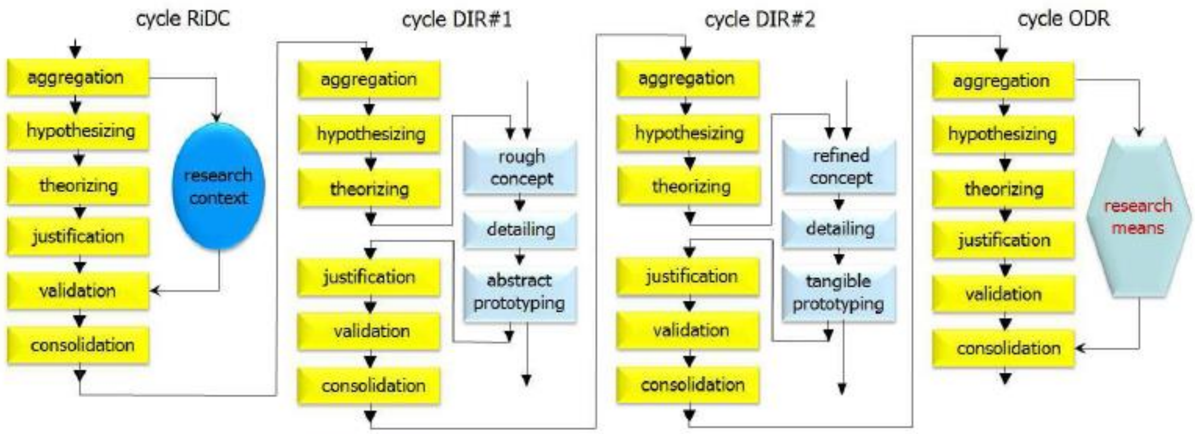

Figure 1; Example for alternative methodological framing of subsequent research cycles in a research project (Horváth, 2013)

Adhering to the above methodological framing strengthens the validity of the research findings. This methodological guidance resolved conflict between differing constructed definitions in various versions of theories thereby provided a stronger link between the design research and the empirical research domain.

2.2 Prototype Development

The WBS-LS system includes more than just the latest technologies and system operation architectures. Actually, it blends various technological and non-technological learning enablers, and considers the personal characteristic and learning style of the individual and community of user's. That is the reason why our research addressed the issue of educational enablers in a broader perspective. Rather than focusing only on the technological ones, we identified complementing enablers, which can effectively engage digitally literate students in problem-driven learning processes, considering their individual needs, capabilities and circumstances.

The system is required to provide a seamless integration of these enablers. It is our contention that the main requirements of the enablers are to (i) motivate students, (ii) provide perceived usefulness (iii) ensure rich knowledge transfer, (iv) enhance problem-solving and (v) develop higher level thinking skills when presented with unfamiliar scenario problems. Obviously, the level and format of stimulation provided by the WB-SLS will vary as it is very much dependent on the human user's perception and psychological state of mind. A crucial issue for the implementation of the multi-enabler based system is to realise that digital learners are not specifically about the technology, but are more about the activities and experience that the technology provides [19]. Implemented by using a commercial programming environment, the proposed WB-SLS relies on a specific methodology that synthesizes the abovementioned enablers. This is shown in Figure 2. On the other hand, this scheme can be interpreted as a reasoning model concerning the development process in as much as it allows us to transfer the need as stated in the beginning of this paper to a first workable concept. The key to this reasoning model is to ensure the pedagogical integrity is maintained when utilising technological enablers for stimulation of procedurally-based construction engineering activities. Our conceptual framework is intended to provide student learning and virtual stimulation of the senses equal to the experience of participating with normal face to face (F2F) delivery of classroom-based workshops. It has also been considered that game engine technology can support virtual learning simulation based on realistic problem scenarios, as it is known from the literature. The literature has determined that, as a technological enabler, the SDK for web-based digital game platforms can provide us with the means to produce (i) visuals, (ii) control, (iii) communication, (iv) interaction, and (v) perceptive immersion for our virtual workshop.

In order to provide virtual stimulation of the senses equal to F2F experience we used digital photography and recordings to capture the look and sensation of real time interactivity, figure 3. Because most, if not all, handheld mobile devices have a digital camera embedded in them, digital learners use this technological enabler to share visual experiences with their peers across a range of interpersonal networked web-based platforms. Therefore it is our contention that digital images have an influence on (i) human perception and cognition, (ii) human condition, motivation, emotion and experience and (iii) that this influence is universal to digital learners because such images are networked across web-based systems frequently with little effort. Another reason for using the digital camera which is a technological enabler is because of its influence on cognitive and social enablers for digital learners.

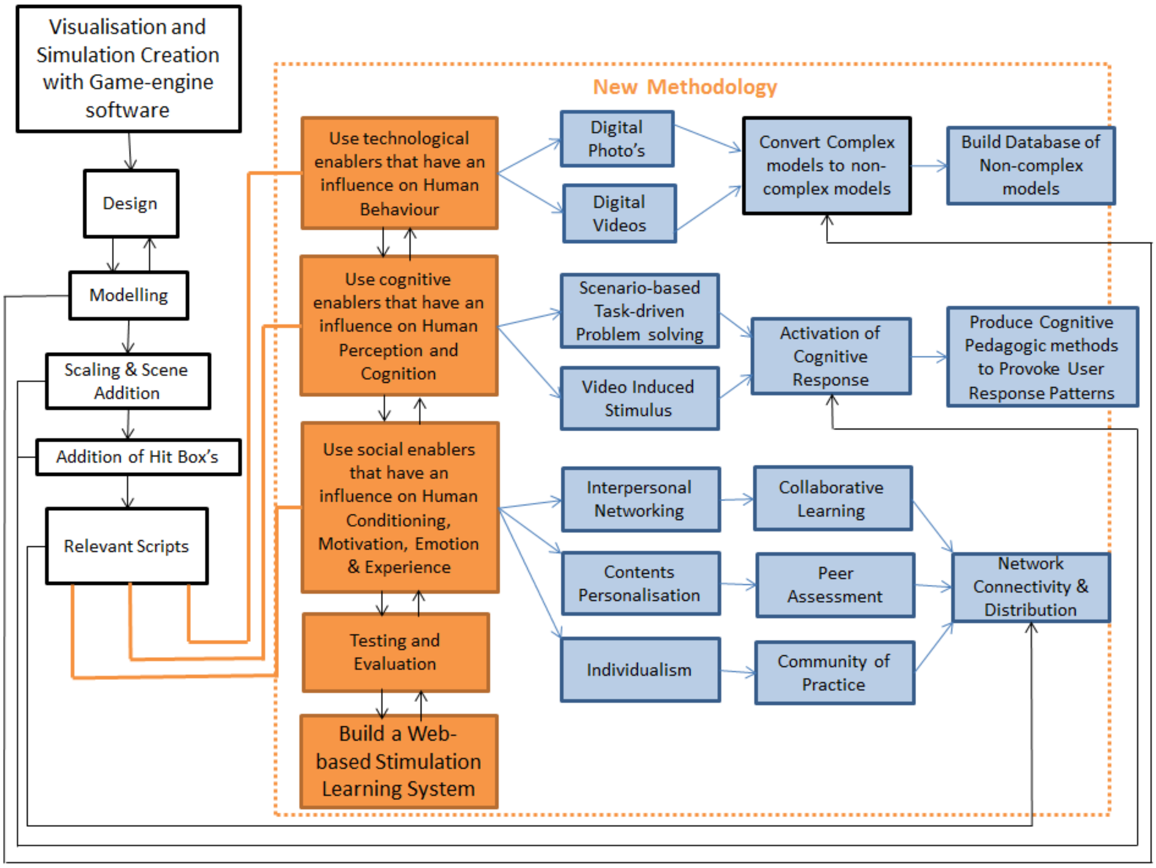

Figure 2: High-level enabler integration and processing model of WB-SLS

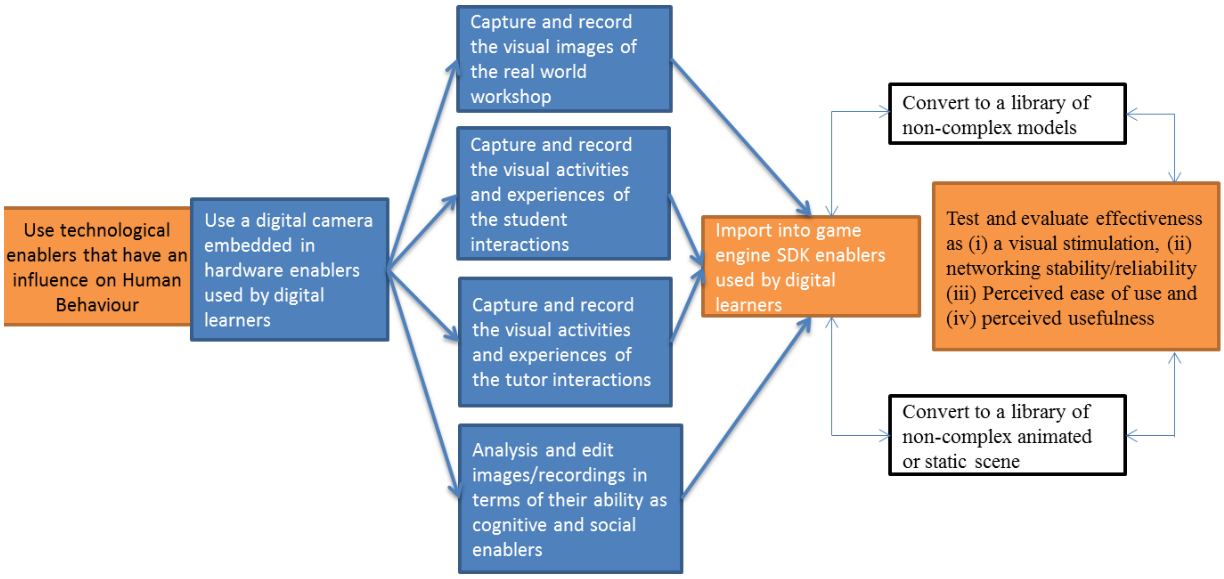

Fig 3; Technological enabler's workflow

From the developed and emerging cognitive enablers, figure 4 demonstrates our cognitive enabler workflow which considers the use of (i) learning induced stimulus (conceptual), (ii) task driven problem solving (procedural), (iii) active participation (meta-cognitive) and individual response patterns (strategic).

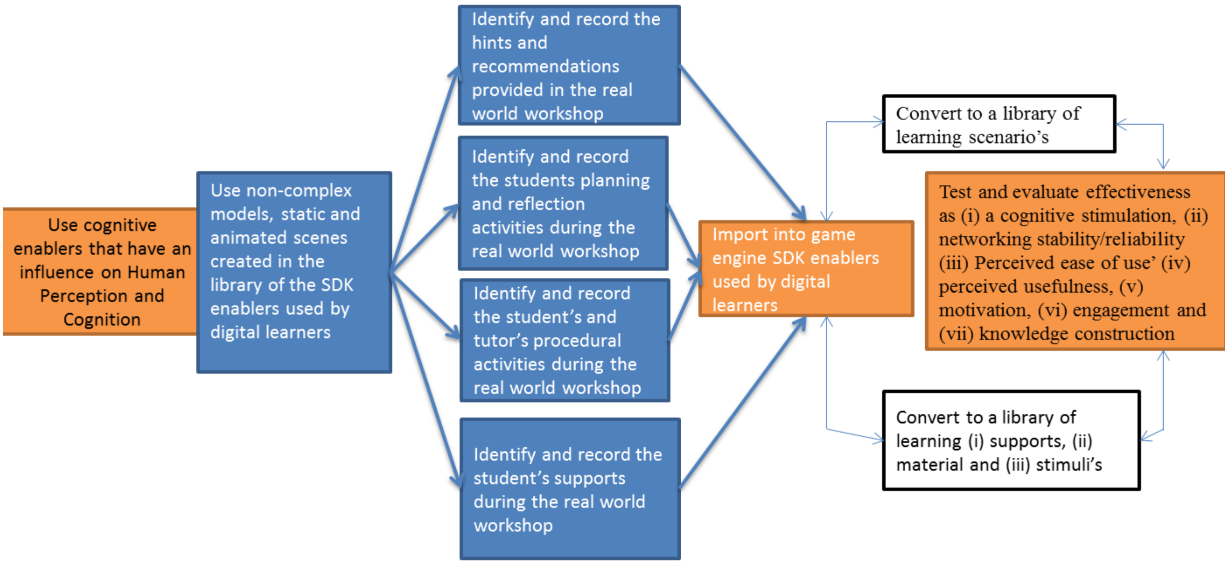

Fig 4; Cognitive enabler's workflow

Online video is a popular form of stimuli's as a social media enabler and is often used both in the classroom and outside of the classroom when students need to gain further information [20]. Ubiquitous web-based networking is strong enough to support and provide a web-based infrastructure network that is capable of (i) receiving various types of content from the users and (ii) supporting communication among large volumes of users thereby supporting the formation of autonomous virtual communities [21]. Research has proven that social media sites add value to teaching and learning [22]. Figure 5 continues with our workflow and in this case demonstrates our social enabler workflow.

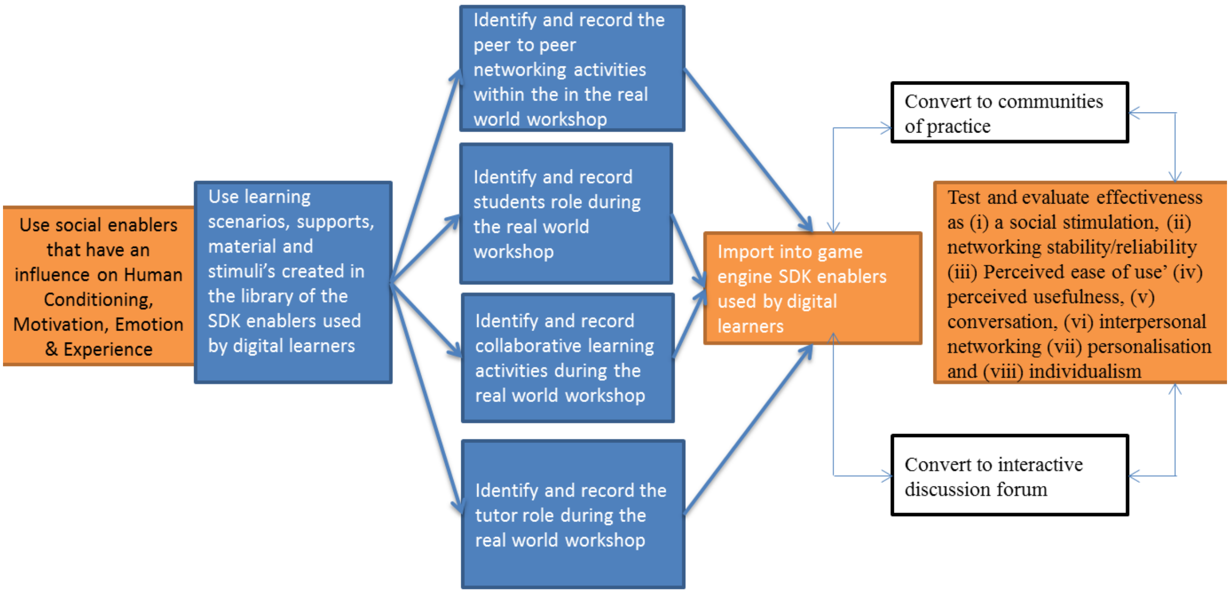

Figure 5; Social enabler's workflow

2.3 Research completed to date

The first four research cycles have been completed and a prototype WBS-LS created. This was constructed using a game engine software platform mashed with cloud based technology. To extend this towards becoming a knowledge and skills acquisition model the additional enabler design framework was applied. The proposed theory set and design framework have been presented to a second expert group for validation. The major assumption presented in RC4 is that the novel system blends various learning enablers, and takes into consideration the personal characteristic and learning style of the individual learners. In addition to the current educational trends and developments in construction engineering education, the investigation into the notion of enablers provided an opportunity for the system design to differentiate between technological, cognitive and social enablers, to effectively engage digitally literate students, consider their individual needs, capabilities and circumstances.

The conceptual framework of the novel system has been designed so as to be able to provide a stimulating learning experience for dislocated digital learners, who are seen as individuals with different perceptions and expectations. In addition to functionally integrating technological, cognitive and social enablers, the system also encapsulates what can be called the principles of cyber psychology. An early evaluation of the effectiveness of the proposed system concept has been made. The first results are promising, but attention must be given to implementation details such as real-time content management, fluency of students' interaction with the system, adaptation to the individual student needs, and the depths of engagement of the students in the highly socialised learning process. These will be considered in the fully-fledged full-scale prototyping of the system, which is on its way now. Future work will focus not only on the prototype-level implementation of the system, but also on the study of its impacts and the increase of efficiency in distributed construction engineering education. The final cycle must now be completed, as indicated in table 1.

Task	Action	Outcome	Status
Research cycle1	Knowledge Gap Exploration	Paper: State of the Art… literature review TMCE 2014,	Complete
Research cycle 2	Causalities	Paper: Using Game Engine Technology … STET 2014,	Complete
Research cycle 3	Conceptualisation	Article: Developing an edugame… Level3 Dublin 2015 Article: Enhancing real life construction…. Knowledge Symposium, Level 3 Dublin 2015 First steps towards a Blended enabler based…. EJEE 2016	Complete Complete Under peer review
Research cycle 4	Prototype Development	Implementation of a prototype of a web based….. TMCE 2016	Under peer review
Research cycle 5	Place in Real World	Testing the impacts of the proposed system and methodology	Under design

Table 1: Summary of research completed to date.

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