SERIOUS GAMING APPROACH FRAMEWORK FOR CONSTRUCTION HAZARDS IDENTIFICATION

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DEDICATION

بسماللهآلرحمنآلرحيم
سبحانالله..... الحمدالله..... اللهاكبر

To my beloved family:
Mama (Wan Hanisah Wan Hassan)
Abah (Mohd bin Mat Hassan)
My little brothers (Ammirul Muhayat, Amirnur Azam and Ammarshah Aidil)
Affizan, Suria, Izzad, Shahanie and Iman
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ABSTRACT

Construction-related workers are always exposed to occupational hazards on a construction site. Hence, safety training is inevitable to reduce the alarming rate of accidents on sites. However, due to the nature of construction environment which is hazardous and harmful current safety training is still lacks hands-on approaches. Training assisted by affordable technology such as serious game would be an effective tool to improve learning and has become a new approach to training delivery. It offers safer, interactive and entertaining learning environment for the construction-related workers. Therefore, the aim of this study is to develop a serious game framework for hazard identification training module. To develop this framework, the Garris's Input-Process-Outcome game model is adopted as the foundation and five objectives are laid out. The first objective is to determine the most suitable instructional design method and the second objective is to determine serious game attributes to support the effective learning. Through content analysis methods, the findings show that there are 12 attributes of the serious game and Gagne's Nine Events Instructional Methods Design is able to support an effective learning. The third objective is to understand user characteristics. Data was collected from 319 construction-related workers using questionnaires and analysed using mean comparison and ANOVA. Findings confirmed that they belong to independent learners' category and inclined to 'vigilant' and 'brooding' types of decision-making style. These objectives become the basis for Input phases of the framework. The Gagne's instructional method also laid out the learning expectation for Outcome phase i.e. skills, cognitive and affective learning. The fourth objective is to design the process of hazard identification. Through content analysis, Recognition-Primed Decision making model (RPD) is chosen and merged with hazard identification process and hierarchy of control to establish the Process phase of the framework. All the findings are incorporated to achieve the fifth objective which is to develop the serious game framework. The framework is validated by three experts specialised in education, construction safety, and information technology. They agreed that this framework would be able to enhance learning in term of skills, cognitive and affective learning. Finally, this serious game framework will provide a safer, more affordable and interactive as well as entertaining for hazard identification training delivery in the construction industry.

ABSTRAK

Pekerja berkaitan dengan pembinaan sentiasa terdedah kepada bahaya pekerjaan di tapak pembinaan. Maka, latihan keselamatan adalah tidak dapat dielakkan bagi mengurangkan kadar kemalangan di tapak pembinaan. Namun, oleh kerana sifat persekitaran pembinaan yang berbahaya dan memudaratkan, latihan keselamatan kini masih kurang pendekatan secara amali. Latihan berbantu teknologi mampu milik seperti permainan serius merupakan kaedah yang berkesan untuk meningkatkan pembelajaran dan telah menjadi satu pendekatan baru bagi menyampaikan latihan. Ia menawarkan persekitaran pembelajaran yang selamat, interaktif dan menghiburkan untuk pekerja berkaitan pembinaan. Oleh itu, tujuan kajian ini adalah untuk membangunkan satu rangka kerja permainan serius bagi modul latihan pengenalpastian bahaya. Untuk membangunkan rangka kerja ini model permainan Input-Proses-Hasil oleh Garris telah dijadikan asas dan lima objektif telah digariskan. Objektif pertama adalah untuk mengenalpasti kaedah rekabentuk pengajaran yang sesuai dan objektif kedua adalah untuk mengenalpasti ciri-ciri permainan serius untuk menyokong pembelajaran yang berkesan. Melalui kaedah analisis kandungan, hasil kajian mendapati 12 ciri-ciri permainan serius dan Sembilan Kaedah Acara Pengajaran Gagne boleh menyokong pembelajaran yang berkesan. Objektif ketiga ialah untuk mengenalpasti ciri-ciri pengguna. Data telah dikumpulkan daripada 319 pekerja berkaitan dengan pembinaan menggunakan borang soal selidik dan dianalisis menggunakan perbandingan min dan ANOVA. Dapatan mengesahkan bahawa mereka tergolong dalam kategori pelajar yang berdikari dan lebih cenderung kepada gaya ‘berwaspada’ dan ‘bimbang’ dalam membuat keputusan. Kesemua objektif ini adalah asas kepada fasa ‘Input’ bagi rangka kerja. Kaedah pengajaran Gagne juga menggariskan jangkaan pembelajaran bagi fasa Hasil iaitu kemahiran, kognitif and afektif. Objektif keempat kajian ialah untuk menentukan proses pengenalpastian bahaya. Melalui analisis kandungan, model Pengecaman Utama Pembuat Keputusan (RPD) telah dipilih dan digabungkan bersama proses pengenalpastian bahaya dan hierarki kawalan bahaya memantapkan fasa Proses bagi rangka kajian. Keseluruhan dapatan kajian kemudiaannya digabungkan bersama iaitu membangunkan rangka kerja permainan serius bagi mencapai objektif yang kelima. Rangka kerja ini telah disahkan oleh tiga orang pakar khusus dalam pendidikan, keselamatan pembinaan, dan teknologi maklumat. Mereka setuju bahawa rangka kerja ini boleh meningkatkan pembelajaran dari segi kemahiran, pembelajaran kognitif dan afektif. Akhirnya, rangka kerja permainan serius ini akan memberikan pendekatan latihan yang lebih selamat, mampu milik, interaktif disamping menghiburkan dalam menyampaikan latihan pengenalpastian bahaya.

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AR	-	Augmented Reality
CIDB	-	Construction Industrial Development Board
DOSH	-	Department of Occupational Safety and Health
HIRARC	-	Hazard Identification, Risk Assessment and Risk Control
IPO	-	Input-Process-Outcome Model
NDM	-	Naturalistic Decision Making
NIOSH	-	National Institute of Occupational Safety and Health
RPD	-	Recognition-Primed Decision making model
VR	-	Virtual Reality

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Hazard is the major factor that influences accident on a construction site (Khalid, 1996, Shafi et al., 2009). When a hazard exists, the probability of accident occurs become higher. People, equipment, materials and environment of working are agents that contribute to an accident. Hazard existed when one of the agents were combined (Khalid, 1996). Hazard is defined as "*a source or a situation with a potential for harm in term of human injury or ill health; damage to property and to the environment; or a combination of these*" (MS1722, 2005 , OHSAS18001, 2007). Meanwhile, danger can be defined as liability or exposure to harm or injury (Gould et al., 2005). With this, hazard becomes a symbol of danger.

1.2 Background of study

The general environment of working combined with plant and machinery on the construction site can create hazard that could expose all trade workers toward danger (Misnan et al., 2000). As an example, for a bricklayer, the bricklaying work mostly is done on or around scaffolding platforms. The workers are exposed to falling, tripping, being hit by falling objects and so on. This kind of exposure can create permanent damage or even worse i.e. death.

Although the presence of Safety and Health Officer (SHO) on a construction site is to manage the safety issues, workers are still exposed to hazard and the number of accidents still increased. The responsibility to control hazard should not be burdened on the Safety and Health Officer (SHO) only. It is the duty of each construction related individual especially the workers to understand, recognise and control the hazard. Hence, to ensure the working environment become safer, training regarding hazard identification is needed for the construction-related workers.

1.2.1 Overview of safety training in Malaysia Construction Industry.

Generally, in Malaysia, there are bodies such as Construction Industrial Development Board (CIDB) and National Institute of Occupational Safety and Health (NIOSH) that through government initiatives, conduct safety training for the construction industry. One of the CIDB roles is to provide, promote, review and coordinate training programmes organised by public and private construction training centres for construction-related workers and construction site supervisors (CIDB, 2007). Training provided by CIDB is known as the Contractor Continues Development (CCD) and Continues Professional Development (CPD). The aim is to enhance the knowledge, skills, experience and build personal qualities required in their duties (CIDB, 2010). Whereas NIOSH focuses on safety, which aimed to ensure the ability in understanding the working safety management systems at workplaces (NIOSH, 2013).

Through CPD and CCD programs, CIDB offers a few safety related training such as Green Card, Project Risk Management and Project Management for individual personnel's and contractor firms (CIDB, 2007). Similarly, NIOSH provides training such as Safety and Health Officer training; Hazard Identification, Risk Assessment and Risk Control training; Chemical Health Risk Assessment training and others (NIOSH, 2013). This training is not specifically for the construction industry; rather it provides the safety training for other industries as well. Mansur and Peng (2009) identified that there are five (5) types of safety

training provided by NIOSH which is induction, on-job training, competency, seminar, and forum. Induction is training which provides disclosure of information about the policies and regulations related to the industry. According to them, the cost for this training is very low. On-job training is also low in cost but more convenient in term of time. Seminar and Forum involve various parties and deliver the latest information related to the industry. On the other hand, competency training involves technical proficiency and hands-on, which requires longer training time and incur higher cost. Regardless of the various types of training, the approach in delivering them are still the same which are lectures, video demonstration and hands-on. Apart from competency training, other types of training allocate less attention on a hands-on approach. Undoubtedly, safety training requires more hands-on or practical based approach, but the nature of hazard itself restricts the implementation of a real-life scenario.

Safety training provided by NIOSH for construction industry can be divided into two categories which are non-competency and competency. The latter is only for construction personnel to enhance their knowledge. However, the competency training is more than that which at the end of the training the individual must sit for a test to get certified. Thus, the fee for training is more expensive. The module can be divided into two aspects i.e. theoretical and practical aspects. The theoretical delivered via lectures, but the delivery of the practical aspects consists of [1] group discussion and presentation, [2] workshops, [3] on-site hands-on and [4] test (Mohd and Ali, 2014).

According to the study that has been conducted by Mohd and Ali (2014) indicated that 62% of safety training focuses on theoretical aspect, and the rest is based on practical i.e. group discussion, workshop, hands-on, and on-site test. This is evidence that practical based has less attention than the theoretical aspects of training, which on-site hands-on has 7% amount of training time allocated only to the programmes. This is believable due to the nature of a certain hazard that is harmful to be practically implemented in real-life. Hence, many researchers have explored other methods to improve the delivery of the safety training especially on the usefulness of technology to develop a safety module (Assfalg et al.,2002 ; Choudhry

et al., 2008; Tichon and Burgess-Limerick, 2011). With the technology, training becomes more flexible in term of time, cost and experience (West and Slatin, 2009).

1.2.2 Technology for safety training

Technology application for safety training has been explored by many researchers (Tsay et al., 1996). The research interest on the benefit and usefulness of technology to be adopted in training has been increasing. In Florida (US) for example, they have developed a virtual-reality safety-training system for construction-related workers (Zeng et al., 2008). This program help worker to visualise hazards which cannot be visualised in term of the degree of risk, air quality, the level of chemical exposure and the effect of all those things (Xie et al., 2006). Ellis et al. (2006) have developed virtual construction environment using a combination of 3D modelling package and VR software package for hazard visualisation. This model focuses on a few components in construction building such as floor opening, floor edges tops of walls, wall openings, and portable ladders. The model helps workers to recognise hazards and the effects of those hazards. Plant operator training simulation has been developed using augmented technology. Simulations using augmented technology are created for heavy excavations and other plants that potentially have dangerous implication (Tichon and Driver, 2010). Combinations of technology have given great impact in visualising the things that cannot be seen.

Similarly, in the manufacturing sector, the new approaches to learning related to the identification of hazard in their workplace have also been explored. They have developed Computer Numerical Control (CNC) machining procedure using VR technology to build a virtual environment to train operators (Duffy, 2003). This CNC operator can identify more correctly a hazardous condition that is different from what was predicted by a human being (Duffy, 2003). At the same time, logging sector benefited from the advancement of 3D Technology which it is used to develop a hazard recognition training tools for a lumberjack. The aims are to increase the

levels of skills among the loggers and to reduce the numbers of death and injury rate in logging sector (Bryan, 2011).

Simultaneously, Mining Industry which is the most hazardous sector among all is also combining new technology to improve learning approach. This industry has become a leading industry that uses advanced technology to train their workers on how to identify hazards. Cai et al. (2011) have developed a simulation of a mining workplace to help workers to get the real experience about the consequences of the hazard using Virtual Reality (VR) technology. Similarly, Lucas et al., (2008) developed a plant operation simulation using Virtual Reality (VR) and Augmented technology for belt conveyor to control accident by reducing human error, improper maintenance procedure and recognise possible hazards. Application of this technology has allowed the mining industry in analysing the risk accident in a mining environment (Linqin et al., 2011; Kizil and Joy, 2001)

Although many of researchers agree that Virtual Reality (VR) can provide the best tools for giving the real experience visually in educating people about safety (Duffy, 2012; Tichon and Driver, 2010; Ellis et al., 2006; Xie et al., 2006; Hadipriono and E.Larew, 1996), VR technology required some high-end requirement of hardware and software which only researchers who have high budgets can apply this technology in their research (Ebersole, 1997). According to Filigenzi et al. (2000), the VR training system will cost USD 10,000, or even USD 100,000 for the mining industry. Thus, he highlights the use of affordable technology.

Affordable technology is a technology that can be developed using a simple software but is able to give the same experience that offered by other technology applications i.e. web-based training, learning via cd-room and game (Dickey, 2006). The web-based training like e-learning has been explored by CIDB in creating a new approach for providing distance learning environment such as virtual classroom, virtual library and etc. (CIDB, 2017). Meanwhile for learning via cd-room can be used offline as it has the capacity to store vast amounts of textual content (El-khouly, 2008), an approach that has been practised by NIOSH in their training delivery.

Hence, the gaming approach is still not being applied in the Malaysia construction industry.

In New Zealand, transportation department used affordable technology to develop a simulation of driving to measure the awareness and decision making among those new drivers in identifying hazards (Isler and Isler, 2011). Before getting the driving licence, they will be tested for their reactions on road hazard and how they make decisions to avoid an accident after they have identified the hazard (Chapman et al., 2002). These modules have been developed using video game-based and also computer-based interactive multimedia training (Isler and Cockerton, 2003) . By using this module, the novice drivers can react promptly when they exposed to the risk, this due to the train that has been received regarding handling hazard wisely (Fisher et al., 2002). Besides that, there are a few of safety game that has been developed for construction industry for example Tower game. This game was developed by RMIT to train diploma student about safety in the construction industry. However, in Malaysia game training module still unavailable. Thus, this module application proves that affordable technology can be used as a training tool.

1.2.3 Gaming approach in training delivery

Learning using gaming approach seems to be more productive and have been proven in term of cost and retention of knowledge versus conventional classroom teaching (Kirriemuir and McFarlane, 2004). Game tends to be flexible to different types of learning (Kirriemuir and McFarlane, 2004). It allows players to participate in activities that are too costly, too dangerous or difficult to be implemented in a real-life scenario (Kiili, 2005). Other than that, using simple software such as *Adobe Flash*, *Sploder*, *Game maker 8*, *Phrogram*, *RPG Maker XP* and *Pygame* make game development becomes affordable (Bennet, 2012). By using this affordable technology, affordable training module can be produced.

This types of games can create a more exciting and better interactive approach in the context of delivering complex or boring learning content (Prensky, 2005). As noted by Whitton and Moseley (2012), game can also enhance the process of learning in terms of playfulness, practice and engagement. This statement has been supported by Gee (2005) who holds the belief that games are designed in a way that triggers a deep motivation for learning. The vast majority of electronic games provide a highly structured environment with tutorials for players who are new to the game. Such games often break down complex tasks into smaller and more manageable tasks, which cater for the individual pace of each player and give immediate and continuous feedback along the way (Gee, 2005). Moreover, electronic games often require players to formulate the content and evaluate hypotheses, experiment with the outcome, which is a cycle of activities that are closely related to the learning process defined as 'experiential learning' (Kolb et al. 2001).

Gaming approach provides a competitive environment for players to achieve their goal (Girard et al. 2013). It also emphasises first, learning what to do, then how to do it. Using gaming approach can allow individuals to discover what they have to do in the game, not what they should do, by experiencing themselves (Kirriemuir and McFarlane, 2004). This approach will guide the discovery method of training that empowers individuals to solve the problems that arise in the game, which become a part of the training process. There are various types of game genre i.e. Adventures game, Action game, Role-Playing game, Strategy Game, Simulations Game, Sports Game, Fight Game, Casual Game, God Game, Educational Game, Serious Game, Puzzles Game, and Online Game (Michael and Chen, 2006). However, only simulation game, adventure game and serious game have been applied in a gaming environment for education and training purposes (Mujika et al. 2011; Kwon and Lee, 2016).

Simulation games attempt to mimic environment that present reality as a method of learning. They can be defined as representations of some real-world environment or imitation of a system and process that also have aspects of reality for

the participants (Ranchhod et al. 2014). Hence, simulation game has the potential to be applied in vocational training. As such, it has been adopted in many industries for CPD and training. It provides the appropriate learning environments that mimic reality and is often designed to engage the learners in situations that would be too costly, difficult or hazardous to be implemented in the real world (Gredler, 1996). One of the advantages of simulation is that it can promote strategic thinking by using repetitive learning methods (Bonk and Dennen, 2005).

Conversely, for adventure game, its purpose is problem-solving which focuses on giving commands or instructions. This kind of game genre can be described as story-based games that usually rely on puzzle-solving to move on along the action in a continuum as players proceed from one level to the next (Michael and Chen, 2006). It will train the player to give commands or instructions to solve arising problems. Commands or instructions can be given in textual or graphical forms and can be communicated from either a first-person, second-person or third-person perspective (Michael and Chen, 2006). In general, adventure game is not played in real time, unless it is an action-adventure hybrid game in which a player usually takes as much time as he wants between turns, and nothing happens in the game environment until he enters a command. More modern adventures are points and click, in which a player indicates what he wants to do by moving the cursor using the mouse around the screen. Players generally expect adventure games to have large, complex world to explore along with interesting characters and a good storyline. This is a mental contest game that follows certain rules and sometimes rules can be broken for amusement, recreation, or winning a stake (Ulicsak and Wright, 2010).

Serious games tend to be linear; the issues, problems and situations are always similar. The focus of these games is to train players on planning and decision-making strategies (Leng et al. 2010). They also tend to be more complex because of their nature being more immersive and focused on strategizing. However, serious games are more structured and well designed to allow learners to experience and practice their knowledge that is likely impossible to be done in the real world because of safety concerns as well as cost and time constraints (Girard et al., 2013).

As pointed out by Mitchell and Savill-Smith (2004), well-designed computer games can enhance a wide range of skills from psychomotor and spatial to analytical and strategic, and gain insights into learning and recollection capabilities, as well as increase visual selective attention.

For simulation, the design criteria must have some focus, specific and systematic steps. It is an immersive and complex approach that allows players to relate and apply their existing real-life knowledge in the simulation. For adventure game, the structure is also complex and heavy design because it wants to entertain, amuse and get the attention from gamers who want to challenge themselves by moving on to the more difficult levels and ultimately win. On the other hand, serious games are designed to give a real experience and hands-on training based on the real situation, so that the players can have a positive impact and further developed their skills.

Serious games are referred to as the type of games when the focus of such games is for training, advertising, simulation or education. This is because when comparing serious games with other computer or video games, serious games are not only about the story, art and software, but they are beyond that. They have the addition of pedagogy which means that in serious games, there are activities related to education from which players gain knowledge and skills (Zyda, 2005). However, pedagogy element must be supported by other elements i.e. art, story and entertainment.

It can be concluded that serious games offer various approaches and benefits as a training tool. With the elements of pedagogy, serious games provide the users with an objective that they want to achieve. The relevant objectives that relate to their business or situation will encourage them to achieve the objectives. Besides that, a serious game also presents information as nested problems through the story elements which can be designed according to the needs of the user. This will give the user motivation to complete the objective. In spite of this, the user has to actively get involved in the scenario to work out how to achieve the objective. Serious games can also utilise interesting characters and reward loops to keep user pushing forward,

which will lead the user to immersive into the scenario and become emotionally invested in seeing it through.

1.2.4 Existing serious game framework

In developing an ideal model for serious games for learning the engagement and learning element should be considered (Prensky, 2003). Learner engagement in learning can be enhanced by bringing in enjoyment element into the game training module. The previous study has suggested serious games framework, but still ambiguous and lacking in producing an ideal framework for the hazard identification training module. Garris et al. (2002) purposed the game model known as Input-Process-Outcome; the focus of this model is more on a cognitive approach which needs learners constantly re-engage within the repeated learning process. Due to that, Yusoff et al. (2009) believed that this framework will restrain active learning from taking place. Kiili (2005b) proposes a learning game model based on experiential learning theory by Kolb (1979). This model emphasis on problem-solving activity as a challenge to initiate engaged environment for learning the process, yet it is still lacking another pedagogy element such as reward attribute (Yusoff et al., 2009b).

De Freitas and Oliver (2006) have introduced a framework for supporting life-long learning known as "*evaluation of educational games and simulations*". This framework was designed to evaluate games that can be most effective in particular learning context including their specific subject areas (De Freitas and Oliver, 2006). Therefore, it only can be used at the beginning of designing game learning module only, not at its design (Westera et al. 2008). Hence, Amory (2006) proposes Game object model II, which focus more on design especially on interface requirements for the game, the challenges and the social space. However, Westera et al. (2008) argue that this model is too general and does not include gameplay and flow theory in designing the serious game (Kiili et al. 2014).

'*Eduventure*' is a framework for classroom teachings, this framework has been developing by Hu (2008) which learning process was designed according to use an adventure game. Basically, this framework was designed to aid classroom teaching approach which still needs textbook and teacher to play role in learning the process. However, Yusoff et al. (2009a) stated that this framework is restricted to a textbook style learning and does not encourage exploratory learning style. Thus, to encourage exploratory learning style, Westera et al. (2008) have proposed game framework which based on scenario-based designed. This framework was designed with specific focus which on the expansion of the underlying architecture of scenario-based game development. Unfortunately, this framework relied only on a software called '*Emergo'* to be part of developing the game which makes this framework inflexible. Besides that, this framework also does not offer any design solution to work with other game design tools (Yusoff et al. 2010a).

The latest serious game framework was developed by Yusoff et al. (2010) which combined serious game attributes according to educational perspective. This framework was designed to support learning and pedagogy in combination with the games and produce an effective learning. This framework has been developed as learning module called *Unilink Bus Game.* However, it does not consider the user characteristic during the design of the game. All of the discussed frameworks offer different purposes and criteria. The application of the framework will depend on the goal of the game.

1.3 Problem statement

Construction workers are always exposed to numerous occupational hazards of different kinds and levels of complexity in every project they engage in. Besides that, the working environment on the construction site exposed construction-related workers towards the hazard. They need to have knowledge and ability to handling hazard on a construction site. Therefore, there is a need for training modules which can provide the knowledge to construction workers to acquire the skills necessary for occupational and environmental safety on site. However, current safety training still lacks hands-on approaches and it is theory-oriented. This is due to the nature of the construction environment itself in which hands-on approaches are irrelevant to be applied for certain types of hazards. Hence, the need of training assisted technology is indispensable.

Currently, serious game has become a new approach in training and learning not limited to the field of education but this approach has been applied across disciplines and areas including military, mining, transportation, oil and gas and also the construction industry. Serious game has the ability to offer visual training, immersive and safer learning environment, hands-on training with scenario-based, flexibility and affordable in training delivery (Charsky, 2010b). This can be beneficial in training the construction-related workers . With this approach, hazard training becomes more flexible in term of time, cost and health. The serious game also enables the construction-related workers to practice their skills using "trial and error" approach with their own existing knowledge and experience (Hess and Gunter, 2013). This is where serious games can become the missing link between knowledge and hands-on training.

Hence, in developing an interactive module for hazard identification training, the serious game framework needs to be developed. It is anticipated that the development of such training module will be a significant approach in delivering safety training to construction-related workers. Therefore, a serious game framework for hazard identification training module needs to be in place. The existing frameworks were designed according to the purpose of the game. However, the

serious game framework needs to be designed in such a way it allows construction-related workers to repeatedly simulate their decision and learn from the outcome.

The existing game frameworks are designed according to the purpose of the game. Each of the framework favours more on their purpose of development, for example, Westera et al. (2008) have proposed game framework which is based on scenario-based designed. However, to apply this framework, the software called '*Emergo'* must be part of the game development which makes this framework inflexible. The latest serious game framework was developed by Yusoff et al. (2010) which combined serious game attributes according to educational perspective. This framework was designed generally which allows any game designer or trainer to adapt this framework as the basis for game development. However, this framework is insufficient in terms of understanding the user ability and requirement.

Consequently, to ensure the effectiveness of the serious game training module, a serious game framework needs to be developed. It is important to develop a specific serious game framework for hazard identification training. The approach and process to train decision making are different and need to design comprehensively according to the requirement of the construction industry. In order to have a comprehensive approach and process to train decision-making for such serious game module. There are a few elements that need to be incorporated in a single framework. First is the instructional design method and game attributes that is adhere to the theory of learning. Secondly, the characteristic of the construction-related worker in understanding their ability in making decision and self-directed learning. Lastly is the decision-making process.

1.4 Research Question

Based on the discussion in the previous section, the following research questions are designed to be answered in this study.

RQ1 : What is the relevant instructional design method to support active learning environment in serious game training module (input)?

RQ2 : What is the relevant serious game attributes based on the educational view to support training using game approach (input)?

RQ3 : What are the users characteristic in decision-making and self-directed learning?

RQ4 : What is the common decision-making model that can be used as guidance in designing game training module (process)?

1.5 Research Aim and Objectives

The aim of this research is to develop a serious game framework for the hazard identification training module. The framework is developed based on to Input-Process-Outcome game model by Garris et al. (2002). To achieve the aim of this research, the following objectives have been developed:

RO1 : To determine the suitable instructional learning method to support active training environment.

RO2 : To determine the serious game attributes to support effective training module.

RO3 : To determine user's characteristics in understanding their ability in self-directed learning and decision-making style.

RO4 : To design the process of hazard identification training.

RO5 : To develop the serious game framework for the hazard identification training module.

1.6 Scope of the study

The framework will be developed in order to enhance hazard identification skills and decision-making skills in handling hazard on site. Thus, the data was collected from construction-related workers from the lowest to the highest position on sites i.e. safety trainees, general workers, semi-skilled workers, skilled workers, supervisor, and management team in order to understand their ability to learn by themselves. Besides that, this framework will be designed generally according to the OSH guideline and current practice approach. Thus, it will enable all the related industries such as construction, agriculture, factory, mining and etc can apply this framework to their training development approach. This framework will be a guideline in developing prototypes for the game training module.

1.7 Significant of Study

It is believed that the used of gaming approach in a training format is a promising means to foster effective learning in safety training. Furthermore, the increasing availability of advanced developer and learner-friendly authoring software has enabled the possibility of gaming product being widely integrated into training instruction. When this format is added to a serious game framework as part of the training delivery, the training module may well be a timely and effective addition to assist Malaysian construction-related workers in achieving the safety culture that the DOSH, OSHA, NIOSH, and CIDB has been trying to infuse in Malaysia construction industry. The training module can be a significant part of training approach to enhancing the construction-related worker's knowledge, especially about the hazard.

1.8 Research Methodology

In order to achieve the aim and objectives of this research, the study was conducted in five phases.

In the first phase, the preliminary literature reviews on current issues on training approaches. The questions raised from the issues were addressed and the aims and objectives of the research were formulated. The scope of the study was also determined.

For the second stage, an extensive literature review was conducted. The literature is divided into three chapters which are learning theories, safety training approach practice in the construction industry and lastly the serious game as a training tool. Through these reviews, the instruments for data collection were designed.

For the third stage, data were collected and analysed. Objective one and three were achieving through content analysis method. Meanwhile, for objective two, questionnaires were distributed, and statistical analysis was carried out. The results were then incorporated and a serious game framework was developed. Finally, the framework was validated by experts and the conclusion was made. Figure 1.1 presents the flow of the research methodology.

1.9 Operational definition

This part explains the terms which will frequently be used during the study. More comprehensive definitions and concepts are provided in the following chapter.

TERMS	DEFINITION
Hazard	A source or a situation with a potential for harm in term of human injury or ill health; damage to property and to the environment; or a combination of these (MS1722, 2005 , OHSAS18001, 2007)
Construction-related workers	A person who works in the construction industry such as general workers, semi-skilled workers, skilled workers, supervisor, consultant, management team including trainee.
Training	A systematic learning exercise to enhance the knowledge and skills which needed to improve the performance in work situation (Malcolm, 2002).
Serious game	A training tool that incorporates game technology for the purpose of train decision making in achieving training objectives.
Self-directed	The adult learner taking control of their own learning (Knowles, 1984)
Adult learner	A mature person which can make decision by themselves, responsible for each action that was taken, who legally can vote and have a sense of right and wrong (Knowles et al., 2005)

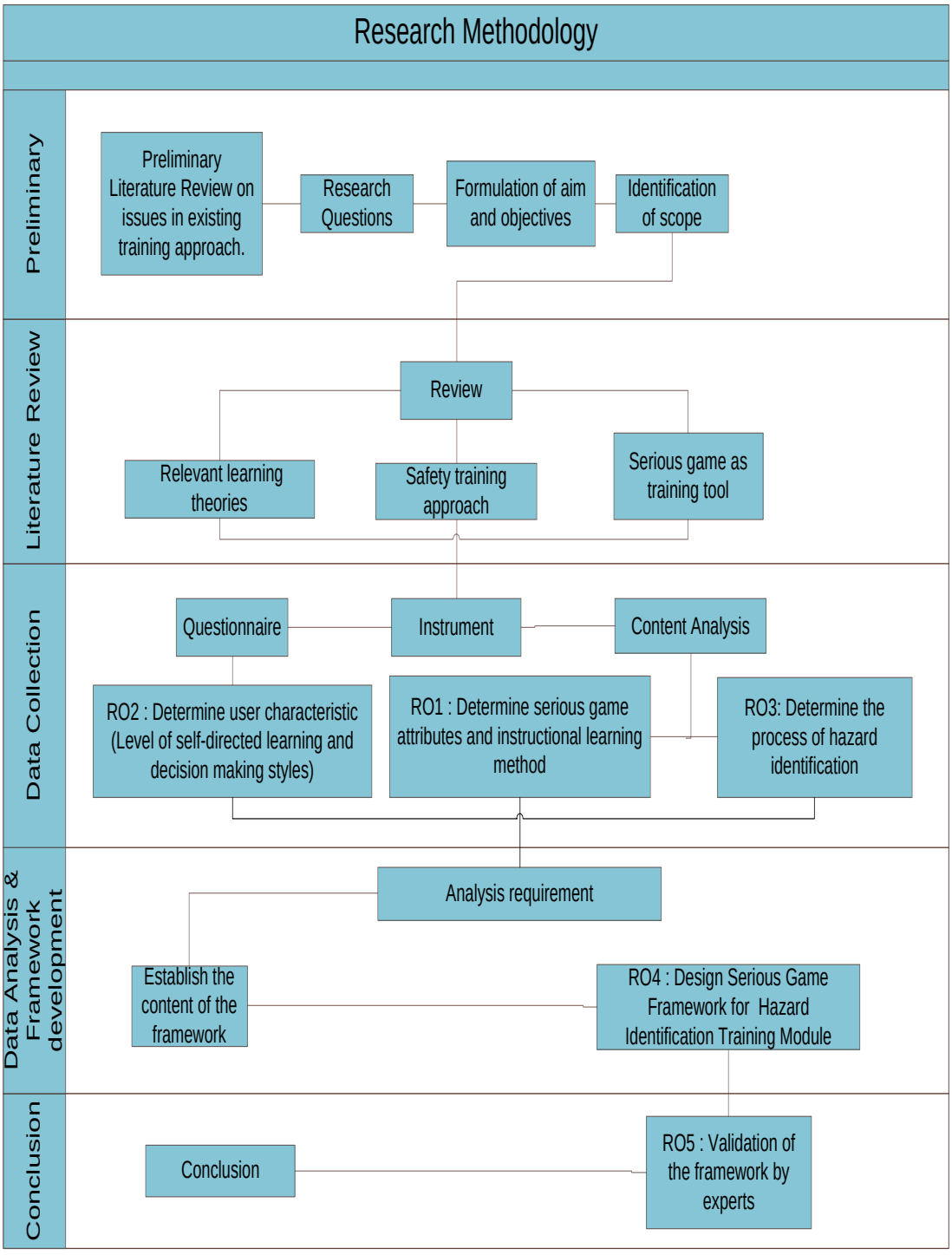

Figure 1. 1: Research Methodology

1.10 Chapter organisation

This thesis is orderly structured into eight chapters.

The first chapter provides an explanation of the background of the study and highlights the needs of a training approach that suit the hazard training delivery. Aims, research questions and research objectives are also explained in this chapter. In the second chapter, extensive reviews and organised on education learning theory i.e. adult learning theory, behaviourist, cognitive, constructivist, self-directed learning and good decision making conducted. Instructional learning method was also reviewed to understand the process of designing effective training module. The third chapter covers the detail on current training approach practised in Malaysia. Followed by the benefits of applied technologies i.e. Virtual Reality, Augmented Reality, Simulation and also discussion on gaming approach in training delivery in other industries.

The fourth chapter evaluates the ability of serious game as a tool for training and discussed the attributes of the serious game according to the learning perspectives. Varieties of previous game frameworks are reviewed in determining the suitable framework to be referred as a basis in the development of the serious game training framework. In this study, the research design is discussed in the fifth chapter where detail explanations on types of research methods, the process of the research right from data collection until validation stage are discussed.

The sixth chapter shows the results gain from the content analysis and survey study. For the content analysis study, the attribute was extracted from the relevant journals. Meanwhile, for the survey, the analysis was performed using SPSS software. Chapter seven present the development of the framework and its validation. This is where all findings were incorporated to become a framework and experts' opinions for validation were discussed. Finally, chapter eight concludes the whole study. This chapter also highlights the research limitation and addressed potential future.

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