Design Phase of Gamification Framework for Hazard Identification Training in Construction Industry

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Abstract—Game has been proven an effective approach tool to improve learning and has become a new tool for training delivery. The development of the gamification framework involves integrating design processes which are input, process, and output. The design phase is considered essential to guide the flow of the gamification framework. It offers a safer, interactive, and entertaining learning environment for construction-related workers. This paper aims to report on the approach to design a gamification framework for hazard identification training in Construction using Garris's Input-Process-Outcome game model as the basis. It focuses on the three main design elements: instructional design, game characteristic, and user characteristic. The study outlines two objectives: (1) to identify the game's attributes and Gagne's Nine Events Instructional Methods Design which supports effective learning, and (2) to determine the user's characteristics of self-directed learning. This study focused on designing the Design phase, which consists of instructional design, game characteristics and user characteristics. Mixed methods were used to extract the attributes and elements of the Design phase. Content analysis was carried out to determine the instructional design model and game attributes, 12 attributes have been identified, and Gagne's Nine Events Instructional Methods Design can support effective learning. Meanwhile, a questionnaire survey is used to determine the user's self-directed learning and decision-making style, where 319 construction-related workers responded. The results showed that construction-related workers belong to the independent learners' category and are inclined to 'vigilant' and 'brooding' types of decision-making style. Following the aim of this paper, these findings were incorporated into the design phase of the game framework.

Keywords—game, safety training, hazard, framework

1 Introduction

Construction workers are constantly 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 to the hazard. Therefore, they must have the knowledge and the ability to handle hazards on a construction site. Therefore, there is a need for training modules that 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, which is theory-oriented [1]. This is due to the nature of the construction environment itself. Hands-on approaches are irrelevant to be applied for certain types of hazards. Hence, the need for training assisted technology is indispensable. The game approach can offer visual training, an immersive and safer learning environment, hands-on training with scenario-based flexibility, and affordable training delivery [2], [3]. This can be beneficial in training construction-related workers. With this approach, hazard training becomes more flexible in time, cost and health [1], [4], [5]. The approach also enables the construction-related workers to practice their skills using the "trial and error" exercise with their existing knowledge and experience [6]. This is where the games can become the missing link between knowledge and hands-on training. This study has adopted the Input-Process-Outcome (IPO) model as the basis for developing the game framework.

2 Input-process-output model

IPO game model was developed by Garris, Ahlers, & Driskell (2002). [7] The aim is to develop a self-directed and self-motivated learner through exciting activities in achieving the outcome. The traditional IPO learning model emphasises single-trial learning, where a learner performs a task over a single trial [8]. Although the current model adopts the input-process-output framework, the critical component is the game cycle triggered by specific game features.

The primary purpose of gameplay is not about how users play a game but to draw users into playing a game repeatedly. For instance, a young person engaged in a computer game may often have to be told to turn off the game or stop playing. Besides that, the game cycle can be viewed as repeating steps, which indicates that the gameplay involves repeated judgement-behaviour-feedback loops. The gameplay cycle can lead to user judgements or reactions such as increased interest, enjoyment, involvement, or confidence. These reactions lead to more remarkable persistence or intensity of effort. In addition, these behaviours result in system feedback on performance in the game context [9]–[11]. Thus, the game cycle defines a computer gameplay characteristic that engages users in repetitive play and continually returns to the game activity. It is this feature of computer gameplay that train professionals to capture and incorporate instructional applications. Figure 1 shows the composition of the Input-Process-Outcome framework.
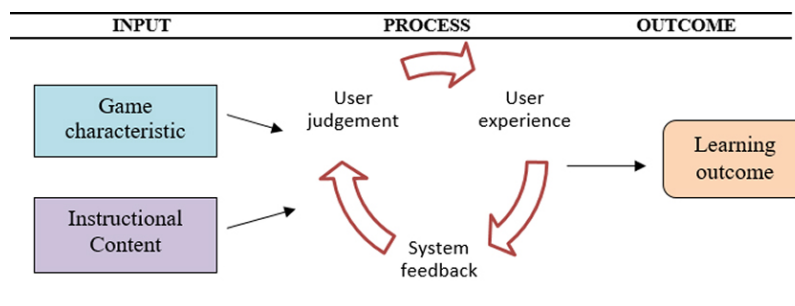

Fig. 1. Input-process-outcome model (Garris et al. 2002)

3   Methodology

This research was conducted using two research techniques which are content analysis and a survey. In the first phase of the study, content analysis was conducted to determine the suitability of Gagne's Instruction design method in balancing the design of the profound game framework. Besides that, these methods also fulfil the necessity to determine and categorise existing serious game attributes according to educational perspectives. For this study's first objective, the deductive content analysis study was carried out to check the suitability of Gagne's nine instructional events to be incorporated into the serious game framework. The keywords and the benefit from both were generated in the analysis of the study's content. Besides that, attributes of the serious game were ascertained through the review of previous studies. These attributes needed to be categorised according to the educational view as a feature in the serious game framework. Subsequently, the content analysis approach was administered to convey the implicit messages from the analysis.

In the second objective, a survey approach was adopted. A set of questionnaires was designed and used to determine the level of self-directed learning and decision-making style among construction-related workers. This data collection aims to understand construction-related workers capability in planning and self-directness learning. Three hundred and nineteen (319) participants have taken part in this survey, fifty-two (52) respondents participated in the online survey, and the rest were participating during training organised by NIOSH Johor.

4   Design phase component for gamification framework

In designing the design phase, three main elements must be included: (1) game attributes, (2) user characteristics, and (3) instructional learning design. Each element included in the design phase will cause a change in the process and the outcome. Hence, the design phase is essential to guide the flow of the gamification framework.

4.1   Instructional content

One of the essential elements in the design phase is the instructional learning design. This element becomes the essence of structuring the cycle of learning in the game framework. A Systematic Literature Review (SLR) was conducted on five instructional design models: ADDIE, Hanaffin and Peck, ASSURE, The Dick and Carey (DC) model, and Gagne's nine events. The target group for this research is the adult and the behaviour taken by construction-related workers in handling hazards on construction sites. According to Kruse, (2008), [12] Gagné's nine events of instruction model focus on the outcomes or behaviours from training. Besides, this model has contributed significantly to instructional technology, especially in designing web-based instruction [13]. Hence, Gagne's nine instructional events are considered compatible with adult behaviours and adult learning styles (Kruse 2008; Jono et al., 2012; Gökdemir et al., 2013).

Ference & Vockell (1994) [14] agreed that Gagne's events of instruction are compatible with adult learners characteristics. They have developed instructional software for an adult using Gagne's events of instruction. Adult learners are mature and responsible learners who only want to learn what they want to know. They already have a mindset to learn something that can give benefit them. This can be supported by Gagne's nine instructional instruction event number one, which is gaining attention and informing learners of the objectives. The third instruction is to stimulate recall of prior learning. It is related to the cumulative knowledge and experience that have been collected previously by the adult learner.

Table 1. Summary of merging between the adult characteristic and Gagne's event of instruction

	Need to Know	Self-Directed	Experience	Ready to Learn	Problem-Solving	Internal Motivation
Gagne's nine events of instruction	Adult learning criteria					
Gaining Attention				x		
Inform learners of the objectives	x					
Stimulating recall of prior learning			x			x
Present the stimulus					x	
Provide learner guidance		x				
Elicit student performance						
Provide feedback						
Assess Performance						x
Enhance retention and transfer			x			

For the rest of Gagne's nine event instructions, events are related to the cycle of the learning process. This entire event provides the instructor with guidance for learning. Therefore, they need to keep up the trainee's both internal and external motivation. Giving motivation is the essential problem-solving skill that will ensure the continuity of the learning cycle. Therefore, according to Knowles (1980), Merriam (2010) and Dzeng & Wang (2017), [15–17] the adult learner have a high motivation to learn. They are self-direct learners who only need guidance, and they also seek problem-based learning, not direct learning. As a result, the merging between the adult characteristic and Gagne's events of instruction is a good balance. Table 1 summarises how the characteristics of adult learners merge with Gagne's events of instruction.

Hence, deductive content analysis has been carried out to determine whether Gagne's instructional design methods are suitable instructional methods for this framework. Hence, fourteen documents which consist of articles and a technical report, were analysed. These articles were scrutinised and grouped based on the pre-determined codes. As a result, four principal codes have been determined, i.e. [1] target group,

[2] application, [3] purpose and [4] outcome. Table 2 shows the finding of deductive content analysis for Gagne's Instructional design.

Table 2. Content analysis Gagne's instructional design

	Key Point	Journal and Publication	Frequency
1	**Target group**		
a	School learning	[18], [19], [20] and [21]	4
b	Higher learning	[18], [22], [23], [24], [25], [21] and [26]	7
c	Adult learning	[14], [27], [28], [29] and [30]	5
2	**Application**		
a	Learning/Training	[20], [21], [28] and [30]	4
b	Online learning—website	[27], [22], [25] and [26]	4
c	Game	[18], [29], [31] and [19]	4
d	Multimedia	[24]	1
e	Learning software	[14], [23]	2
3	**Focus**		
a	User characters	[14], [28], [22], [24], [20] and [21]	6
b	Provide feedback	[14], [27], [28], [22], [29], [31], [23], [24], [25], [20], [21] and [30]	12
c	Motivation	[14], [18], [22], [31], [19] and [26]	6
d	Entertainment	[18], [22], [31], [23] and [19]	5
4	**Outcome**		
a	Transfer skills—motor skills	[14], [20], [24], [20] and [30]	5
b	Transfer knowledge	[14], [18], [22], [27], [29], [31], [23], [24], [25], [19], [26] and [30]	12
c	Behaviour/attitudes	[28], [22], [29] and [21]	4

This instructional design method will improve the learning instruction with a systematic approach for problem-solving, feedback characteristics and improve instructional design and development management by monitoring/controlling function. Besides that, instructional development is a systematic process that focuses on improving learning and instruction effectiveness in various educational environments.

All the nine events of instructions will guide the learning process in the game training module. The learning cycle starts by gaining attention from the learner after informing them about the study's objectives and, next, recalling the prior learning by extracting the existing knowledge. After that, activities or learning will begin. During this stage, learning guidance, eliciting performance, and providing feedback were enclosed together. Finally, learning performance will be assessed at the end of the learning cycle to enhance retention and transfer knowledge and skills.

The findings of this study acknowledge that this instructional design method can be applied to the various level of learners such as school learners, higher learners and adult learners. Besides that, it can also be implemented in various learning approaches conventional learning, online learning, game, multimedia, and learning software [32].

This flexibility of the instructional will be able to generate a diverse approach in training delivery. Furthermore, Gagne's nine events instructional design methods will allow the designer to design a training module according to the purpose of the study. For example, it can enhance learners' motivation, provide feedback to the learner, change user characteristics or behaviours, and entertainment [20]. This study is designed to train hazard identification and decision-making skills in handling hazards on the construction site.

What is more that, this instructional design method also offers learning outcomes according to the learning goal. Transferring skills, transferring knowledge, and changing attitudes or behaviours is the most expected learning outcome generated from this instructional [33]. Consequently, it is expected that this framework will enhance the construction-related worker's ability to identify the hazard and take wise action in handling hazards on the construction site. Besides that, it will also lift their motivation to keep learning and boost their self-confidence in facing hazards on the construction site. For this reason, Gagne's nine events instructional design method was adopted to design the game framework for hazard identification.

4.2   Game characteristics

While the instructional design is to guide the cycle of the learning process, the game attributes are the coordinator to deliver the learning process effectively. Hence, the second element was to determine the game attributes to support the practical game training module. From the systematic literature studies, it has been found that twenty-six game attributes are commonly used in game development (refer to Table 2). However, in their study, Bedwell et al. (2012) indicated that Wilson et al. (2009) new attributes are a fraction of Malone characteristics. Hence, those attributes have been modified according to Malone characteristics, reducing game attributes into only nineteen. The affected attributes are the optimal level of difficulty (Wilson: adaption), performance feedback (Wilson: assessment), challenge (Wilson: Conflict) and control (Wilson: interaction equipment/inter-personal/social).

However, this framework aims to train users in making safer decision-making in handling hazards on the construction site. Thus, these attributes need to be categorised according to educational perspectives. Therefore, to create a practical training module, all these game attributes complement learning theories (behaviourism, cognitivism, constructivism and experiential learning). The study conducted by Mohd, Ali, Faiz, et al., (2019) and Yusoff, Crowder, & Gilbert (2010a) [34–35] indicated twelve game attributes determined to support Gagne's instructional design in designing a practical

game framework. Table 3 and Table 4 show the game attributes and the extraction of game attributes from each learning theory.

There are three game attributes derived from behaviours theory, which focuses on improving user behaviour, especially in designing the aim and activity. From this theory, three main attributes are Interaction, Reward, and Practice and Drill.

Based on the concept behind this theory, all these attributes can enhance skills and motivate the user to keep playing the game. For example, the interaction attribute role ensures the user's ability to adapt and manipulate elements that allow game changes in response to learner actions. Besides, it will ensure that each game level will match the learner's skills level, especially in attaining challenges with possible solutions. The second attribute is practice and drill, which provides repetition and constant rehearsal during the learning process. This attribute enables the user to reinforce memory and support with rewards elements to motivate the learning process. The second theory, which Cognitivism theory, is related to how to deliver the learning process. There are four attributes related to this theory: incremental learning, linearity, attention span, and transfer of learning skills. All these attributes act as guidance in designing the learning process. For example, designing the learning plot should start from the novice to the master level and specific rules and goals. Besides that, it also will direct the flow of knowledge delivery, especially in the arrangement of learning content. Well, design learning content enables the user to focus throughout the whole game learning process.

After plot and learning content has been appropriately designed, the Constructivism theory will help users construct knowledge from their experiences. Hence, scaffolding attributes will encourage learners in constructing knowledge using the trial-and-error approach. This approach can create re-examine and re-assess learning approach, which allows them to learn through experience.

Table 3. Game attributes

	1 Curiosity	2 Challenge	3 Control	4 Level of Player Control	5 Task Nature	6 Role of the Player	7 Rules	8 Goals	9 Context	10 Motivation	11 Conflict	12 Adaptation	13 Assessment	14 Fantasy	15 Suprises	16 Interaction (Equipment)	17 Interaction (Interpersonal)	18 Interaction (Social)	19 Language/Communication	20 Location	21 Mystery	22 Progress	23 Sensory Stimuli	24 Representation	25 Safety	26 Suprises
[36]	×	×	×																							
[37]				×	×	×																				
[38]							×	×	×																	
[39]								×		×																
[40]		×					×	×						×							×		×			
[41]		×	×	×		×	×	×			×	×	×	×		×	×	×	×	×	×	×	×	×	×	×
[42]		×					×	×			×	×	×	×	×	×	×	×	×	×	×	×	×			×
[9]		×	×			×	×	×			×	×	×	×		×	×	×	×	×	×	×	×	×	×	×
[43]		×	×	×		×	×	×	×		×	×	×	×		×	×	×	×	×	×	×	×			×
[44]		×					×	×			×		×	×		×	×	×	×							

Table 4. Game attributes based on learning theory [34], [45]

Theory	Attributes	Description
Behaviourism	Interaction	Engagement in learning
	Reward	Incentives for the learner
	Practice and drill	Learning activities and exercises within the game
Cognitivism	Incremental learning	The learning material is delivered in an incremental way
	Linearity	Learning is arranged sequentially
	Attention span	Duration for learning concentration
	Transfer of learnt Skilled	Applying Skills to new learning based on previous learning
Constructivism	Scaffolding	Support and help during the learning
	Learner control	Self-learning and active learning based on learner pace
Experiential Learning	Accommodating the learner's style	Learning process to suit learner preferences
	Scenario-based learning	Learning where the learner can relate what is being learnt within the game to the outside world.
	Intermittent feedback	Just-in-time feedback for learning

Similar to constructivism theory, experiential learning theory also proposes learning through experience but needs to accommodate the learner's style, using scenario-based learning and providing intermittent feedback. Accommodating the learner's style attribute will enrich the game design based on user preferences, incorporated with the learning environment designed similar to the real-life situation. This attribute will adequate users to experience a similar feeling when dealing with the actual situation in the natural working environment. Besides that, the user also will get prompt feedback by checking their progress of learning through the intermittent feedback attributes. The learning activities can be designed according to Gagne's instructional design guideline from the game attributes. Table 5 shows the learning activities extracted from Gagne's nine events instructional integration with the game attributes in designing the gamification framework.

Table 5. The game attributes are based on learning theory [34], [45]

Game Attributes (Based on Educational Perspective)	
Learning Activities	**Game**
Get learner's attention	Scenario-based learning
	Incremental learning
Inform learner of the learning outcome	Linearity
Extract some information the learner already knows	Learner control
Game activity and lesson to be learnt	Accommodating the learner's style
	Attention span
Help and support learners.	Scaffolding
Ask the learner to do what has been taught by acting within the game.	Interaction
	Transfer of learnt skills
Inform learner of his performance	Intermittent feedback
Evaluate the learner on his knowledge of the subject matter.	Reward
Assist learners in remembering and applying new skills.	Practice and drill

4.3 User characteristic

Input-Process-Outcome (IPO) in Figure 1 shows only two essential elements in the design phase: the instructional design and the game attributes. However, to design a practical training module that fulfils the user's needs and requirements, the characteristic user element also needs to be infused into the Design phase. Hence, the purpose of the third element is to determine the user's characteristics in understanding their ability in self-directed learning and decision-making styles. Both elements will be mixed to ensure the user can learn by themselves and make a safer decision in handling hazards in the gaming environment.

According to Candy & Brookfield (1991), [46] individuals who enjoyed self-directed learning have high moral, emotional, and intellectual autonomy. They further asserted that an individual ready to learn by himself is a context-free person. This individual already masters technical skills and consists of three major components: identifying learning purposes, locating learning resources, and managing learning endeavours. Thus, to determine the capability and ability among construction-related workers regarding the level of self-directed learning, five broad areas (awareness, learning strategies, learning activities, evaluation and interpersonal skills) were adopted [47]. From the findings, the construction-related workers have a high level of self-directed learning, which implies that all workers can learn by themselves. Besides that, they also have the know-how skills to take the initiative to determine their learning needs, formulate learning goals, and choose resources for learning. Moreover, using existing experience, they can decide on suitable learning strategies and assess the learning outcome according to their needs. These findings show the construction-related workers can choose their own need of learning and learn by themselves.

The second element is to determine the decision-making style among the construction-related worker. This is because the decisions taken are significantly different. However, many experts have proven that every individual has the same tendency to solve problems [48]. Since the focus of this study is to understand the construction-related worker's decision-making style, eight styles were adopted from Leykin and DeRubeis (2010) study [49]. The findings indicate that five groups are skill workers, supervisors, Consultants, the Management Team, and Trainees vigilant in making decisions. Meanwhile, general workers and semi-skill workers are categorised under the brooding style for making a decision.

Unexpected findings have given a new perspective on construction-related workers, General Worker in particular. General workers are categorised as brooding style, defined as a thinker who is always worried about making a decision. This style means that they are aware of their capability and responsibility. However, they are always worried about making a decision [50]. Hence, this finding is surprisingly different from their role on the site. Usually, at the construction site, they are followers who take orders from the top management. Therefore, they are not required in making a big decision and have a limited scope of work [50]. Nevertheless, ironically, this group is the riskiest group involved in accidents on construction sites.

Meanwhile, skills workers, supervisors, consultants, management teams, and safety trainees are more vigilant in deciding. This group are independent people who have insights and are very careful in protecting their interests. Nevertheless, they are loyal and always alert to criticism (Mohd et al., 2019). However, both styles need to be improved and changed because time is the essence in handling hazards. Therefore, the construction-related workers must take immediate action to prevent accident occurrences on the construction site.

5   Conclusion

The Design phase of a game framework is essential in understanding the construction-related worker's self-directed learning and decision-making styles. There are three main elements in the Design phase, i.e. instructional design, game characteristic and user characteristic. The study identified 12 attributes and verified Gagne's nine events instructional methods design to support effective learning. As for user characteristics, the construction-related workers belong to the independent learners' category and are inclined to 'vigilant' and 'brooding' types of decision-making style. Figure 2 below shows the integration between all three elements in the Design phase: Gagne's nine events Instructional Method design, the game attributes, and user characteristics. This entire element will become the guideline in designing the game training module for hazard identification. Hence, it is essential to integrate all the elements in designing the design phases of the game.
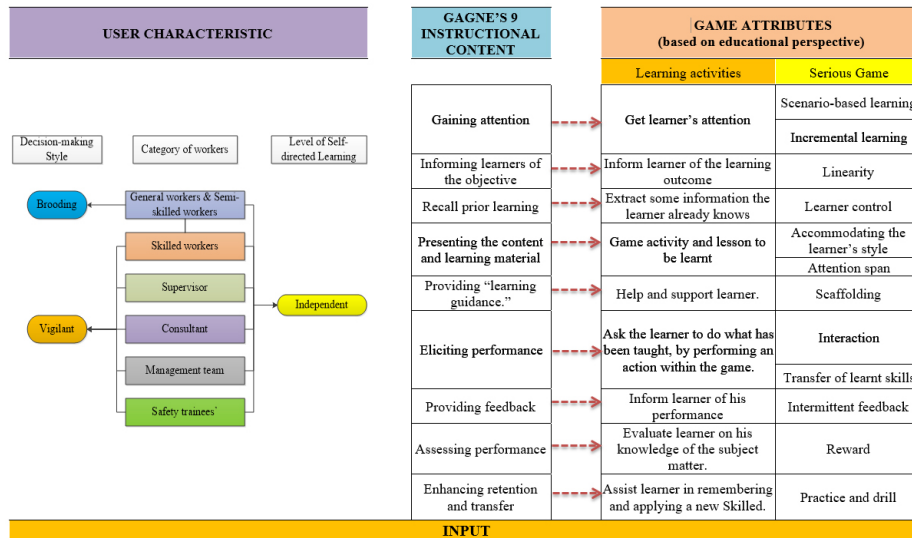
Fig. 2. Input in the game framework

6   Acknowledgement

7   References

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