Digital Game-Based Learning (DGBL) Development for Professional Upskilling Toolkit

Version 1.0

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1 Introduction

The *Digital Game-Based Learning (DGBL) Development for Professional Upskilling Toolkit* ("Toolkit") assist course developers in developing a set of requirements and objectives for the DGBL course. Although this Toolkit can be used in any teaching and learning context, the target audience of this Toolkit is course developers who will be or currently developing DGBL for professional upskilling. This Toolkit also presents a case study of how it was applied to a real-world professional upskilling course.

This Toolkit is developed as part of the research project **"Evaluating the effectiveness of digital game-based learning (DGBL) for professional upskilling: Bringing construction safety knowledge into architects' and engineers' workplace"** and supported by SkillsFuture Singapore under the Workforce Development Applied Research Fund (WDARF) grant [GA19-05].

1.1 Digital game-based learning (DGBL)

DGBL is an approach to learning using an interactive digital game with defined learning objectives. A DGBL should balance learning content with digital gameplay. It can help a learner to understand, retain, and apply knowledge to real-world situations. DGBL is used as it easily adapts to learners' different learning preferences, motivates, and engages learners better, and promotes creative thinking.

DGBL can allow for learning in a simulated environment, thus offering learners a valuable opportunity to learn through hands-on experiential activities without the logistical challenges or safety risks associated with such activities.

1.2 How to use the Toolkit

The Toolkit is structured based on a DGBL framework with guiding questions. The DGBL framework has four modules that guide the design of the major components of the DGBL: learner's profile, course design, game design, and collaborative design. Learner's profile, course design, and game design are the modules that directly influence the design of the DGBL. The collaborative design module serves to guide the interactions that will take place between the groups of stakeholders of the DGBL.

An *objective-driven* approach is adopted here. The framework is first used to determine the course objectives for the different components, which are used to design the DGBL activities. This is an intentional approach towards DGBL design that ensures that all activities are aimed towards achieving the learning objectives.

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To develop the DGBL course requirements, it is suggested that course developers go through the learner's profile, course design, and game design modules in that order. This Toolkit contains sample guiding questions for each module. These guiding questions will assist course developers in developing a comprehensive list of objectives that must be completed for each module. Course developers should also consider if there are other requirements, beyond those of the provided guiding questions, that are specific to their course and learning objectives.

For each module, it is suggested that the course developers work with the relevant experts to develop the requirements. Table 1 shows a list of suggested experts that should be consulted at each stage. In every stage where collaboration between different parties is required, the requirements established in the collaborative design module become relevant.

Table 1 List of suggested experts

Modules	Objectives	Suggested experts
Learner's Profile	Establish the characteristics of the learners in the course, which drives the course and game design	• Course developers • Industry experts
Course Design	Establish objectives that must be met upon completion of the course	• Course developers • Industry experts
Game Design	Establish the requirements for the game, and hence the design of the game	• Course developers • Game developers • Industry experts

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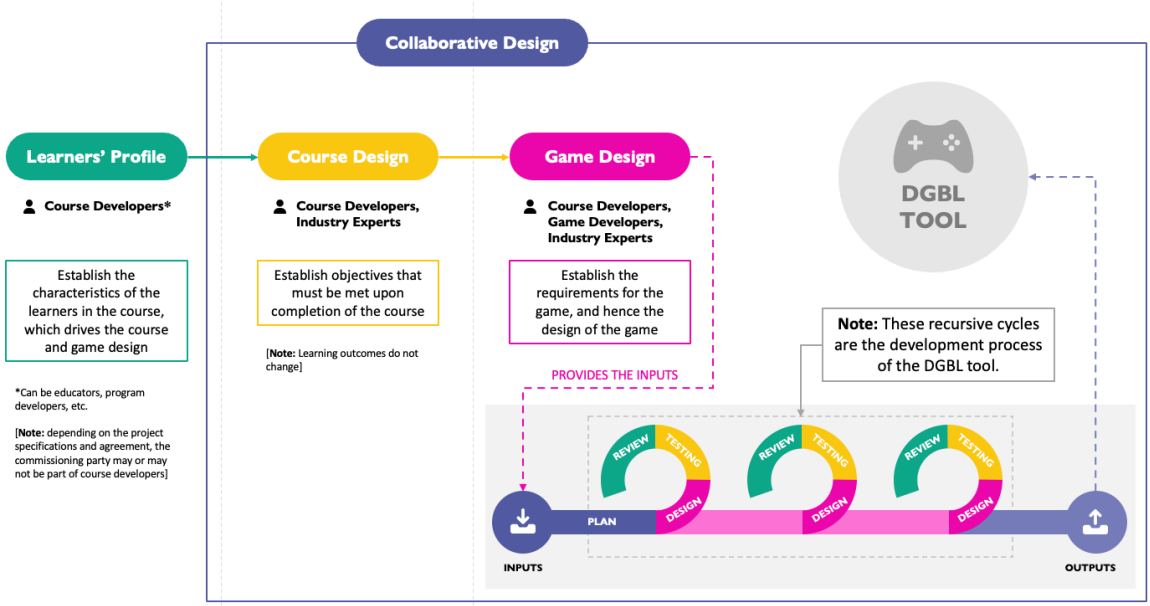

Figure 1 DGBL design and development process

The recursive cycles in Figure 1 are part of the development process of the DGBL tool, not in the game design process. The game design module provides the inputs for the plan, design, testing, and review cycles. This ultimately resulted in the output, the DGBL tool (i.e., digital game). Refer to Project Management Body of Knowledge (PMBOK®) 7th Edition Section 2 to understand the development approach and the importance of project manager in managing a DGBL development project.

1.3 Terms of usage

All guidelines, templates and examples listed in this Toolkit are free for all to use. User can refer to **Annexe A** on how this Toolkit is used in a case study. NUS reserves the right to edit, update or replace any part of the content within this Toolkit at any time. Proper attribution is required for others to distribute, display, perform the work, and make and distribute derivative works based on it.

Please refer to the below on how to cite this Toolkit.

Cite Us (APA 7th Edition)

Safiena, S., Tay, J., Lim, M., Lan, T., Goh, Y. M., Bound, H. (2023). *Digital Game-Based Learning (DGBL) Development for Professional Upskilling Toolkit.* National University of Singapore (NUS). https://github.com/NUS-DBE/DGBL

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2 The DGBL framework

The DGBL framework was created based on literature reviews of peer reviewed research and the author's experiences from developing multiple DGBL-related projects. The authors identified four modules in the DGBL framework: learners' profile, course design, game design, and collaborative design.

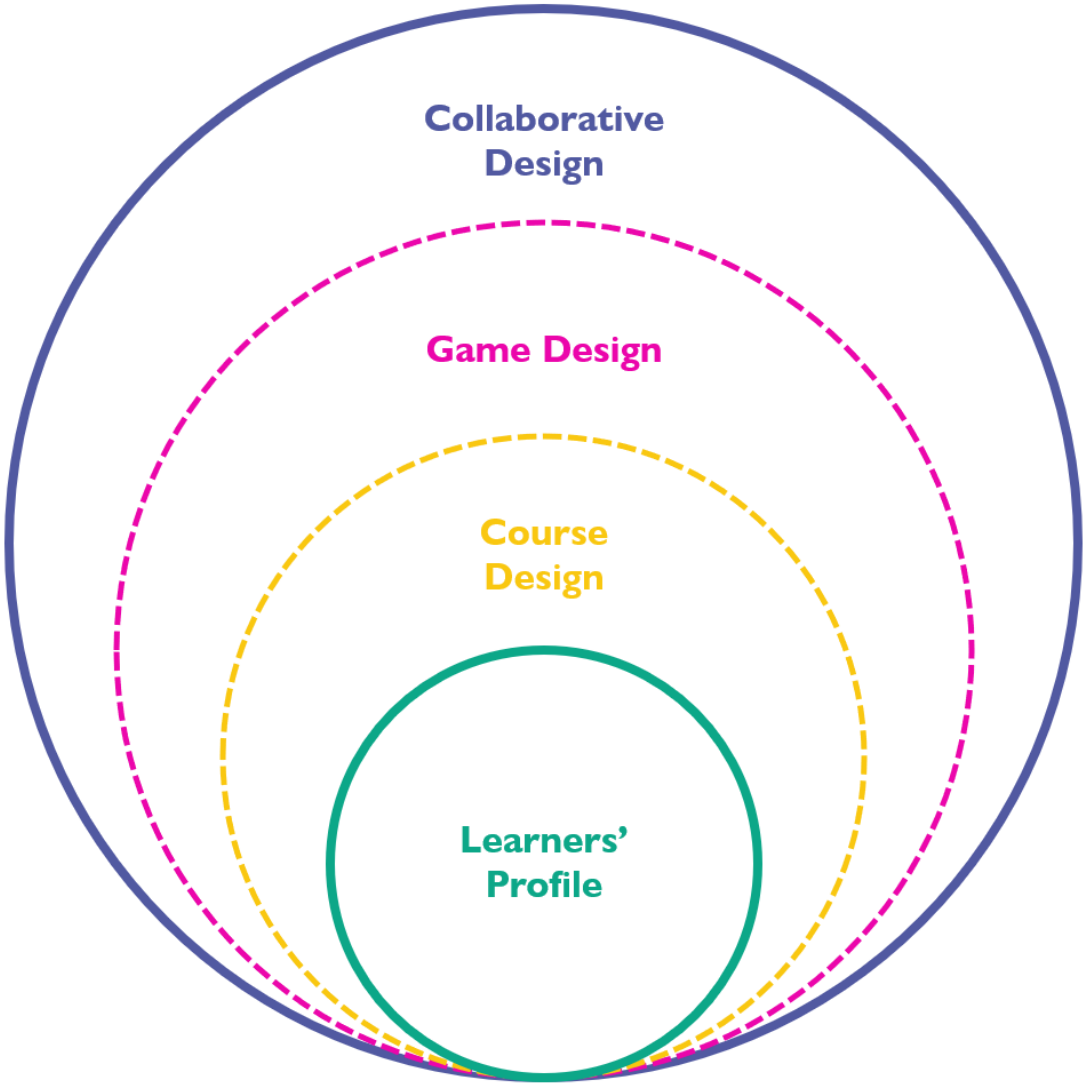

Figure 2 Overarching DGBL framework with four modules

The first module in the DGBL framework is the learners' profile module which helps course developers identify and understand their target learners. The learners' profile module is also the main driver for the subsequent two modules, course, and game design modules, as illustrated in Figure 2. Identifying and profiling learners provides the foundation to set the overall learning objectives.

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Next, the course design module is focused on the overall structure of the course: designing the learning activities, performance assessments, and instruction to achieve the learning outcome of the DGBL project. Third, the game design module addresses the selection of gamification elements and the gameplay design to support the learning activities identified in the course design. Lastly, the collaborative design module, refers to the collaboration between the various stakeholders involved.

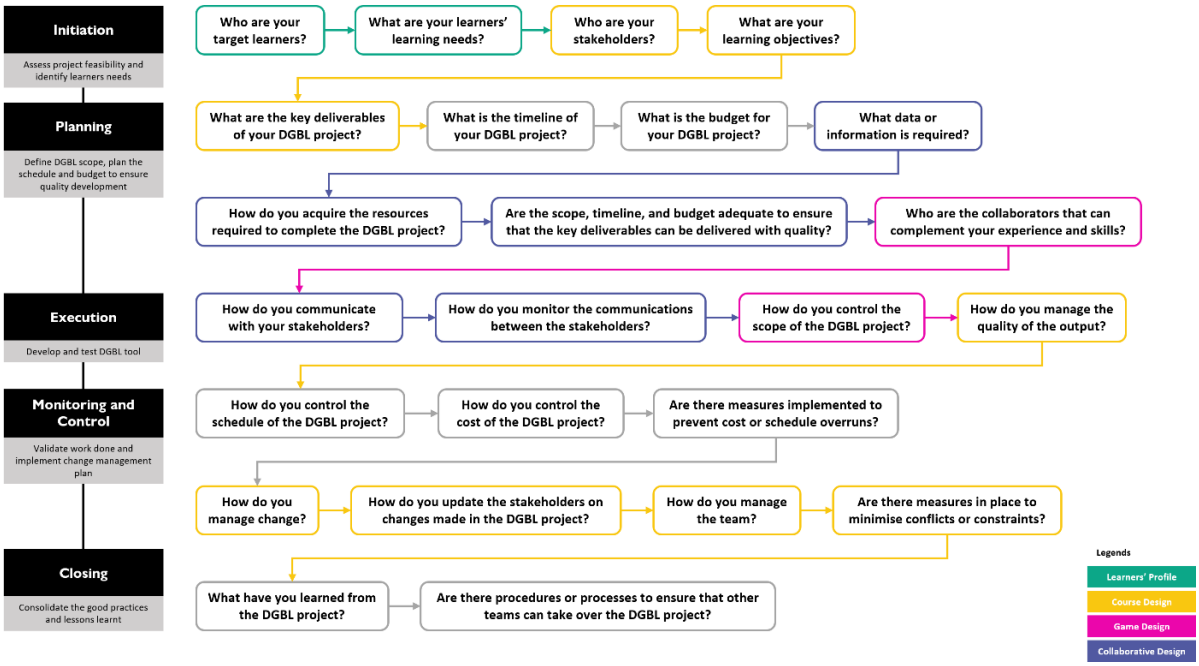

Figure 3 The key stages of a typical DGBL project for DGBL project management

In the following sections, the authors explain the key elements and guiding questions to develop a DGBL. Additionally, the guiding questions can be further divided into the five stages of project management when implemented (Figure 3).

2.1 Learners' profile

Understanding the learners is a critical component of teaching. With a greater understanding of the learners, there is increased trust and engagement. In addition, this allows for differentiation and the personalization of instruction. Educators can better tailor instructions by understanding the learners' educational background, strengths, knowledge, and learning preferences. Therefore, the learners' profiles must be established at the beginning of the DGBL development project. The design of the overall DGBL, including the course and game, will be dependent on this profile. A list of guiding questions to establish the profile is in.

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Guide 1 Learners' profile

Components	Sample Guiding Questions
Education Level	• What are the learners' typical education levels? • What are the learners' working language?
Work Experience	• What working experience do the learners have? • How long have the learners been in the industry?
Technical Ability	• Do the learners have gaming experience? • Do the learners have access to information technology (IT) devices, e.g., laptop, personal computer (PC), smartphone, or tablet?
Needs and Expectations	• What are the learners' needs? • What prior knowledge and experience do learners bring to the DGBL learning experience? • How will their work experience enrich the DGBL learning experience?

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2.2 Course design

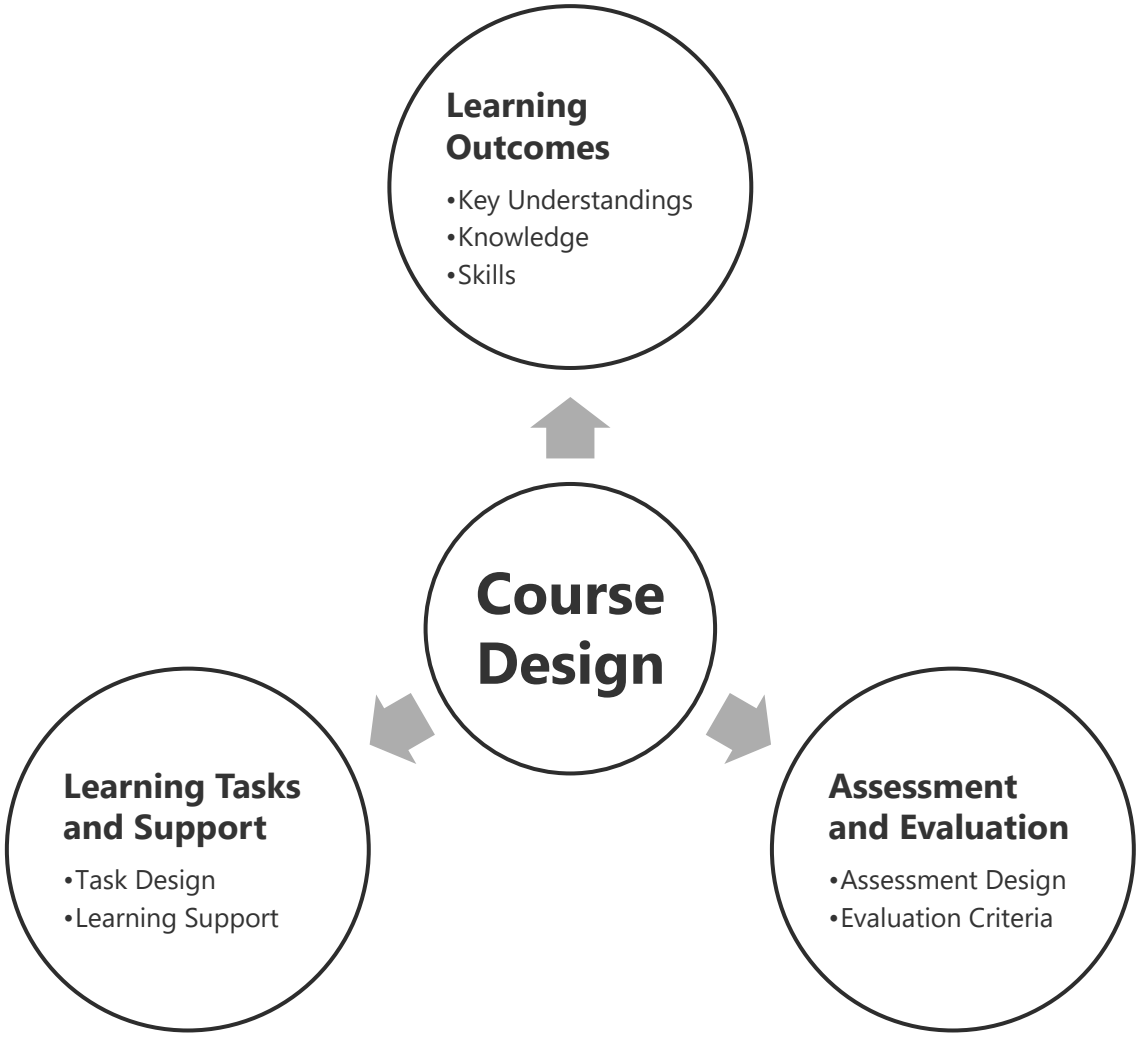

Figure 4 Key components of course design

The course design module will assist educators and program developers in developing core learning outcomes based on learners' profiles and key knowledge to be gained from the DGBL program. The course design module has been broken into three components: learning outcomes, assessment and evaluation, and learning tasks and support (Figure 4).

First, there are three elements in the 'Learning Outcomes' component: key understandings, knowledge, and skills. These three elements will guide the course developers to set concise and realistic learning outcomes for the learners to achieve when undergoing the DGBL program.

Next, there are two elements in the 'Assessment and Evaluation' component: assessment design and evaluation criteria. It is unfair to assess the learners' knowledge and skills based on one mode of assessment. Thus, having multiple

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modes of assessment allows for a more holistic and authentic approach to assessing the knowledge gained. Therefore, this component assists course developers design assessments for fairer evaluation. Several types of assessments can be used to evaluate learners. This includes short-answer quizzes, free-response questions, and graded assignments. Table 2 list types of assessments and examples for each type.

Table 2 Types of assessment and their examples

Assessment Type	Example(s)
Short-answer quizzes	**What does the G stand for in the GUIDE process?** a) Gather b) Group c) Garner d) Generate [Choosing the correct option from a predefined list.]
Free-response questions	**Give three (3) examples of engineering control.** 1. _____ 2. _____ 3. _____
Graded assignments (e.g., case study, report)	**The task is to complete the DfS register for the case study given, identifying at least five (5) design risks in the design. Appropriate design controls or changes must be proposed to mitigate the design risks. Provide explanations for at least three (3) of the risk ratings given, describing your rationale for the ratings given. References must be made to the design risk's severity and likelihood. Make reasonable assumptions whenever necessary to complete the task. State these assumptions in the register.** [Provide a case study with supporting documents and images, a sample template of the DfS register.]

Lastly, the 'Learning Tasks and Support' components comprise two elements: task design and learning support. Instructional scaffolding is critical since it helps learners to master tasks and enhances their learning. This is best used for teaching new concepts, tasks, or strategies that can be broken down into several steps.

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Components	Elements	Sample Guiding Questions
Learning Outcomes	Key Understanding	• What big ideas should the learners understand?
	Knowledge	• What information should the learners master when they leave the DGBL program? • What facts, concepts, and principles should the learners retain?
	Skills	• What specific skills should the learners acquire? • What processes, strategies, and methods should the learners master?
Assessment and Evaluation	Assessment Design	• How will the assessment distinguish the learners who fully understand from those who only seem to understand? • How would the educators know if the learners have achieved the desired results?
	Evaluation Criteria	• What criteria are used to evaluate the attainment of competencies? • What is sufficient evidence to demonstrate understanding?
Learning Tasks and Support	Task Design	• What "real-world" tasks will reveal learners' understanding and proficiency? • What learning activities are needed to achieve the learning goals? • What activities will equip the learners with the needed knowledge and skills? • What resources/ platforms are best suited to accomplish these goals? • Are there opportunities for the learners to share and collaborate?

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	Learning Support	• What instructional strategies are needed to guide the learning process? • What instruction is needed to guide the learners to attain the learning outcomes? • How will you monitor the learners' progress toward acquiring and transferring knowledge during the course? • What are potential rough spots and the learners' misunderstandings? • How will the learners get the feedback they need and have opportunities to use it?

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2.3 Game design

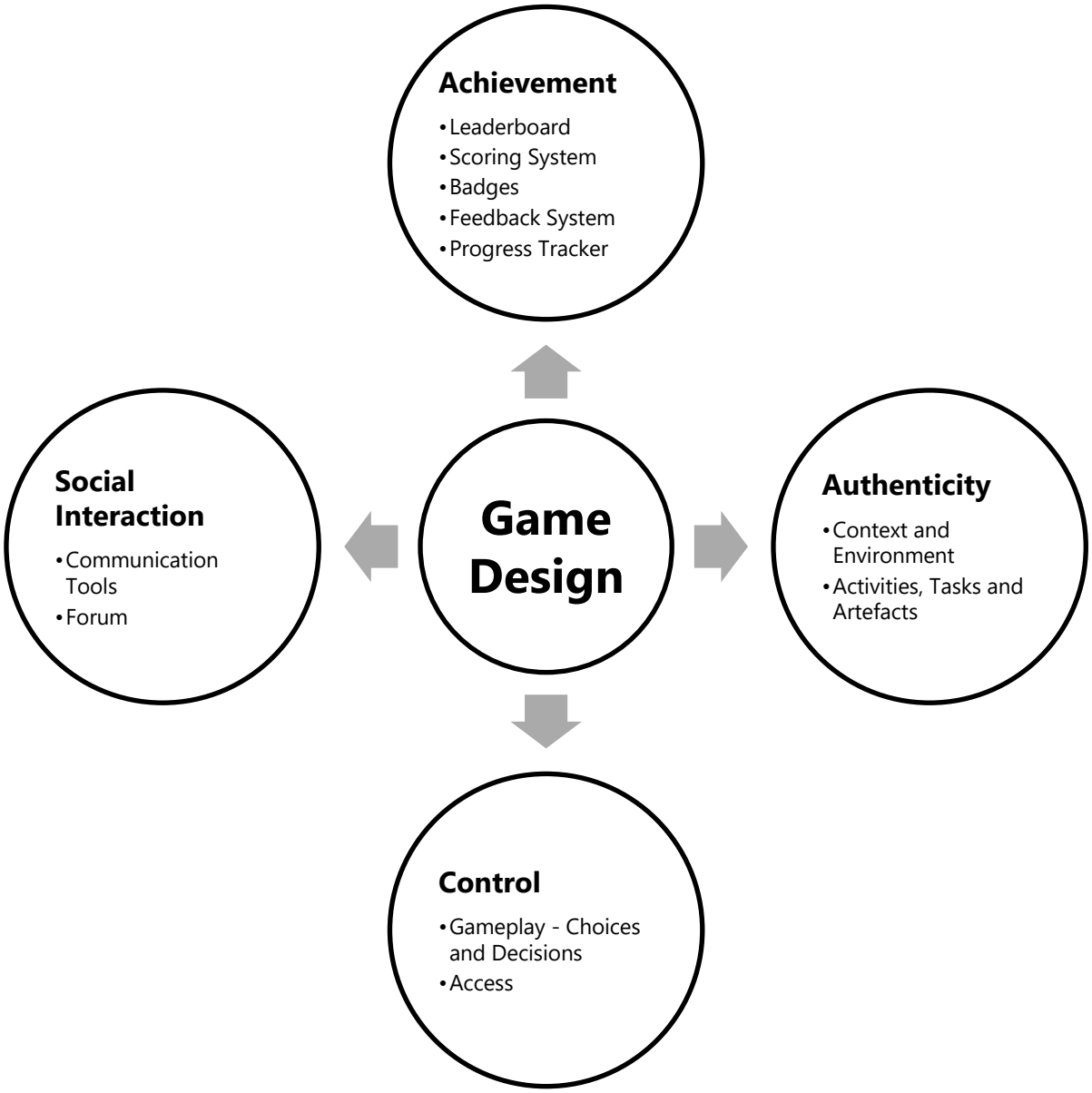

Figure 5 Key components of game design

Game design is the elements that form the game's overall look, feel, and features. This includes the user interface, the user experience, the gamification elements, the game flow, and the interaction. Not all gamification elements are required within the game. The gamification elements required to achieve the learning objectives can be identified based on the learner's profile and the course learning objectives.

During the game design stage, game designers, course designers and industry experts will participate. Game developers should propose game features and architecture based on the design requirement developed by the course developers

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and industry experts in the previous stages (i.e., learners' profiles and course design). It will no longer be a linear process as it requires several iterations to develop and validate the digital game (see iterative process in Figure 2), ensuring that the DGBL tool meets the intended learning outcomes.

The authors identified four primary needs of learners that can be fulfilled through game design: achievement, authenticity, control, and social interaction (Figure 5). Within each category, there are complementary gamification elements and teaching strategies. Firstly, player achievements are integral to a learner's experience, forming a key part of the motivation to complete the course.

Therefore, five gamification elements were identified in the 'Achievement' category: leaderboard, scoring system, badges, a feedback system, and a progress tracker. Next, there are two elements in the 'Authenticity' component: context and environment, activities, tasks and artifacts. Lastly, in the 'Control' and 'Social Interaction' components, two elements are identified: gameplay and access for 'Control', and communication tools and forums for 'Social Interaction'.

Guide 3 Game design

Components	Elements	Sample Guiding Questions
Achievement	Leaderboard	• How can the information on the leaderboard contribute to the learners being engaged and motivated?
	Scoring System	• How is the scoring related to the game context/ gameplay? • How is the scoring system a measurement of learning? • Is the scoring system deliberate and reasonable? • Does the scores award commensurate with the difficulty level of the learning tasks?
	Badges	• Are the badges reflective of the learning objectives? • Are the badges appropriate for the learners' context?

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	Feedback System	• What kind of feedback (e.g., summative, immediate) is provided? • How can the learners make use of the feedback for their learning? • Are there enough resources (i.e. trainers, educators, teaching assistance) to sustain the proposed feedback process? • What are the ways that the learners can respond to the feedback?
	Progress Tracker	• How does the progress tracker inform learners about their performance? • How can the information from the progress tracker guide learners in completing the activities?
Authenticity	Context and Environment	• Does the setting of the game meet the instructional objectives? • How authentic is the game environment in comparison to the real environment?
	Activities, Tasks and Artifacts	• Are the game-based activities/ tasks comparable to actual activities/ tasks? • How are the learning tasks meeting the instructional objectives? • In what ways are the game build/ models reflective of the real-world context? • Are the artifacts used in the game realistic and required in real-life situations?
Control	Gameplay – Choices and Decisions	• Are the learners able to determine their learning path?

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		• How critical are the learners' choices expected to make in the game to the instructional objectives? • Are the decisions the learners expected to make reflective of real-life situations?
	Access	• What kind of access do the learners have to the game? • How much autonomy do the learners have about the timing and duration they play the game?
Social Interaction	Communication Tools (e.g., chat box)	• How will the social interaction help learners meet the instructional objectives? • What opportunities are available for the learners to learn from each other?
	Forum	• In what ways can the educator/ instructor support the learners' learning? • What opportunities are available for the educator/instructor to provide guidance/ support/ challenges to the learners? • What can the educator/ instructor do to differentiate the learning opportunities for the learners?

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2.4 Collaborative design

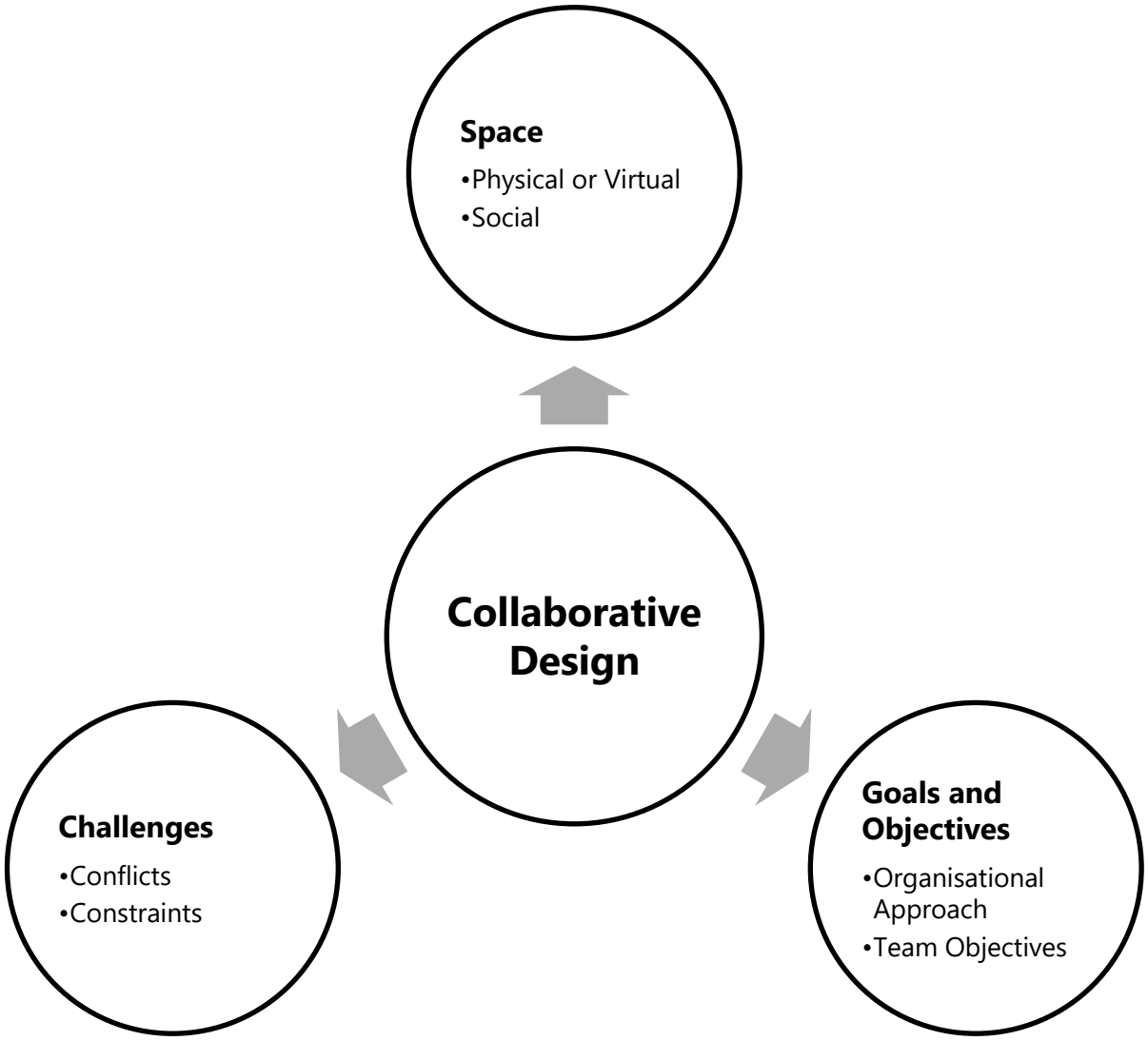

Figure 6 Key components of collaborative design

Collaborative design is a module that blends the course and game design. It sets the expectations and the roles and responsibilities of the different stakeholders in the project. Parties in a project must establish a robust communication system for collaboration to work effectively. The collaborative design mainly appears in the monitoring and controlling stage of the DGBL project but is also critical across the other project management stages.

Depending on the requirements and context of the DGBL development, the stakeholders involved in the DGBL project may differ. The common stakeholders are usually the course developers, industry experts, and game developers. In circumstances where the commissioning group is not an educator, they can appoint a consultant team to design and manage the DGBL project. Each group has their

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expertise and capabilities, i.e., the expert team has the subject matter knowledge, the developer team has the technical knowledge to develop a game, and the consultant team has the knowledge and skills to merge the content and development to develop a learning tool.

The collaborative design modules cover space, goals and objectives, and challenges (Figure 6). For each of these components, there are two elements. In the 'Space' component are physical or virtual and social spaces. The 'Goal and Objectives' component includes organizational approach and team objectives. Lastly, in the 'Challenges' component, there are conflicts and constraints.

Guide 4 Collaborative design

Components	Elements	Sample Guiding Questions
Space	Physical or Virtual Space	• How is the physical space/ virtual space set up for collaboration? • Are there options/ avenues for group conversations and informal cross-training? • How will the conversation and information be documented for reference and follow-up?
	Social Space	• Are there formal/ informal opportunities for the team members to share their knowledge and motivations? • How are the team members encouraged to learn from each other? • Are the team members empowered to support one another? • How can situational awareness (awareness of what others are doing) be developed among team members?
Goals and Objectives	Organisational Approach	• How is the organisation structure influencing the team's attitude and culture?

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		• What kind of organisational support is in place to facilitate collaboration? • Are there systems in place that can normalise collaborative practices?
	Team Objectives	• What is the process of deciding the team objectives? • How are individual team member's contributions to the team objectives communicated to the team? • What are different avenues used to monitor and evaluate the team's progress? • What are the different forms of coordination mechanisms that are in place to support the team?
Challenges	Conflicts	• What are some of the conflicts (relationship, data, value) that can arise from collaborative work? • What steps/ procedures/ structure can be implemented to address conflicts (role definitions, time constraints, power/authority distribution)?
	Constraints	• Are there alternatives to in-person meetings? • How are meeting times protected and used efficiently? • Is there sufficient time for team members to interact and complete their tasks?

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3 Conclusion

3.1 Recommended readings

The application of the Toolkit in a case study is available in **Annexe A**. A detailed recounting of the development of the DGBL framework and the case study involved is available in these readings:

Tay, J., Goh, Y. M., Safiena, S., & Bound, H. (2022). Designing digital game-based learning for professional upskilling: A systematic literature review. Computers & Education, 184, 104518. https://doi.org/10.1016/j.compedu.2022.104518DGBL

Safiena, S., Tay, J., Miang Goh, Y., & Lim, M. (2023). SafeSim Design: A digital game-based learning approach to address Design for Safety (DfS) competency. In G. Geng, X. Qian, L. H. Poh, & S. D. Pang (Eds.), Proceedings of the 17th East Asian-Pacific Conference on Structural Engineering and Construction, 2022 (Vol. 302, pp. 360-372). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-7331-4_29

Tay, J., Safiena, S., Lan, T., Lim, M. S., & Goh, Y. M. (2024). Design for safety training for construction professionals: A digital game-based learning approach. Safety Science, 177, 106588. https://doi.org/10.1016/j.ssci.2024.106588

3.2 Acknowledgements

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Lee, Y. Y. R., Samad, H., & Miang Goh, Y. (2020). Perceived Importance of Authentic Learning Factors in Designing Construction Safety Simulation Game-Based Assignment: Random Forest Approach. Journal of Construction Engineering and Management, 146(3), 04020002. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001779

Safiena, S., & Goh, Y. M. (2022). A hazard identification digital simulation game developed based on the extended authentic learning framework. Journal of Engineering Education, 111(3), 642–664. https://doi.org/10.1002/jee.20459

Tay, J., Goh, Y. M., Safiena, S., & Bound, H. (2022). Designing digital game-based learning for professional upskilling: A systematic literature review. Computers & Education, 184, 104518. https://doi.org/10.1016/j.compedu.2022.104518

Yang, F., & Goh, Y. M. (2022). VR and MR technology for safety management education: An authentic learning approach. Safety Science, 148, 105645. https://doi.org/10.1016/j.ssci.2021.105645

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5 Annexes

5.1 Annexe A – Application of Toolkit to case study

5.1.1 Background of the Case Study

The construction sector in Singapore has consistently emerged as a top contributor to workplace fatalities over the years. Developers and designers can help to improve workplace safety and health (WSH) performance through conscious and collaborative efforts to identify design risks upstream and integrate appropriate control measures. To create a safer working environment, the Workplace Safety and Health (Design for Safety) Regulations 2015 ("WSH (DfS) Regulations") was introduced in Singapore in 2016. Design for Safety (DfS) is a process of identifying and removing potential occupational safety and health hazards and risks associated with construction and maintenance during the design and planning phases.

The authors wanted to develop a course to teach Design for Safety competency. This would involve the learners being able to anticipate and avoid hazards and risks during a construction project's construction, maintenance, and demolition phases. A way to improve the DfS competency of designers is through DGBL, a research-based educational approach developed to motivate and engage learners through interactive gameplay. The DGBL approach can help learners improve their Design for Safety competency by delivering various types of information through short, interactive sessions.

5.1.1.1 Details of the DGBL DfS Course

The scope of the case study was adult learners, undergoing professional upskilling. The authors developed an online self-directed DGBL Design for Safety (DfS) training course targeted at construction practitioners/professionals, mainly designers (i.e., architects and engineers) who are involved with designing structures in the construction industry. The learners are expected to achieve the following learning outcomes:

1. Explain the duties under the WSH (Design for Safety) Regulations 2015,
2. Identify common design risks that can affect the safety and health of construction and maintenance workers,
3. Evaluate design risks based on severity, likelihood, risk priority number, and risk matrix,

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4. Identify industry standards, guidelines, and norms when mitigating design risks,
5. Formulate and critique different design alternatives based on the hierarchy of control.

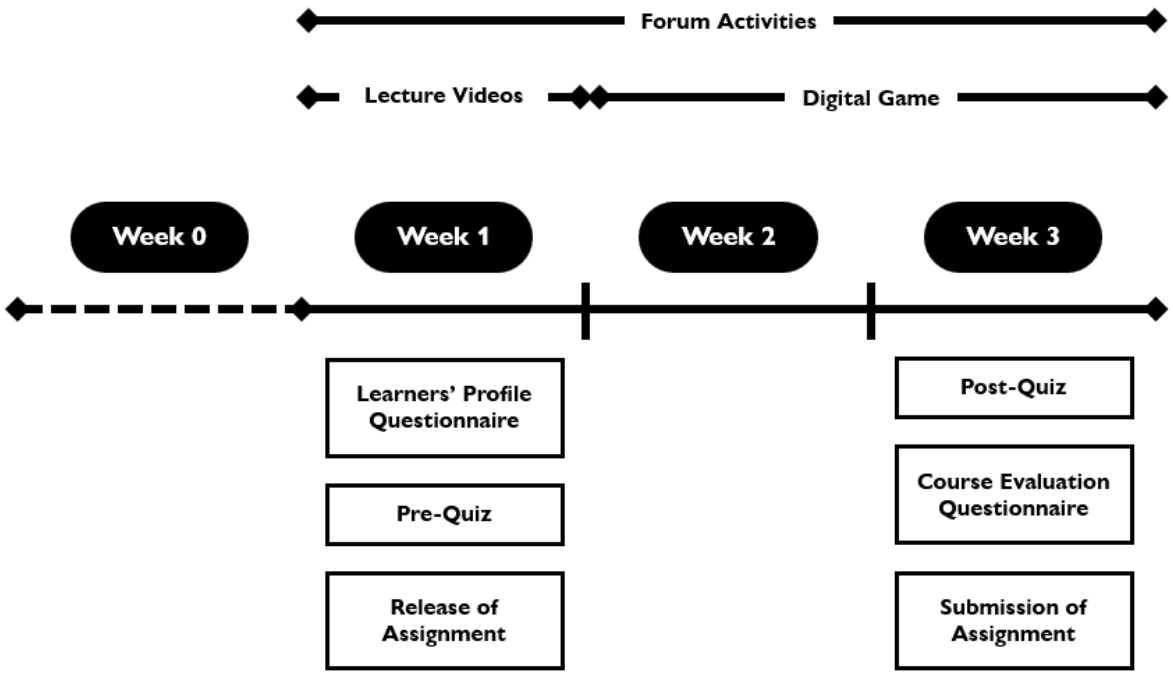

Figure 7 Proposed course schedule and activities

The DGBL DfS course was designed as a three-week online course where the learners are introduced to the DfS concepts via a series of videos and the learners apply the concepts in the digital game to reinforce learning. Each week, learners are given a list of activities to complete independently. Learners must complete a pre and post-test quiz and various questionnaires, submit a final assessment and interact and collaborate with other learners in the forum. A sample of the course structure is available in **Annexe B**.

As the DGBL project is an online and self-directed course, whereby the learners go at their own pace and have no fixed schedule, it is important that the DGBL developed provides sufficient instruction and guidance for the learners to troubleshoot any problems that they might face without having to wait for further instructions from the educator. Therefore, the authors developed the digital game, SafeSim Design (SSD), as a corresponding instructional DGBL tool. SSD is a first-person desktop game where learners identify design risks and provide solutions to mitigate them.

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5.1.2 Learners' profile

Table 3 Example usage of learners' profile guide

Components	Guiding Questions	Remarks
Education Level	• **What are the learners' typical education levels?** Most professionals would have at least a bachelor's degree. • **What are the learners' working language?** Most professionals in Singapore would speak and understand English fluently.	Learners are proficient in English and will not have problems understanding the game instructions or control. Therefore, there is no need for translation.
Work Experience	• **What working experience do the learners have?** Level of experience might differ for some groups of learners. Some might have more on-site experience (e.g., civil structural engineers, mechanical and electrical engineers), and some spend less time on site (e.g., architects). • **How long have the learners been in the industry?** There is a wide range in working experience. It can be as low as less than a year or as high as more than 30 years in the construction industry.	Most learners have site experience and hence knowledge of construction concepts, facts, and information. It will be better to design tasks that account for these experiences. This will require tasks involving reflection, thoughtful analysis, and assessment that contribute to their personal growth. The graphics in the game environment and the in-game tasks/ activities must be as authentic as possible to reflect the real-world context
Technical Ability	• **Do the learners have gaming experience?** The younger generation of professionals may have some gaming experience. It is reasonable to assume the older	Without gaming experience, some learners would initially have problems controlling the 3D environment and require

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	generation have limited gaming experience. • **Do the learners have access to information technology (IT) devices, e.g., laptop, personal computer (PC), smartphone, or tablet?** The majority would have at least two IT devices – one smartphone and one PC/laptop or tablet.	some guidance. The game should be designed simply to allow learners to perform the activities without support.
Needs and Expectations	• **What are the learners' needs?** o Acquiring new and relevant skills and information for the future o Conduct self-learning at their own time and target (flexible and modular learning style) o Ability to collaborate and share their ideas o Relevance to work and focus on practical and applicable skills o Clearly defined learning outcomes o Easily sharable and recognisable (i.e., credentials, professional certification, etc.) • **What prior knowledge and experience do learners bring to the DGBL learning experience?** Due to the different fields of work, learners can share their experiences and different point of view (e.g., architects might prioritise aesthetics over function, while engineers might	Learners prefer to have opportunities to apply their learning (i.e., applying the concepts to tasks or problems) as they attend the course rather than learning theory only**.** The course should be asynchronous and allow for flexibility in task completion. Learners need social interactions with other learners to share ideas and discuss their experiences. Learners need avenues to apply or share their experience, and the course/game should acknowledge this experience. They must also connect their newly acquired knowledge to past events or projects. Learners want recognition for their

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	focus on function more). Different sets of professionals with different jobs and skills will allow for the collaboration of ideas and solutions.	efforts through sharable and recognisable certifications or credentials.

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5.1.3 Course design

Table 4 Example usage of course design guide

Components	Elements	Guiding Questions
Learning Outcomes	Key Understandings	• **What big ideas should the learners understand?** Learners should understand that: 1. Design for Safety (DfS) is the process of identifying design risks and mitigating them through design-related changes or controls. 2. Designers can manage design risks to ensure workplace safety and health (WSH) by applying design-related controls based on the hierarchy of control (i.e., elimination, substitution, engineering control, administrative control, and personal protective equipment (PPE)).
	Knowledge	• **What information should the learners master when they leave the DGBL program?** Learners will: 1. Utilise their roles as designers to apply the hierarchy of control in the DfS process. 2. Identify common design risks that can affect the safety and health of construction and facility maintenance workers. 3. Identify industry standards, guidelines, and norms when mitigating design risks.
	Skills	• **What specific skills should the learners acquire?** Learners will: 1. Evaluate design risks based on likelihood, severity, and risk level,

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		including if a detailed safety review is needed. 2. Critique design alternatives to eliminate or reduce design risk related to construction and facility maintenance work. 3. Formulate alternative design changes to manage design risks to ensure the safety and health of construction and facility maintenance workers.
Assessment and Evaluation	Assessment Design	• **How will the assessment distinguish the learners who fully understand from those who only seem to understand?** The learners are assessed through different modes of assessment, such as in-game activities, forum discussions, quizzes, and individual assignments. The cumulative assessment score will distinguish the learners. Assessment breakdown: o Game participation score [20%] o Forum participation (i.e., discussions, peer review, sharing of ideas and solutions) [20%] o Online MCQ quizzes [20%] o Individual assignment* [40%] *The individual assignment consists of an authentic assessment for learners to apply the DfS concepts. The assignment replicates the actual DfS review. Learners are tasked to identify five design risks, evaluate the risk levels and propose a design-related control for each design risk identified.
	Evaluation Criteria	• **What criteria are used to evaluate the attainment of competencies? What is sufficient evidence to demonstrate understanding?**

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		1. Game progress • Ensure that the points awarded are commensurate with the difficulty level of the learning tasks • Stars are awarded to learners who reach the target score (e.g., learners will earn one star if they reach the passing score, and they can obtain a maximum of three stars, which is the highest attainable score) 2. Evaluation of individual assignment* • Use of rubrics to differentiate the different levels of achievement among learners • Learners' answers will be evaluated using three levels: not proficient, proficient, and advanced • Proficient: 50% - 74%, Advanced: > 75% *The sample marking criteria are in **Annexe C**.
Learning Tasks and Support	Task Design	• **What "real-world" tasks will reveal learners' understanding and proficiency?** The authors worked with construction industry experts to design a game environment that reflects real-world situations. The scenarios in the game are based on real cases in the industry provided by industry experts. The authors designed the in-game tasks to be as close to authentic as in a real-world context. Thus, learners can use existing knowledge and share their working experience on an actual construction site with the DGBL course.

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		Learners, who are design professionals, can propose new design-related mitigation solutions based on their experience or knowledge, which may not be covered in the DGBL.

	Learning Support	• **What instructional strategies are needed to guide the learning process?**
		  ○ Use the forum as a platform for educators to provide guidance/ support/ challenges to the learners
		  ○ Provide different types of feedback (summative, formative, immediate) throughout the course to inform learners of their learning progress
		  ○ Provide consultation slots with the educator to clarify doubts or the assignment
		  ○ Use a non-playable guiding character (Mr Chief Designer) within the game to guide the learners through the basic tasks and controls (Figure 8)

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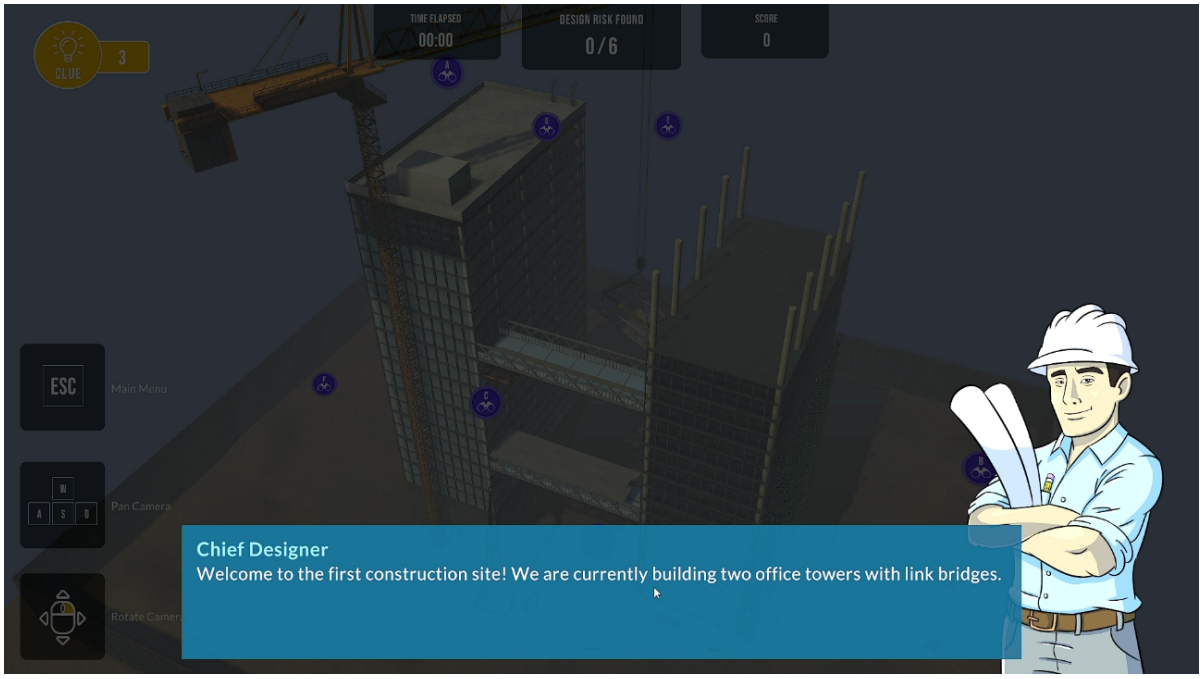

Figure 8 Use of Mr CD to guide learners

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5.1.4 Game design

Components	Elements	Guiding Questions
Achievement	Leaderboard	• **How can the information on the leaderboard contribute to the learners being engaged and motivated?** The learners can track their progress and achievements as a form of performance review. The leaderboard can also create competition between peers as it displays the top scorers within the game. This would thus motivate learners to play the digital game again to attain a higher score.
	Scoring System	• **How is the scoring system a measurement of learning?** The game will reward the learner with points for correctly identifying and answering the MCQs. However, the game will deduct points if the learner chooses the wrong hazard or answers the MCQ incorrectly. Therefore, a higher score would mean that the learner learnt more.
	Badges	• **Are the badges reflective of the learning objectives?** There are no badges, only stars to recognise achievement. To get a star, learners must earn a specific score (Figure 9). The learners are given bonus rounds to earn more points. To unlock these bonus rounds, learners must get the correct answer for the question attached to it. These bonus rounds motivate learners to learn about DfS as they allow greater control over their answers (Figure 10). An example of a bonus round is illustrated in Figure 11.
	Feedback System	• **What kind of feedback (e.g., summative, immediate) is provided?**

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		Immediate feedback will be given to the learners to indicate whether they have answered it correctly. Explanations will also be given for the wrongly answered questions (Figure 12). • **How can the learners make use of the feedback for their learning?** Learners can review and reflect on their chosen options based on the immediate feedback and rationale given.
	Progress Tracker	• **How does the progress tracker inform learners about their performance?** o Attainment of scores will be fed through the scoreboard in real time o Use of sound effects to alert learners if they have met their target o Tracker to indicate the remaining number of design risks to be identified
Authenticity	Context and Environment	• **How authentic is the game environment in comparison to the real environment?** The 3D environment reflects the real-world construction site. Industry experts were asked to validate the simulated environment to ensure the authenticity of the surrounding elements' look, feel and activities.
	Activities, Tasks and Artifacts	• **Are the artifacts used in the game realistic and required in real-life situations?** All scenarios, structures, plant and machinery, materials, and activities are designed to reflect the actual construction site (see Figure 13 and Figure 14).

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Control	Gameplay – Choices and Decisions	• **Are the learners able to determine their learning path?** The game gives learners the freedom to explore the simulated construction site without a pre-determined path to follow.
	Access	• **How much autonomy do the learners have about the timing and duration they play the game?** The game is designed to have a 30-minute gameplay per session to prevent fatigue. However, learners can replay the session at any time indefinitely. This allows them to play at their own time.
Social Interaction	Communication Tools (e.g., chat box)	• **What opportunities are available for the learners to learn from each other?** Although the game is designed to be a single-player game, the learners can network and share ideas, solutions and findings through the forum provided in the course. The forum allows for the collaboration of ideas from learners with different areas of expertise (Figure 15).
	Forum	• **In what ways can the educator/ instructor support the learners' learning?** Educators can provide specific instructions on how to play the game and address any queries by the learners through email support or a forum. Learners can also post their queries on the forum for others to comment on.

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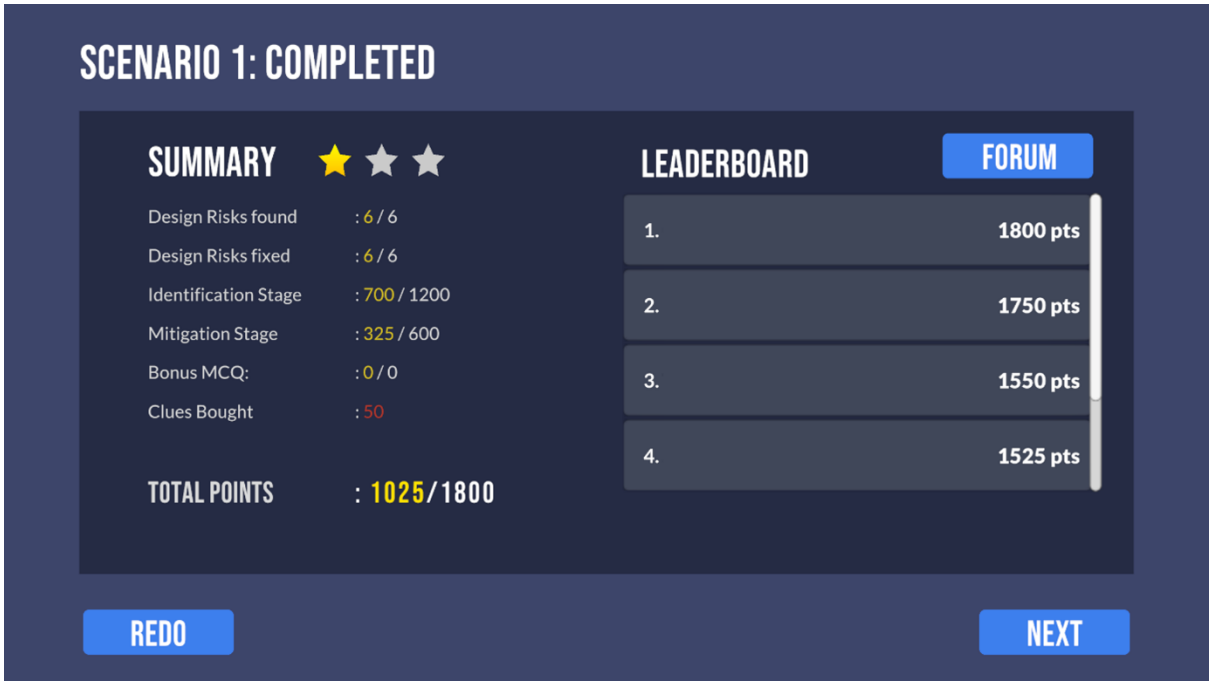

Figure 9 Breakdown of scores and the leaderboard for top scorers

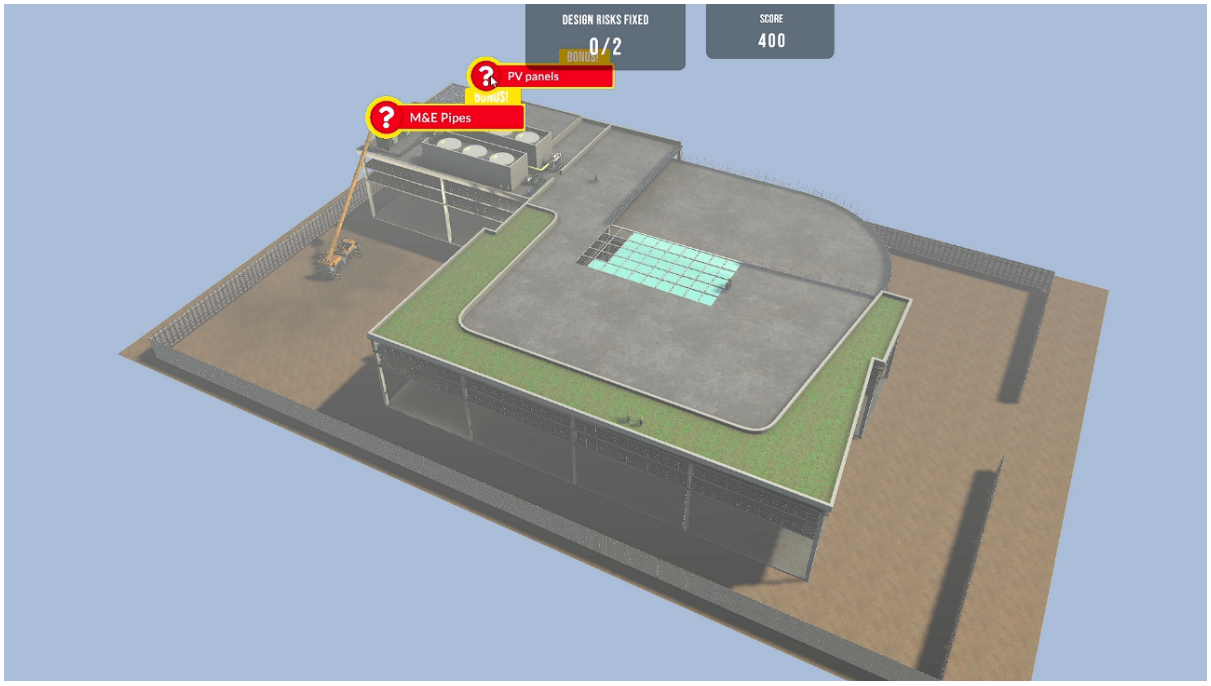

Figure 10 Bonus round indicator

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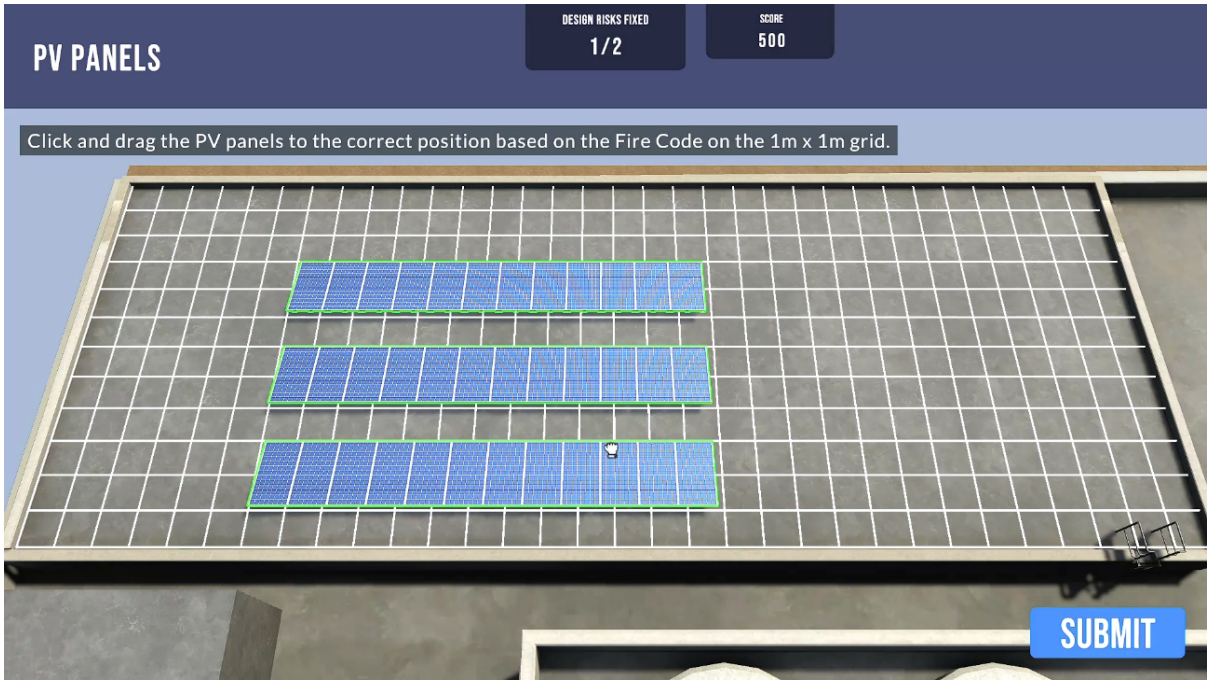

Figure 11 Learners can shift photovoltaic (PV) panels along the grid

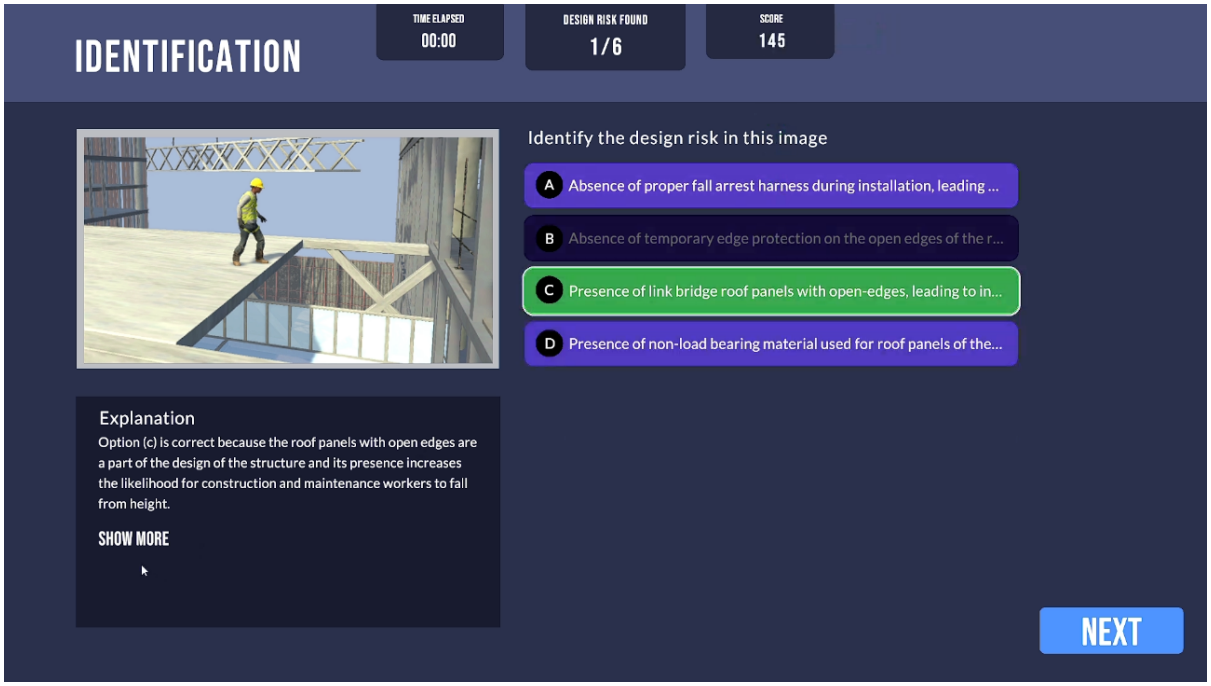

Figure 12 Immediate feedback and explanation for the chosen answer

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Figure 13 Replicated the actual Mobile Elevating Working Platform (MEWP)

Figure 14 Replicated the permit display board in the simulated construction site

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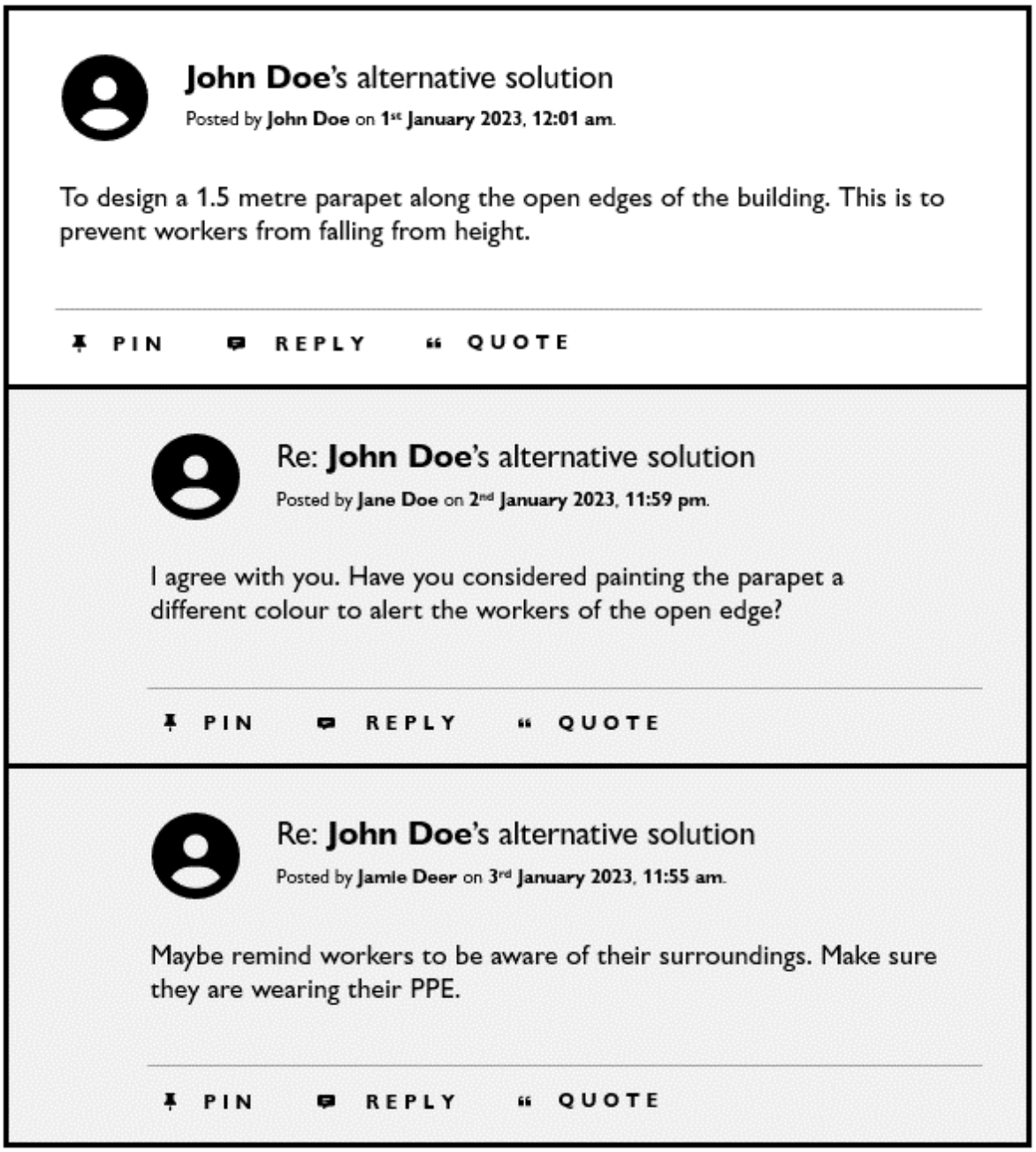

Figure 15 Sample on how learners can use forum to share ideas and solutions

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5.1.5 Collaborative design

Components	Elements	Guiding Questions
Space	Physical or Virtual Space	• **How is the physical space/ virtual space set up for collaboration?** Due to COVID-19, all collaboration and communication were held online. A dedicated work channel was set up in Microsoft Teams to facilitate discussions and sharing of files and information. Smaller informal chat groups were created within the different sub-teams for quick discussions and to clarify doubts or queries. These chat groups are set up either via Microsoft Teams or WhatsApp. • **How will the conversation and information be documented for reference and follow-up?** Meeting agendas were set for each formal meeting that will be held every fortnightly. Meeting notes were uploaded to Microsoft Teams folder after each meeting. In the meeting notes, there is a column named 'Actions and Deadlines', which indicates the tasks, deadlines and the person in charge. In Microsoft Teams, different stakeholders can view and edit the shared documents concurrently. Furthermore, all shared documents are date stamped in YYMMDD format and marked with the initials of the last person who updated the document.
	Social Space	• **Are there formal/ informal opportunities for the team members to share their knowledge and motivations?** The 3D artist from the game development team was encouraged to contact the industry expert team

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		informally through WhatsApp to clarify doubts or to validate the 3D models, ensuring that the environment and the assets are as authentic as possible. The team also used informal chat groups to ask quick questions within themselves and the subgroups. For example, the game developers would send a mock-up design of the UI changes, and the team members can comment on it. Formal meetings were used to discuss major decisions that might impact the project's schedule. • **How can situational awareness (awareness of what others are doing) be developed among team members?** There were weekly internal subgroup meetings for the developers and the course developers' team (the authors) to follow up on the game development. The subgroup will meet up before the formal meeting to track the progress of the tasks stated in the priority list*. Periodic meetings with different focus groups were also set to stay focused on the different tasks. * Priority List is a list that contains the tasks ranked based on the goal of achieving a minimum viable product (MVP). MVP is the "first version" of a product that meets the necessary requirements for use in the project. The authors used three types of priorities: o P1: Must complete within the current two-weeks period o P2: Important but can complete in the next two-week period o P3: Good to have, but not crucial for the minimum viable product

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Goals and Objectives	Organisational Approach	• **Are there systems in place that can normalise collaborative practices?** o Clear articulation of project goals o Designated member as the point of communication among various groups o Clear definition of duties and expectations o Fortnightly formal meetings involving all team members to discuss progress and highlight issues encounter o Standardised documentation of meeting and information-sharing documents
	Team Objectives	• **What are different avenues used to monitor and evaluate the team's progress?** o Team members' awareness of each other's strengths and contribution o Documentation of work progress to recognise team members' contribution (i.e., priority list) o Formal and informal chats for team members to discuss and highlight concerns
Challenges	Conflicts	• **What are some of the conflicts (relationship, data, value) that can arise from collaborative work?** 1. Differences in Views Due to the different expertise within the team, there are bound to be differences in their point of view. For instance, the course developer team may design a gamification feature that the game developers find not value-adding. For example, the course developer team requested for an additional step in the game flow process (i.e., multi-stage MCQs) but the game developers find that adding another step does not add

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		value to the game flow and would only induce fatigue in the players. Changes in the game flow and content would also result in scope creep. This may cause tension within the team if no clear decision is made. 2. Differences in Priorities Different stakeholders have different priorities. For example, the experts might take longer to reply to questions from the team, which might affect the project's schedule. 3. Differences in Working Style and Personality Types Work style refers to the set of behaviours and attitudes a person applies to their tasks and relationships at work. Different personality types thrive in different situations and environments. This may cause tension among team members. • **What steps/ procedures/ structure can be implemented to address conflicts (role definitions, time constraints, power/authority distribution)?** o Regular meetings to discuss project development and to mitigate issues arising from time constraints o Discuss alternative solutions, such as reducing the scope of projects or simplifying aspects of the work o Engaging more members to join the team to handle the extra work o Refer back to the learning objectives or seek the project lead for final decision o Have informal discussions and meetings to build teamwork and relationships

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	Constraints	• **How are meeting times protected and used efficiently?**
		  o Schedule meetings at least two weeks ahead
		  o Set clear agenda that focuses on all team members' contributions
		  o Only discuss significant issues that will affect the project's scope and schedule
		  o Smaller issues should be discussed within the affected subgroups, and propose the recommended solution and its impact on the project should be discussed during the formal meeting
		
		• **Is there sufficient time for team members to interact and complete their tasks?**
		It is vital to allow and trust the team members to set their own time to complete their tasks rather than micro-managing them. This way, they will gain confidence in themselves and boost their morale and productivity.

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5.1.6 Lessons learnt

Once the DGBL project is completed, it is advisable to list all obstacles faced during the development and consolidate the lessons learned during the closing stage. These can be collated through educators' observations, interviews, and focus group discussions with the learners. Throughout the three-week DGBL course, the authors learnt that:

1. Learners prefer having a guiding character to provide scaffolding for learning. Although SSD has an existing guiding character (i.e., Mr CD in Figure 8), the learners felt that it could be more engaging so they could have a better connection with him.

2. Learners appreciate the authentic 3D environment as it helps them visualise the scenarios better. This is especially useful for professionals with limited site experience or just starting in the industry.

3. Designing authentic tasks and activities within the game allows the learners to appreciate and apply their existing knowledge and practice their newly acquired skills. Learners also prefer having more control to explore and manipulate the simulated environment.

4. Learners are unfazed by the competitive elements within the game. They are more interested in understanding the DfS process and content in the game. Therefore, the competition element might be optional for professional upskilling DGBL.

It is advisable to also investigate the perspective of project management for DGBL. The authors have compiled a list of obstacles and mitigation measures for future DGBL developments (Table 5).

Table 5 Obstacles faced and its possible mitigation

S/N	Obstacles	Possible Mitigation
1	Game content was not validated and resulted in frequent changes	• Have a dedicated expert team to validate the content at every iteration of the project progress

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2	Scope creep due to changes in in-game features	• Course developer team can conduct a pilot study and in-depth literature review to determine the scope of the game features • Discuss the impact of scope change with the development team and prepare the list of additional resources required for the change
3	Experts were not frequently updated on the progress of the project	• Schedule periodic monthly meetings to present the game prototype • Blast an email update to inform the project progress and the changes made from the last iteration
4	Response time for email support for learners	• Provide a dedicated person in charge to answer email queries during the weekends (when the professionals are more active during the online course) • Provide a frequently asked questions section online where learners can troubleshoot their problems on their own • Set up an automated email reply indicating that their emails will be replied to within three working days

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5.2 Annexe B – Sample course structure

Week	Activity	Strategy	Expected Hours	Learning Outcomes

1	**<u>Design for Safety and its Importance</u>**
	• Definition of DfS and its concept
	• Introduce the relevant regulations
	• Address the importance of DfS and the roles of designers
	• Introduction to Risk Management (RM) and its components (based on the RMCP)
	  o Conducting Risk Assessment (RA)
	  o Identification of hazards
	  o Risk rating (S&L)
	  o Examples of hierarchy of control
	  o HSE Framework
	• Introduction to GUIDE process
	• Explain the difference between design risk (DR) and operational hazards (OH)
	  o Use of the flow chart
		1. Learners' Profile Questionnaire
		2. Pre-test quiz
		3. 2-hour introductory video lecture
		  a. Introduce DfS concepts
		  b. Provide examples of risks identification
		  c. Practice questions on risk assessment
		4. Release assignment descriptions
			~2 hours	• Utilise their roles as designers to apply the hierarchy of control in the DfS process
				• Identify common design risks that can affect the safety and health of workers
				• Evaluate design risks based on severity and likelihood, risk levels and detailed safety review

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	○ Provide examples to differentiate design risk and operational hazards			
2	**<u>Scenario 1: Two office towers with link bridges</u>** • Identification of DR and OH • Introduction of OH as red herring • Emphasise the flow chart (**Focus:** identification of design risk) • Conducting S&L rating for DR • Provide explanations for the model answer **<u>Scenario 2: Development of shopping mall</u>** • Conducting S&L rating for DR • Emphasise the flow chart (**Focus:** implementation of controls to mitigate the DR) • Introducing industry standards, guidelines, and norms ○ *PV Panels* – checking against the Fire Code and BCA's requirement	1. SSD Scenario 1 and 2 2. Forum discussions	2 hours	• Identify common design risks that can affect the safety and health of workers • Evaluate design risks based on severity and likelihood, risk levels and detailed safety review • Identify industry standards, guidelines, and norms when mitigating design risks

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	• Introduction to detailed safety review o *M&E Pipes* – no fixed requirement and require participants to think out of the box			

3	**<u>Scenario 3: Underground railway project</u>**
	• Emphasise the flow chart (**Focus:** applying known design changes and controls from other projects, standards or codes)
	  o Basement construction
	  o Temporary opening
	
	<u>Scenario 4: Housing project with detention tank</u>
	• Emphasise the flow chart (**Focus:** conducting a detailed review of DR and considering design options)
	• Introduction to detailed safety review
	  o *Detention Tank* – small openings and require
		1. SSD Scenario 3 and 4
		2. Forum discussions
		3. Post-test quiz
		4. Course evaluation questionnaire
		5. Submission of assignment
			~2 hours	• Identify industry standards, guidelines, and norms when mitigating design risks
				• Critique different design alternatives to eliminate or reduce design risks
				• Formulate alternative design changes to manage design risks

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	participants to change the construction sequence			

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5.3 Annexe C – Sample marking criteria

Criteria	Not Proficient	Proficient	Advanced
Identify design risks present in the scenario (25%)	[1 – 2 marks] Less than half of the hazards: • Includes necessary case details or industry knowledge • Indicated lifecycle • Clearly described as design risk	[3 – 4 marks] More than half of the hazards: • Includes necessary case details or industry knowledge • Indicated lifecycle • Clearly described as design risk	[5 marks] All or almost all the hazards: • Includes necessary case details or industry knowledge • Indicated lifecycle • Clearly described as design risk
Evaluate the risk levels of identified design risks based on the risk matrix (25%)	[1 – 2 marks] Less than half of the hazards: • Have suitable inherent risk levels • Have a suitable reduction in severity and likelihood	[3 – 4 marks] More than half of the hazards: • Have suitable inherent risk levels • Have a suitable reduction in severity and likelihood	[5 marks] All or almost all the hazards: • Have suitable inherent risk levels • Have a suitable reduction in severity and likelihood
Suggest suitable design changes or controls to mitigate the design risks (25%)	[1 – 2 marks] Less than half of the controls: • Clearly described as design-related • Have referenced relevant legislation or standards	[3 – 4 marks] More than half of the controls: • Clearly described as design-related • Have referenced relevant legislation or standards	[5 marks] All or almost all the controls: • Clearly described as design-related • Have referenced relevant legislation or standards

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Apply the principles of hierarchy of control in the design of mitigation measures (15%)	[0 – 8 marks] No or very few design-related controls are elimination or substitution; have some engineering controls	[9 – 12 marks] Mainly engineering controls with some elimination or substitution	[13 – 15 marks] More than half elimination or substitution with some engineering controls; at least one elimination
Overall clarity of written communication and formatting (10%)	[0 – 5 marks] Several portions are hard to understand or need more clarity.	[6 – 8 marks] • Demonstrate clear and effective communication in the written report. • Produce a report that reflects consistent effort.	[9 – 10 marks] • Demonstrate clear articulation of knowledge and ideas, organized and effective communication in a written report. • Produce a report that reflects a sustained original effort.

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