THE DEVELOPMENT, VALIDATION AND EVALUATION OF PERSUASIVE GAMIFICATION PROBLEM-BASED LEARNING IN MEDICAL CURRICULUM

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by

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.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ATLAS.ti	Archiv für Technik, Lebenswelt und Alltagssprache (Archive for Technology, Lifeworld and Everyday Language.text interpretation)
BESS	Burch engagement survey for student
CA	California
CE	Cognitive engagement
CFA	Confirmatory factor analysis
CGPA	Cumulative grade point average
CI	Confidence interval
CL	Cognitive load
CLS	Cognitive load scale
CLT	Cognitive load theory
CM	Concept map
Corp.	Corporation
CRS	Classroom response system
CSF	Cerebrospinal fluid
CVI	Content validity indices
df	Degree of freedom
EBL	Example-based learning
ECG	Electrocardiogram
EE	Emotional engagement
EFA	Exploratory factor analysis
EL	Extraneous load
ERIC	Education Resources Information Center
e-learning	Electronic learning
FGD	Focus group discussion;
FVI	Face validity index
GBS	Guillain Barre Syndrome
GmbH	Gesellschaft mit beschränkter Haftung
GPA	Grade point average
HFHS	High-fidelity human simulation

ICL	Informal cooperative class
IQR	Interquartile range
ICC	Intraclass Correlation coefficient
IIUM	International Islamic University Malaysia
IL	Intrinsic load
Inc	Incorporation
IR 4.0	Industrial revolution
IT	Information technology
I-CVI	Item-level content validity index
I-RPVI	Item-level response process validity index
LBL	Lecture-based learning
MD	Mean difference
MESH	Medical Subject Headings
MQA	Malaysian Qualification Agency
MTFQs	Multiple true false questions
MUET	Malaysian University English Test
NCBI	National Center for Biotechnology Information
NGT	Nasogastric tube
NY	New York
PBL	Problem-based learning
PG-PBL	Persuasive gamification problem-based learning
PE	Physical engagement
PhD	Doctor of Philosophy
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Review
Q&A	Question and answer
RCT	Randomised controlled trial
RPVI	Response process validity index
SBAs	Single best answers
SBQs	Scenario-based questions
SD	Standard deviation
SP	Standardised patient
SPL	Self-perceived learning
SPSS	Statistical Package for the Social Sciences
S-CVI	Scale-level content validity index

S-CVI/UA	Scale-level content validity index universal agreement
S-CVI/Ave	Scale-level content validity index averaging method
S-RPVI	Scale-level response process validity index
S-RPVI/UA	Scale-level response process validity index, universal agreement
S-RPVI /Ave	Scale-level response process validity index, averaging method
TL	Traditional lecture
USA	United States of America
USM	Universiti Sains Malaysia
VR	Virtual learning
WA	Washington
WoS	Web of Science

LIST OF APPENDICES

PEMBANGUNAN, PENGESAHAN DAN PENILAIAN PEMBELAJARAN BERASASKAN MASALAH YANG MENGGUNAKAN GAMIFIKASI PERSUASIF DALAM KURIKULUM PERUBATAN

ABSTRAK

Pembelajaran berasaskan masalah (PBL) ialah pendekatan berpusatkan pelajar yang menggalakkan pelajar memperoleh dan mengguna pengetahuan dan kemahiran untuk pembelajaran sepanjang hayat. Walau bagaimanapun, untuk memupuk minat penglibatan pelajar kepada aktiviti pembelajaran dalam PBL adalah mencabar kerana kerumitan prosesnya dan kewujudan interaksi pelbagai pembolehubah. Gamifikasi persuasif adalah kaedah yang terbukti berkesan dalam pendidikan tinggi, di mana elemen reka bentuk permainan digunakan untuk meningkatkan penglibatan dan merangsang tingkah laku pembelajaran pelajar. Oleh itu, menggabungkan elemen reka bentuk permainan dalam reka bentuk pengajaran PBL boleh menjadi kaedah yang berkesan untuk menarik minat penglibatan pelajar dengan aktiviti pembelajaran. Kajian ini bertujuan untuk membangunkan garis panduan PBL gamifikasi persuasif yang sah dan berkesan untuk pensyarah dan meneroka kesannya terhadap pembelajaran pelajar. Kerangka Pembelajaran Berasaskan Masalah Gamifikasi Persuasif (PG-PBL) telah dibangunkan dengan menggunakan strategi yang terbukti secara empirikal daripada dua tinjauan skop, yang meneroka tingkah laku pembelajaran pelajar yang berkesan dan unsur gamifikasi persuasif dalam persekitaran pembelajaran kolaboratif. Elemen yang dikenal pasti telah digabungkan ke dalam pendekatan PBL 7 langkah Maastricht yang menghasilkan 7 langkah PG-PBL dengan dua langkah tambahan iaitu “step prep” dan “step add”. Kajian pengesahan kandungan, proses respon, dan kesahan struktur dalamannya dinilai dalam beberapa siri kajian

kesahan yang melibatkan lapan pakar pendidikan perubatan dan 12 tutor PBL. Keberkesanan PG-PBL dikaji dalam satu kajian percubaan rawak terkawal yang melibatkan 27 pelajar dari universiti perubatan awam di Malaysia, di mana PG-PBL dibandingkan dengan model PBL atas talian yang menggunakan 7 langkah Maastricht. Kesan PG-PBL terhadap beban kognitif pelajar, tahap penglibatan pelajar, dan perolehan ilmu telah dikaji. Pengalaman mereka menghadiri sesi PBL tersebut juga diterokai dalam beberapa sesi perbincangan berfokus secara berkumpulan. Tidak terdapat perbezaan yang signifikan antara perbezaan kumpulan bagi tiga konstruk beban kognitif, walaupun skor pembelajaran intrinsik dan persepsi kendiri pembelajaran didapati lebih tinggi dalam kumpulan PG-PBL. Di samping itu, PG-PBL mempunyai impak yang besar dalam mengurangkan beban kognitif extraneous pelajar dan impak yang sederhana terhadap persepsi kendiri pembelajaran pelajar, di mana pendekatan ini melibatkan pelajar untuk menumpukan sumber mental yang penting untuk membentuk hubungan mental dan skema maklumat yang dipelajari. Tambahan pula, kumpulan PG-PBL mempamerkan penglibatan kognitif dan emosi yang lebih besar berbanding dengan kumpulan kawalan. Namun, perubahannya tidak ketara. PG-PBL diperhatikan mempengaruhi penglibatan kognitif pelajar secara sederhana, yang mana faktor ini boleh mempengaruhi pemahaman pelajar tentang kandungan PBL. Kumpulan PG-PBL mengatasi kumpulan kawalan dalam pemerolehan ilmu, walaupun mereka mempunyai ilmu asas yang sama. Analisis kualitatif mengenal pasti empat kategori yang mencerminkan pengalaman pelajar selepas menghadiri sesi PBL iaitu ciri-ciri sesi PBL yang dapat menarik minat penglibatan pelajar, faedah pembelajaran yang diperolehi hasil dari sesi tersebut, faktor yang menyumbang kepada pengunduran diri pelajar dari terlibat dalam sesi PBL tersebut, dan cadangan untuk meningkatkan penglibatan pelajar dalam sesi PBL. Sungguhpun hasil kajian kerangka PG-PBL

menghasilkan dapatan yang positif, isu kebolehlaksanaan telah diutarakan oleh para pensyarah dimana mereka mencadangkan agar versi akhir garis panduan PG-PBL menekankan supaya pelajar dapat membiasakan diri dengan kerangka PG-PBL tersebut. Usaha ini diharap dapat memperkasakan pemilikan dalam pembelajran pelajar supaya mereka dapat mengambil tnaggungjawab terhadap pendidikan mereka, memupuk pemikiran kritis dalam penyelesaian masalah, dan menggalakkan kerjasama serta memupuk sikap kerja berpasukan.

THE DEVELOPMENT, VALIDATION AND EVALUATION OF PERSUASIVE GAMIFICATION PROBLEM-BASED LEARNING IN MEDICAL CURRICULUM

ABSTRACT

Problem-based learning (PBL) is a learner-centred approach that encourages students to acquire and apply knowledge and skills for lifelong learning. However, engaging students to learning activities in PBL can be challenging due to its complexity and the interplay of various variables. Persuasive gamification has emerged as an effective method in higher education, whereby game design elements has been used to enhance engagement and stimulate learning behaviours. Therefore, incorporating game design elements in the design of PBL instruction could be an effective way to engage students with the learning activities. This study aims to develop a valid and effective persuasive gamification PBL guideline for tutors and explore its impact on students learning. The Persuasive Gamification-Problem-based Learning (PG-PBL) framework was developed by utilising empirically proven strategies from two scoping reviews that explored effective learning behaviours and persuasive gamification elements in collaborative learning environment. The identified elements were incorporated into the Maastricht 7-step PBL approach which resulted in the PG-PBL 7-step with two additional steps—step prep and step add. The content, response process, and internal structure validity of PG-PBL were evaluated in several series of validity studies involving eight content experts and 12 PBL tutors. The effectiveness of the PG-PBL was investigated in a randomised controlled trial involving 27 participants from one public medical school in Malaysia, whereby PG-PBL was compared with the online PBL that utilised Maastricht 7-steps method. The

impact of the PG-PBL on students' cognitive load, engagement scores, and knowledge acquisition were investigated and their experience attending the PBL session were explored in several focus group discussions. There are no significant between group difference of the three constructs of cognitive load, despite higher intrinsic and self-perceived learning scores in PG-PBL group. In addition, The PG-PBL has large impact on reducing students' extraneous load and moderate impact on self-perceived learning, whereby this approach engaged students to devote significant mental resources to form mental connections and schemata of the learned information. Furthermore, they exhibited greater cognitive and emotional engagement as compared to the control group, however the changes were not significant. The PG-PBL was observed to moderately affect students' cognitive engagement, which could have influenced the students understanding of the PBL content. The PG-PBL group outperformed the control group in knowledge acquisition, despite similar baseline knowledge. Qualitative analysis identified four categories reflecting student experiences which include characteristics of engaging PBL sessions, the benefits associated with such sessions, the factors that contribute to disengagement, and suggestions for enhancing engagement in PBL sessions. While the framework yielded positive outcomes, feasibility issues were addressed by the faculty members. Therefore, the researcher suggests a final version of the guideline, emphasising students' familiarity with the PG-PBL framework. This effort empowers students to take ownership of their education, fosters critical thinking and problem-solving, and promotes collaboration and teamwork.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter elaborates the research background, problem statement, research questions, significance of research, research objectives, research questions, research hypotheses and operational definitions related to this study.

1.2 Background of the research

Problem-based learning (PBL) is an educational approach that was introduced by the McMaster Medical University in 1965 to address the content-driven nature of preclinical subjects, which were lack of clinical application (Barrows, 1996). This new method had prompted the change of the medical curriculum from a traditional lecture-based to an integrated student-centred PBL-based approaches (Barrows & Tamblyn, 1980). The PBL pedagogy is a systematic approach that utilises authentic real case scenarios as a context for students' learning (Taylor & Miflin, 2008; Bai et al., 2023). In PBL, tutor serves as a facilitator to guide a group of students during the learning process, whereby the students are required to solve problems through collaborative group discussion (Rakhudu, 2015; Hmelo-Silver et al., 2019). The ability of students to identify gaps in their knowledge and acquire new skills to bridge the gap is important in the PBL process (Radcliffe & Kumar, 2017; Rotgans & Schmidt, 2019).

PBL has been implemented in a wide variety of undergraduate and graduate degree programmes, including medicine (Doherty et al., 2018), nursing (Choi et al., 2014), science (Pepper, 2009), engineering (Van Barneveld & Strobel, 2009), architecture (Banerjee & Graaff, 1996), law (Wijnen et al., 2017a), economics (Harun et al., 2012), and business (Smith, 2005). In addition, PBL also has been adopted in

primary and secondary education programmes (Wilder, 2015; Siew & Mapeala, 2016; Li & Stylianides, 2018). Despite a wide range of PBL practice in different disciplines, each discipline contains three common important elements in the PBL conduct: (1) a problem as the catalyst for learning, (2) a tutor as the learning facilitator , and (3) a dynamic group as the stimulus for collaborative learning (Dolmans et al., 2005). All the three elements must be presented for the students to create a positive PBL environment and foster a problem-solving learning experience.

In medical education setting, PBL utilises clinical case problems as the context for students to attain knowledge on the basic medical and clinical sciences. One of the commonly used models is the Maastricht 7-step method (Schmidt, 1983; Wood, 2003; Servant-Miklos, 2019a), which consists of identifying unfamiliar terms, defining the problem, brainstorming the problem, analyse and structure the results of the brainstorming session, formulate learning issues, perform self-study and discuss the findings. Using the aforementioned 7-step method, the students are trained to use the clinical reasoning skills in the problem-solving process, identify important and relevant learning needs for their self-study, and subsequently apply the newly gained knowledge to solve the given problem. The learning outcomes of this approach are considered achieved when the students manage to propose a solution to the problem (Barrows, 1985).

To ensure a successful PBL session, students are required to be actively engaged in PBL session, in which it requires the student to participate willingly in the proposed learning activities through teamwork and collaborative learning (Garcia & Roblin, 2008; Saqr & López-Pernas, 2023). In addition, the PBL itself is designed to stimulate student involvement by enabling them to develop a more autonomous and responsible attitude towards learning, as well as self-awareness towards student-directed learning

activities (Schmidt et al., 2009; Leary et al., 2019). Cognitive, emotional, and physical engagement, collectively termed academic engagement, constitute a multifaceted construct (Fredricks et al., 2004; Collie et al., 2016; Graham et al., 2023). Within this construct, cognitive engagement explores the psychological dimensions of learning, physical engagement encapsulates the actions taken during the learning process, and emotional engagement refers to the emotional attachment to peers, teachers, and the overall learning environment (Fredricks et al., 2004; Collie et al., 2016; Graham et al., 2023). Hence, studies have shown that academic engagement among allied health science students have a positive correlation with student academic achievement (Casuso-Holgado et al., 2013; Wong, 2013; Green et al., 2018; Khaze et al., 2020; Muca et al., 2023; Saqr et al., 2023). In addition, Carini and colleagues (2006) revealed that academic engagement managed to transform low ability student to achieve better academic achievement and perform better on critical thinking tests as compared to their classmates and even their seniors. Furthermore, Almulla (2019) reported that active engagement, encompassing activities such as knowledge sharing, information dissemination, and discussions, significantly contributes to enhanced academic achievement among students.

Cognitive, emotional, and physical engagement play essential roles in students' learning processes as they are positively associated with knowledge acquisition (Feroz et al., 2022). This connection is particularly vital as the acquisition of knowledge is regarded as the most important aspect of students' achievement, performance, and learning in higher education institutes (Feroz et al., 2022). Aligned with constructivist principles, PBL underscores knowledge acquisition as an internally guided process within a social context (Schmidt et al., 2019). This perspective posits that knowledge is gained through a socially mediated process as students assimilate new concepts based

on the synthesis of current and prior knowledge and experiences (Schmidt et al., 2019). Therefore, successful acquisition is measured by the extent to which students can immediately recall information based on predetermined learning objectives that required them to understand and apply specific concepts and principles to real-world conditions, extending beyond rote memory (Hidayati et al., 2020). This outcome reflects the ability of students to internalise and configure the knowledge in their minds for easy recall in the future (Hidayati et al., 2020).

Nevertheless, an area that is sometimes disregarded but holds significant importance in the instructional design is the cognitive load (Bentley, 2020) as it plays a crucial role in redesigning gamification strategies, specifically within the context of PBL sessions, where students need to engage in complex problem-solving activities within designated time constraints (Klepsch & Seufert, 2020). According to cognitive load theory (CLT), students can only process a limited amount of information in working memory at a time (Sweller, 1988, 2020). Thus, surpassing the working-memory limit restricts the information processing capacity for problem-solving activities, as these complex cognitive skills demand sufficient memory space and cognitive resources to perform (De Jong, 2010; Sweller et al., 2019). In addition, learning activities that exceed these cognitive limits impede the learning process (De Jong, 2010; Sweller et al., 2019). Therefore, strategies aimed at managing and optimising the allocation of cognitive resources—by reducing extraneous load and fostering self-perceived learning—are pivotal in determining the effectiveness of instructional learning strategies (Sweller et al., 1998; Van Merriënboer & Sweller, 2010; Chen, 2016; Sweller, 2020). Hence, addressing extraneous cognitive load is crucial to optimise the learning experience within PBL, as learners grappling with the complexities of ill-structured problems can benefit significantly from instructional

designs that reduce unnecessary cognitive burden such as the presentation of irrelevant or unnecessary information within the task or activity (Delahunty, Seery, Lynch, & Lane, 2014; Ninaus, Kiili, Wood, Moeller, & Kober, 2020).

The socio-cultural factors has a substantial impact on how students interact with educational activities and participate in learning environments (Frambach et al., 2012; Ogan et al., 2015; Li et al., 2020; Roux, 2022). In PBL context, socio-cultural factors play a crucial role in shaping how students engage and it has been challenged repeatedly by scholar due to its Western origins (Bleakley et al., 2008; Frambach et al., 2012; Frambach et al., 2019). For instances, feelings of uncertainty about the independence required in self-directed learning, a focus on tradition that impedes the uptake of a new approach to learning, a dependence on hierarchical sources rather than oneself or one's peers, and pressure to achieve rather than intrinsic motivation to learn pose challenges for students from both East Asia and the Middle East as compared to the Western Europe students (Frambach et al., 2012). In addition, non-Western students also refrain from active participation in discussions, which includes reluctance to speak up, ask questions, and challenge others (Frambach et al., 2014). Furthermore, study in one of the local Malaysian university discovered that socio-cultural issues may exacerbate the challenges associated with PBL implementation, particularly in the critical thinking aspect—students' hesitancy to engage in open and honest discussions on sensitive issues, avoidance of difficult topics, reluctance to offend or challenge prevailing views, perception of futility in offering differing opinions, and discouragement of questioning issues related to race and religion—contribute to discussions that occasionally remain at a surface level (Joseph Jeyaraj & Wald, 2020). These cultural factors contribute to variations in students' discussion behaviours and skills across different cultural

backgrounds, complicating the straightforward transfer of PBL to such cultural contexts (Frambach et al., 2012, 2014, 2019; Joseph Jeyaraj & Wald, 2020).

Over the past decade, gamification—the use of game design elements in a non-game context have been the topic of interest to researchers in various fields particularly in formal education settings (Caponetto et al., 2014; Dicheva et al., 2015; Dicheva et al., 2020). The popularity of gamification was primarily due to its function to motivate and enhance engagement with its game design elements to stimulate particular user behaviours (Chang & Wei, 2016; Poondej & Lerdpornkulrat, 2016; Khaleel et al., 2020). In a landscape review of gamification in medical education, McCoy et al. (2016) have gathered evidence that by incorporating game elements, it has the potential to promote active learning, increase student engagement, allow risk-free clinical decision making, and enhanced collaboration in medical education setting. Furthermore, in a time-constrained medical curriculum settings, gamification have been proven to be useful methods to improve retention of knowledge among medical students (Nevin et al., 2014). Moreover, in the context of collaborative problem-solving, gamification emerges as a powerful tool in educational innovation as it facilitates cross-cultural activities to alleviate fear among students while enhancing engagement, collaboration, motivation, and students' academic performance (AlSaad & Durugbo, 2021). In addition, despite cultural variances and language barriers, the incorporation of game elements such as randomness and rewards in collaborative learning activities has proven transformative (Titus & Ng'ambi, 2023). These game elements not only facilitated the reshaping of existing practices but also fostered the creation of new approaches in solving problems, resulting in a notable increase in productivity level as the game elements allowed for the adaptation of actions that enable learners to gradually build confidence over time (Titus & Ng'ambi, 2023). Furthermore, a study revealed that most

students expressed a preference for specific gamification features such as receiving points through interactions with peers from diverse cultural backgrounds when engaging in specific activity, such as sending messages, participating in video chats, and sharing documents to increase group collaboration, as opposed to earning points solely for playing games (Zhang et al., 2017). Moreover, in a collaborative learning environment where students may have little or no experience working in a culturally diverse team, prompt feedback facilitated by a notification system is crucial for enhancing user engagement, awareness, communication efficiency, and overall satisfaction within the multicultural learning environment (Lau et al., 2019).

The fundamental premise of this study is that there is a correlation between the quality of instructional design and the outcomes achieved by learners (Sweller et al,, 2011; Andrade et al., 2015; Jung et al., 2019). One of the key factors in instructional design is to validate the extent to which learning is personalised to individual learners' needs and learning environment, as opposed to learning that is based on a one-size-fits-all model (Bray & McClaskey, 2015; Huh & Reigeluth, 2017; Bingham, 2019). By considering these elements, instructional designers can create more engaging and meaningful learning experiences, encouraging inclusiveness and cultivating an environment that is more favourable to learning (Li et al., 2020; Roux, 2022). Hence, this study assumes that effective learning behaviour driven by persuasive gamification elements, specifically tailored for collaborative learning in a PBL context, contributes to the enhancement of learner achievement outcomes. Based on that premise, this study aims to identify evidence-based persuasive gamification elements that could promote students' engagement and achievement of learning outcomes in PBL context. These elements were explored from two scoping reviews related to students' effective learning behaviour in PBL, and persuasive gamification strategies in PBL. Subsequently, the

elements were used in the development of persuasive gamification PBL (PG-PBL) framework that serves as a guideline for tutors to conduct an engaging PBL session. The present work was conducted in three phases: Phase 1 involved the development of PG-PBL framework, Phase 2 involved the validation of the PG-PBL framework, and Phase 3 involved a pilot study that evaluated effectiveness of PG-PBL framework in promoting students' learning, whereby the PG-PBL framework was compared with the online PBL that utilise Maastricht 7-step framework in a randomised controlled trial.

The Coronavirus disease 2019 (COVID-19) pandemic, originating in Wuhan, China, in late 2019, rapidly spread worldwide, prompting global social distancing measures in 2020 (Kumar et al., 2021). These measures, including lockdowns in countries like Malaysia, led to the closure of non-essential sectors, including education, due to the virus's primarily close-contact transmission (Kumar et al., 2021; Roslan et al., 2021). In this study, the intervention phase encountered challenges due to COVID-19 security measures. With all students off-campus as a direct consequence of the pandemic, the necessity to conduct sessions online rather than face-to-face significantly affected students' commitment to online PBL sessions and the implementation of PG-PBL sessions. Despite students' familiarity with online PBL sessions, sustaining commitment proved challenging, given that all students were off-campus, and the study was conducted on weekends outside formal academic sessions. For instance, students working from home faced competing priorities, such as personal responsibilities and potential family obligations, hindering their focus on the research task. To address these challenges, retention strategies, including weekly reminders with clear deadlines, highlighting the study's benefits, and reinforcing incentives, were implemented.

While the initial plan focused on implementing PG-PBL in face-to-face sessions, utilising interactive questioning techniques, turn-taking mechanisms,

interactive learning tools like Padlet for schematic mapping, and gamification elements such as manual point systems and leaderboards that would be projected in the PBL session, either using a projector or individual students' laptops or phones, the study's scope was not limited to this format. In addition, acknowledging the need for flexibility and adaptability in instructional design, the study also considered the integration of role-play as one of the interactive presentation strategies, particularly in face-to-face PG-PBL session. Furthermore, with the growing significance of online education, especially in response to the COVID-19 pandemic, the study explored how these interactive and gamification strategies could be effectively translated to online PG-PBL environments to ensure continuity and effectiveness across different modes of instruction.

1.3 Problem statement

Despite the popularity of PBL in higher education setting, it is argued that the effectiveness of PBL varies depending how it is being implemented (Dolmans et al., 2005; Azer et al., 2013; Servant-Miklos et al., 2019; Mabley et al., 2020). Indeed, there are several systematic reviews and meta-analyses performed to gather evidence of effectiveness of PBL method (Norman & Schmidt, 1992; Albanese & Mitchell, 1993; Berkson, 1993; Colliver, 2000; Newman, 2003; Neville, 2009; Manuaba et al., 2022; Alreshidi & Alreshidi, 2023; Sharma et al., 2023). These secondary studies examined the impact of PBL on various aspects of students' learning outcomes, such as knowledge acquisition, self-directed learning, problem solving abilities, group dynamic, and soft skills. Nevertheless, the results from these reviews were inconclusive (Norman & Schmidt, 1992; Albanese & Mitchell, 1993; Berkson, 1993; Colliver, 2000; Newman, 2003; Neville, 2009; Manuaba et al., 2022; Alreshidi & Alreshidi, 2023; Sharma et al., 2023).

Besides that, having a good group dynamic is a pertinent factor in a PBL session (Edmunds & Brown, 2010; Hammar Chiriac et al., 2021). A poor group dynamic discourages students to actively engage in problem solving activities in PBL (Hendry et al., 2003; Hung, 2011; Azer et al., 2013; Oo et al., 2020; Tang et al., 2020). For examples, having student who is dominating the group discussion prevents other students to contribute and to learn at their own pace (Hendry et al., 2003; Oo et al., 2020). A dominant student occasionally intimidates other students in the group. As a result, other students especially the quiet one would feel bad about themselves and may perceive that they are not benefiting from the PBL session (Hendry et al., 2003; Oo et al., 2020). In addition, students who are passive during PBL sessions may not be well-prepared in the subsequent PBL session, and subsequently may impose more pressure to other group as they may need to cover more learning issues independently (Dolmans et al., 1998; Hendry et al., 2003; Tang et al., 2020). Consequently, some learning issues might be missed or overlooked (Hendry et al., 2003). Besides that, passive students might feel compelled to keep quiet, especially when they perceived their idea is being rejected by the group members (Dolmans et al., 1998). Henceforth, they might stop trying and end up with frustration and resentment (Skinner et al., 2016).

When students begin to deviate from specific steps of PBL approach, it produces negative effect to their learning process and outcomes. For example, students occasionally skip the brainstorming and elaboration steps to cut short their case discussion, or automatically convert any predefined problems into learning issues (Moust et al., 2005; Mabley et al., 2020). Dolmans et al., (2005) reported that despite the use of prior knowledge during the discussion, students had difficulty to apply this knowledge within the context of the discussed problem, which indeed a crucial step in the problem-solving process. This situation would result in failure to restructure and

integrate the knowledge that they have acquired during the learning process (Moust et al., 2005; Mabley et al., 2020).

Besides that Dolmans et al. (2013) discovered that when the brainstorming and elaboration process failed to take place, the students generated vague learning issues that could not demarcate the content that should be studied during the self-study. As a result, the students were unable to connect the information gathered by their peers during the discussion sessions as they had deliberately studied different issues (Azer et al., 2013; Mabley et al., 2020).

On the other hand, having a good and clear learning issues does not necessarily guide the students on to how much time required for them to learn these topics during self-revision (Dolmans et al., 1994; Phage et al., 2023). Study have shown that despite having a list of relevant learning issues, they still prepared minimally for the next PBL session. In this situation, the students may have read the learning material but they do not master the subject matter (van den Hurk et al., 1999). Furthermore, many students tend to utilise the same learning resources as their peers while doing self-revision on the assigned learning issues (Moust et al., 2005). Hence, the input shared among themselves during the knowledge sharing session of PBL would be similar and redundant. Besides that, students tend to read aloud their own notes because they were unable to confidently apply their knowledge to the problem being discussed. These situations have hindered knowledge restructuring process in PBL because the students were unable to collect enough facts about the particular topic during the self-study period (Moust et al., 2005).

All the aforementioned problems could lead to declining students' engagement and motivation to learn during the PBL session. Hence, it is crucial to modify the PBL

session process to capture students' motivation and engagement. The PG-PBL framework incorporated into PBL session is seen as a potential solution to address these challenges.

1.4 Significance of the research

This study developed a PG-PBL framework and provides empirical evidence of the effectiveness of this framework. Based on the PG-PBL framework, several solutions were proposed to the current PBL practice to overcome the problems of PBL approach that utilise the Maastricht 7-steps method. The PG-PBL framework serves as a guideline for tutor in conducting an interactive PBL session via utilisation of gamify elements. Besides, the PG-PBL framework is useful for instructional design and professional development courses as PBL is a common instructional method in higher education setting. The implementation of PG-PBL framework, which is more systematic and engaging compared to the online PBL approach that utilise the Maastricht 7-steps method, would allow the formation of good group dynamic during the discussion, and facilitate students in managing their time during the discussion and self-revision. The format of PG-PBL requires every student to interact with their peers rather than to passively learned during the session. Indeed, the PG-PBL framework ensures students to receive a real-time feedback, which is occasionally practiced in the traditional PBL setting (Winning et al., 2005; Shamsan & Syed, 2009; Darungan et al., 2016; Almulhem & Almulhem, 2022). Indeed, PG-PBL is a promising approach to enhance teamwork skills, problem solving skills, communication skills and self-regulated learning.

Ever since its inception, evidence of effectiveness of PBL method has been inconclusive (Hendry et al., 2003; Moust et al., 2005; Hendry et al., 2006; Wells et al., 2009; Hung, 2011; Azer et al., 2013; Hung et al., 2019; Hallinger, 2021). The

effectiveness of PBL is largely dependent on how the learning process is conducted and implemented (Azer, 2005; Azer et al., 2013; Hung et al., 2019). Hence, a PBL session should be flexible and dynamic through utilisation of information technology (IT) and gamify elements as to meet the needs of the curriculum that align with the Industrial Revolution 4.0 (IR 4.0).

In response to evolving educational landscapes and the advent of diverse instructional modalities, this study emphasises the versatility of the PG-PBL framework in accommodating both face-to-face and online environments. The integration of gamification elements—ranging from interactive questioning techniques and turn-taking mechanisms to schematic mapping tools like Padlet and dynamic scoring systems—enriches the PBL experience across these varied settings. For face-to-face sessions, such gamified strategies, which can be projected in the PBL sessions using a projector or displayed on individual students' laptops or phones, leverage the physical co-presence of participants. This fosters immediate interaction and engagement by utilising tangible resources and live feedback to stimulate learning. Conversely, online implementations adapt these gamification strategies to digital platforms, enabling broader collaboration and resource accessibility. Furthermore, this shift not only addresses logistical constraints, such as those imposed by the COVID-19 pandemic but also capitalises on the unique opportunities of virtual environments to enhance learner engagement through flexible and innovative engagement strategies. Hence, understanding and leveraging the distinct advantages of each setting are crucial for the effective application of the PG-PBL framework, ensuring that it remains a robust and adaptable tool for modern educational challenges.

1.4.1 Research questions

The research questions are written according to the study phases.

1.4.1(a) Phase 1: The design and development of the PG-PBL framework

1. What are the elements of the PG-PBL framework?

1.4.1(b) Phase 2: Validation of the PG-PBL framework

2. What are the content validity evidence of the PG-PBL framework?
3. What are the response process validity evidence of the PG-PBL framework?
4. What are the experts' and users' level of agreement towards the PG-PBL framework?

1.4.1(c) Phase 3: Evaluation of the effectiveness of PG-PBL session

5. What is the difference of the students' intrinsic load, extraneous load, and self-perceived learning scores between control and intervention groups?
6. What is the difference of the students' emotional, physical, and cognitive engagement scores between control and intervention groups?
7. What is the difference of the students' pre-PBL and post-PBL test scores between control and intervention groups?
8. What are the changes of the students' test score within the study groups?
9. How do the students experience learning through the PG-PBL session?

1.5 General objective

To design and develop a PG-PBL framework that is effective for students' learning.

1.5.1 Specific objective

1.5.1(a) Phase 1: The design and development of the PG-PBL framework

1. To identify effective learning behaviours and persuasive gamification elements in PBL.
2. To design a PG-PBL framework based on the identified effective learning behaviours and persuasive gamification elements in PBL.
3. To develop an instructional guideline of the PG-PBL framework.

1.5.1(b) Phase 2: Validation of the PG-PBL framework

4. To investigate the content validity of the PG-PBL framework by evaluating the relevancy of PG-PBL strategies to its principles.
5. To investigate the response process validity of PG-PBL framework by evaluating the intelligibility and applicability of its principles and strategies.
6. To examine the internal structure of PG-PBL framework by measuring the degree of agreement among content experts and potential framework users.

1.5.1(c) Phase 3: Evaluation of the effectiveness of PG-PBL session

7. To investigate the effects of the PG-PBL session on the students' cognitive load with regards to intrinsic load, extraneous load, and self-perceived learning.
8. To investigate the effects of the PG-PBL session on the students' learning engagement with regards to emotional, physical, and cognitive engagements.
9. To investigate the effects of the PG-PBL session on the students' test performance score.
10. To explore students learning experience after attending the PG-PBL session.

1.6 Research hypotheses

The hypotheses are categorised based on the study phases and limited only for the quantitative variables of this study. Since Phase 1 involved with the development of the PG-PBL framework, there is no hypothesis formulated for this phase. In Phase 2, the formulated hypotheses reflect the expected validity indices of the PG-PBL framework, evaluated during the validation study, where the hypotheses were not subjected to statistical analysis. Hypotheses for Phase 3 were used for hypothesis testing and align with Research Objectives 7, 8, and 9, and are formulated as alternative hypotheses, including hypothesis 10 for baseline knowledge. Given that this study controlled for factors influencing students' baseline knowledge, it is anticipated that there will be no significant difference in students' baseline knowledge. Therefore, alternative hypothesis 10 resembles the null hypothesis.

1.6.1 Phase 1: Development phase

1. No hypothesis generated because this is the development stage.

1.6.2 Phase 2: Validation phase

2. Hypothesis 1 (for Objective 4): The content validity indices of the PG-PBL framework are more than 0.78.
3. Hypothesis 2 (for Objective 5): The response process validity indices of the PG-PBL framework are more than 0.8.
4. Hypothesis 3 (for Objective 6): The internal structure of the PG-PBL framework is good with intraclass correlation coefficient of more than 0.8.

1.6.3 Phase 3: Intervention phase

The alternative hypothesis 10 resembles the null hypothesis.

5. Hypothesis 4 (For objective 7): The group's intrinsic load score for the intervention is lower than the control group.
6. Hypothesis 5 (For objective 7): The group's extraneous load score for the intervention is lower than the control group.
7. Hypothesis 6 (For objective 7): The group's self-perceived learning score for the intervention is higher than the control group.
8. Hypothesis 7 (For objective 8): The group's emotional engagement score for the intervention is higher than the control group.
9. Hypothesis 8 (For objective 8): The group's physical engagement score for the intervention is higher than the control group.
10. Hypothesis 9 (For objective 8): The group's cognitive engagement score for the intervention is higher than the control group.
11. Hypothesis 10 (For Objective 9): There is no significant difference of baseline knowledge between the control and intervention groups.
12. Hypothesis 11 (For objective 9): The group's post-PBL test score for the intervention is higher than the control group.
13. Hypothesis 12 (For objective 9): The group's change of test score within group for the intervention is higher than the control group.

1.7 Operational definition

1. **Persuasive gamification elements:** This term refers to gamification elements identified through evidence-based synthesis method that have been to yield positive learning outcomes, with the goal of reinforcing, changing, or shaping behaviour in non-game contexts (Ghani et al., 2022). In this study, the results of the evidence-based synthesis method lead to the incorporation of game elements such as challenge, competition, constant feedback, and rewards through

activities like rating understanding with rubrics, tracking progress on leaderboards, and using interactive learning platforms for showcasing understanding, receiving feedback, and facilitating collaborative interactions with peers. These persuasive gamification elements were utilised to develop the PG-PBL framework, aiming to reinforce effective learning behaviour in PBL.

2. **Effective learning behaviour in PBL:** This term refers to any learning behaviour that is related to PBL instruction and has been shown to successfully attain the desired learning outcomes (i.e., cognitive, skill, or affective)—either quantitatively or qualitatively—in any intervention conducted in higher education institutions (Ghani et al., 2021).
3. **Control group (Online PBL):** This term refers to the control group that employed traditional PBL instructional strategies in a synchronous online PBL setting. In this context, it challenges students to develop their learning skills by working cooperatively in groups to seek solutions to real-world problems in an online learning environment (Nicolaou & Petrou, 2023).
4. **Intervention group (PG-PBL):** This term designates the intervention group that employed PG-PBL instructional strategies in a synchronous online PBL setting. Within this setting, students learning skills and collaborative work in groups are enhanced using the persuasive gamification elements to address real-world problems in an online collaborative learning environment (Ghani et al., 2022).
5. **Validation of the PG-PBL framework:** This term refers to validity studies conducted to examine the degree of agreement among content experts on the relevancy of PG-PBL items to the PG-PBL principles (Polit et al., 2007; Yusoff, 2019a), the clarity of language and instruction to interpret the items in the PG-

PBL framework among PBL facilitators (Polit & Beck, 2006; Yusoff, 2019b) and the inter-rater agreement among experts on construct of the PG-PBL framework (Koo & Li, 2016).

6. **Student engagement:** This term refers to the time and energy that students devote for educational activities inside and outside the classroom, and adhere to the institutional policies and practice that encourage students to take part in these activities (Kuh, 2003; Carini et al., 2006). In this study, three types of engagements were measured, which are emotional, physical, and cognitive engagement.
7. **Emotional engagement:** This term refers to the affective dimension of learning, which involves students' investment of emotions in learning activities, namely self-regulation and commitment to the mastery of learning (Fredricks et al., 2004). Furthermore, emotional engagement comprises of student interest to learn and their belonging experience within the PBL group (Fredricks et al., 2004). In this study, emotional engagement is reflected by students' feeling towards: (1) attending a PBL session, (2) the content learn within the PBL sessions, and (3) PBL assignments.
8. **Physical engagement:** This dimension of engagement entails active participation and involvement of students in PBL group that tutors instantly recognise. Hence, physical engagement comprises of students effort and persistence during learning activities (Meyer & Turner, 2002). In this study, physical engagement is reflected by students' effort in putting energy towards PBL sessions and completing the assignment in the PBL sessions.
9. **Cognitive engagement:** This dimension of engagement entails students' psychological state of willingness to take on the learning task at hand, which

includes the amount of effort students are willing to invest in their working memory as to ensure that they could truly understand the learned content (Corno & Mandinach, 1983), and persist studying over a long period of time (Richardson & Newby, 2006). In this study, cognitive engagement is reflected by students' willing to invest their working memory to focus on discussion, pay attention, and be immerse in the PBL sessions.

10. **Cognitive load:** This term refers to the demands imposed by a learning situation such as learning materials and learning activities on a learner's working memory. It also refer to the intensity of cognitive activity required to achieve specific learning objective within limited time frame (Kalyuga & Singh, 2016). Intrinsic load and extraneous load add up to overall cognitive load (Sweller et al, 2019). In this study, three types of cognitive loads were measured, which are intrinsic load, extraneous load, and self-perceived learning.
11. **Intrinsic load:** This cognitive load dimension is imposed by the complex nature or difficulty of the instructional content. Learning materials which contain high elements of interaction imposed high intrinsic load and is often perceived to be difficult by learners. (De Jong, 2010). Besides that, intrinsic load is influenced by the learner's prior knowledge. Learner with prior knowledge on the learned content experience lower intrinsic load and perceives the instruction to be less difficult compared to those without prior knowledge (Kalyuga, 2011).
12. **Extraneous load:** This cognitive load dimension hampers learning as it does not contributes to essential cognitive processing (Van Gog et al., 2004). This load is imposed by unnecessary or unrelated input, which can be perceived as distraction. (Sweller, 1994). It is also the avoidable load that results from suboptimal materials and activities (Kalyuga, 2011).

13. **Self-perceived learning:** The self-perceived learning is a cognitive load domain that is also known as germane load. This load refers to learners' extra efforts using mental resources to acquire and construct a schema for long-term memory (Sweller, 1994). Hence, this load is important to enhance learning ability because it is the result of learners' abstractions and elaboration process (Gerjets & Scheiter, 2003).
14. **Knowledge acquisition:** This term refers to obtaining information from external sources (Ogu & Adekunle, 2013). Successful acquisition is measured by the amount of information the student able to immediately recall based on predetermined learning objectives (Ammons, 1956; Ogu & Adekunle, 2013). In this study, knowledge acquisition was evaluated through a pre- and post-PBL test score—as these variables involve in information processing, storage and retrieval (Ammons, 1956).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a comprehensive literature review on PBL, persuasive gamification in PBL, and the outcomes of learning that were evaluated in this study. It is divided into six main sections: PBL, gamification, validation, cognitive load theory, engagement, and knowledge acquisition in PBL and gamified environments. The first part of the chapter provides an overview of PBL, encompassing its definition, inception, evolution, and its concept as a student-centred approach. It also elaborates how PBL aligns with constructivist instructional design principles and describes the traditional seven-step process of PBL, as adopted by Maastricht University. The second part of the chapter describes gamification and its application in education, particularly in the context of PBL. It then delves into the importance of persuasive design, which is an essential element for successful gamification. The third part of the chapter delves into validity in education, discussing various sources of validity evidence for assessment in the educational context. The fourth part of the chapter focuses on cognitive load theory, elucidating the different types of cognitive load that could be experienced by learners during learning process. This section also sheds light on how understanding cognitive load theory can inform the design of effective instructional strategies. The fifth part of the chapter elaborates on student engagement, which comprises physical, emotional, and cognitive dimensions. It examines the factors that contribute to learning engagement and highlights its significance in facilitating effective learning experiences. The sixth part of the chapter delves into knowledge acquisition in the context of PBL. It explores the processes and mechanisms through which students acquire knowledge within the PBL framework, emphasising the role of gamification in enhancing

knowledge acquisition outcomes. Finally, the conceptual framework is elaborated in the final subheading of this chapter.

2.2 Problem-based learning

PBL is an instructional approach that emphasises the use of real-world problems to promote active learning (Mumtaz & Latif, 2017), critical thinking (Zabit, 2010), and problem-solving skills (Smith, 1995). PBL has been used in various educational settings, including medical education (Neville, 2009), engineering education (Dahms, 2014), law education (Wijnen et al., 2017b), social studies education (Hughes et al., 1998), science education (Akcay, 2009), business education (Zabit, 2010), and economic education (Roche Carioti, 2020). The central idea of PBL is that learners are presented with a problem or scenario that reflects a real-world situation to promote discussion and work collaboratively to plan out their work toward a solution (Henry et al., 2012). Hence, PBL is often designed to be student-centred, where students take ownership of their learning and are responsible for identifying their own learning needs (Ghaemi & Potvin, 2020). In medical education, PBL uses patients as the context of the problem to help students learn basic sciences and clinical knowledge as they engage in small group discussions organised around complex clinical situations that simulate real-life scenarios, with the tutor acting as a facilitator (Barrows, 1983; Wood, 2003).

2.2.1 History of problem-based learning

The preliminary concept of PBL can be traced back to the works of a renowned American educational philosopher John Dewey, who introduced the Harvard case method that was implemented at Harvard Business School from the 1920s onward (Fraser, 1931). Dewey believed that learning is an experiential process that connects with a person's lived experience, often referred to as "learning by doing," and that it

should be triggered by a "problem," which is defined as an unclear situation or phenomenon that needs an explanation (Dewey, 1933). The Harvard case method inspired by Dewey, which is commonly used in business and law schools, shares some similarities with PBL in terms of its focus on problem-solving and critical thinking. This concept became the foundation of PBL, which emphasises the use of real-world problems to facilitate learning, which involved small groups of students under the guidance of a teacher or tutor (Servant-Miklos et al., 2019). However, the approach of the two methods is different, whereby the Harvard case method requires the students to prepare selected readings before attending the group discussion; while PBL involves students working in small groups to approach and solve new real-world problems fresh and unprepared, with nothing but their prior knowledge to tackle what was at hand (Fraser, 1931; Servant-Miklos, 2019c).

The modern version of PBL, began in the 1960s at McMaster University Medical School in Hamilton, Ontario, Canada (Barrows, 1996; Servant-Miklos et al., 2019). The development of PBL at McMaster University was a response to the limitations of traditional lecture-based teaching methods, particularly in medical education, where the traditional lecture approach at that time was criticised for being too passive, emphasising memorisation of fragmented biomedical knowledge, and hindering students' ability to apply their knowledge practically, which, in turn, may have contributed to unsatisfactory clinical performance (Barrows & Tamblyn, 1980; Spaulding & Cochran, 1991; Barrows, 1996). As a result, medical students at McMaster needed help applying their knowledge to real-world patient cases because they were left feeling disenchanted and bored with their medical education (Spaulding & Cochran, 1991). In contrast, during their residency, medical students were excited to work with patients and solve problems, highlighting the need for a more hands-on approach to