Abdul Ghani *et al. RPTEL* (2022) 17:21
https://doi.org/10.1186/s41039-022-00193-z

Research and Practice in
Technology Enhanced Learning

REVIEW

Open Access

Developing an interactive PBL environment via persuasive gamify elements: a scoping review

Azril Shahreez Abdul Ghani[1,2], Ahmad Fuad Abdul Rahim[2], Muhamad Saiful Bahri Yusoff[2] and Siti Nurma Hanim Hadie[3*]

*Correspondence: snurma@usm.my

[3] Department of Anatomy, School of Medical Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, 16150 Kota Bharu, Kelantan, Malaysia
Full list of author information is available at the end of the article

Abstract

The application of gamified elements to PBL to promote student engagement has not been systematically described. Hence, we conducted a review based on Arksey and O'Malley's five-stage scoping review framework, involving research question identification, relevant study identification, study selection, data charting, and result collating and reporting. We searched three databases using five search terms combined with a Boolean operator: "problem-based learning" AND "persuasive OR gamify OR gamification OR game". The initial pool of 5532 sources was evaluated according to the eligibility criteria, and 14 original articles were selected for the final data extraction. A content analysis was performed, and several persuasive gamification elements for PBL were identified. The results were reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. The analysis unearthed six main categories of persuasive gamification elements, which have been proven to be effective in the achievement of learning outcomes: high-fidelity simulation, inquisitive exploration, collaborative learning, interactive instruction, guidance and feedback, and rewards. These findings highlight the persuasive gamify elements that can be incorporated to support the active learning and engagement of students in PBL, thus preparing them to be lifelong, self-directed learners.

Keywords: Problem-based learning, Gamification, Active learning, Engagement, Persuasive gamification

Introduction

Problem-based learning (PBL) is a student-centred instructional strategy that is characterised by three elements: triggers, tutors and students (Mustard, 1982). A PBL involves small group discussion and presentation, whereby the students learn using authentic real-world problems, guided by a tutor. The quality of these elements and the dynamic interactions among them determine the success of a PBL session. Triggers usually contain case scenarios or problems created by content developers to initiate students' discussions in the PBL sessions, and thus facilitate the problem-solving process (Schmidt et al., 2011). Hence, PBL is an effective platform for integrating the basic sciences with clinical knowledge (Azer et al., 2012; Hmelo-Silver, 2004). In addition, the trigger should be designed in a way that can stimulate students' enquiry and promote sustainable group discussion to ensure the achievement of a possible solution (Majoor et al., 1990).

A PBL tutor also plays a major role in ensuring the smooth running of discussions during a PBL session by establishing a mechanism that would allow all students to actively partake in the discussion. Such mechanisms include obtaining students' consensus in assigning learning roles and asking mind-blowing questions that can stimulate discussion (Azer, 2004; Schell, 1998). Furthermore, a tutor needs to instil students' interest and motivation by encouraging the group members to share their experiences that are related to the learning context (Azer et al., 2013).

The students' role in PBL is to discuss the triggers in a small group of eight to ten students, whereby they need to identify and clarify any new terminologies, categorise issues related to the problem, brainstorm possible hypotheses based on their prior knowledge, develop an enquiry plan and refine their hypotheses based on the evidence from the provided information in the problem scenario (Hendry et al., 1999; Orrill, 2002). Subsequently, the students need to formulate suitable learning issues and agree upon these issues before proceeding with task distribution and execution. During self-exploration and self-study, students need to gather all resources related to the learning issues and integrate the new information into the issues raised during the discussion. The findings of the self-task will be presented to the group members during the second PBL session (Wood, 2003). It is worth highlighting that the primary aim of PBL is to stimulate discussion and integrate various branches of knowledge while attempting to solve problems (Taylor & Miflin, 2008).

PBL has gained popularity as an effective method to instil problem-solving skills in undergraduate medical students (Demirören et al., 2016; Karunathilake, 2019; Tayyeb, 2013). Several recent reviews have documented the positive impact of PBL on students' learning. Torre et al. (2016) revealed that PBL has the capability to enhance students' intrinsic motivation and active learning, which consequently promotes a deep learning approach. Norman and Schmidt (1992) concluded that students who attended PBL sessions achieved a higher retention of knowledge over a period, acquired essential skills for integration of basic sciences with clinical knowledge and strengthened their self-directed learning skills throughout the medical programme.

Prince et al. (2005) revealed that medical graduates who attended a PBL-based curriculum perceived their communication skills as well-developed, as they could confidently communicate with others during their internship. The application of PBL during medical school also prepared students to be competent in decision-making, which is well aligned with the needs of future physician (Schmidt et al., 2006). A systematic review of the impact of PBL-based curriculum also revealed a positive achievement of medical graduates' competencies, namely related to cognitive and affective learning domains (Koh et al., 2008).

However, the implementation of PBL has some limitations. A survey by Al-Naggar and Bobryshev (2012) revealed the low receptivity of this method among medical students. Students in the PBL-based curriculum perceived their workload during PBL learning as taxing, not rewarding and time-consuming compared to traditional lectures (Dolmans et al., 2016). As a result, students opted for a simple, short-cut discussion before making an immediate diagnosis, rather than exploring the process to achieve the diagnosis (Moust et al., 2005). Most of the students failed to engage in self-study and were thus unprepared for the second session. Consequently, the PBL discussion was ineffective and failed to construct new knowledge (Hung, 2011; Moust et al., 2005). Therefore, educational researchers need to evaluate and explore different strategies in which PBL can be integrated with other pedagogical approaches to augment the positive effects of a single approach. One way of doing this is by utilising gamification in PBL.

Gamification is the utilisation of game design elements or experiences in a non-gaming context to increase student engagement and stimulate their active participation, thus enhancing educational outcomes (Deterding et al., 2011). Lazzaro (2004) stated that game elements stimulate human emotions, such as enjoyment, amazement, sense of achievement, happiness, greed and frustration. Gamification motivates and enhances learners' engagement and promotes the achievement of learning outcomes (Hamari et al., 2016; Mahmud et al., 2020; Ott & Tavella, 2009). Gamification also increases students' participation in class, strengthens their collaboration, motivates them to perform self-study and complete assignments, promotes exploratory approaches to learning and enhances their creativity (Dichev & Dicheva, 2017). Hence, gamification is an effective way to enhance learners' engagement and collaborative skills in problem-solving (de la Peña Esteban et al., 2020; Huang et al., 2010).

The backbone of gamification is the game design elements that help students to achieve task performance. A seminal study by Toda et al. (2019a, 2019b) synthesised 21 game elements for gamification relevant in the educational context. The study was based on a survey conducted among 19 gamification and educations experts. The game elements synthesised in the study include: (1) acknowledgement: appreciation given to the players in the game; (2) chance: possibility of certain actions to occur; (3) competition: players strive towards common goals; (4) cooperation: players working together to achieve common goals; (5) economy: using monetary transactions within the game; (6) imposed choice: decisions that must be made by players to proceed in the game; (7) level: hierarchical layers present in a game; (8) narrative: chronological events that occur in a game; (9) novelty: new and updated data and information; (10) objectives: guides the players' actions; (11) points: unit awarded for players' achievement; (12) progression: unit to measure players' progress; (13) puzzles: challenges in a game to stimulate thinking in players; (14) rarity: application of limited resource elements in the game; (15) renovation: act of a player that can repeat; (16) reputation: recognition that players accumulate in a game; (17) sensation: players create new experiences and connections in a game; (18) social pressure: peer pressure interaction within the game; (19) stats: data that represent players in a game; (20) story telling: activity of a game that is told; and (21) time pressure: pushing factor through time within a game.

Successful gamification is not just applying game elements or game experience. Learners also need to consider other instructional elements, namely the context of instruction that is gamified (Hamari et al., 2014), and the theoretical application that is suitable for that context (Van Gaalen et al., 2021). Among various established educational theories, self-determination theory (SDT) is aligned with the implementation of gamification in PBL as this theory emphasises the function of motivation in a social context to drive individual and collaborative learning (Ryan & Deci, 2000). According to Ryan and Deci

(2000), motivation is the desire to perform a task, explained in two ways: (1) intrinsic motivation—defined as internal desire to perform a task because of love and enjoyment; and (2) extrinsic motivation—defined as doing a task solely for the outcome purpose.

The SDT satisfies three basic psychological and social needs that could stimulate their intrinsic motivation to learn: autonomy, competence, and relatedness. Autonomy refers to the sense of will when performing a task. For example, when a learner performs an activity by his or her own personal will and interest, the learner perceives high learning autonomy, which subsequently enhances his intrinsic motivation (Van den Broeck et al., 2010). Competence refers to the need of learners to be efficient in performing a task and willingness to participate in challenges. To improve learners' perceived competence, constructive feedback is given by instructors or tutors during and after each task completion to improve students' intrinsic motivation (Sailer et al., 2017). Relatedness refers to a learner's feeling of being connected to other group members and the tutor. By having the sense of relatedness, a learner perceives receiving full learning support, which in turn increases their intrinsic motivation (Ryan & Deci, 2000).

The SDT has been proven to be beneficial in medical science disciplines that involves collaborative learning activity. A qualitative study by Patiwael et al. (2021) that explored students experience in learning physical examination skills unearthed several themes related to collaborative learning, namely "interaction", "thinking for themselves" and "active participation". These themes also comply with the framework of the SDT. Similarly, Burgess and Ramsey-Stewart (2014) reported the use of SDT elements in whole-body dissection group activities facilitated by surgeons that could facilitate student motivation. The sessions had instilled students' enthusiasm, the sense of having group support and good learning achievement, and provided optimal challenges in group activities, which consequently facilitated their motivation to learn (Burgess & Ramsey-Stewart, 2014). Hence, this scoping review aims to unearth the persuasive gamify elements related to PBL and collaborative learning that fulfil the three psychological needs of SDT.

Methods

Scoping review protocol

Two ethical approvals were obtained prior to the review (Human Research Ethics Committee Universiti Sains Malaysia,(USM/JEPeM/19120849) and International Islamic University Malaysia Research Ethics Committee (IREC 2019-242).This scoping review was performed using the protocol by Arksey and O'Malley (2005), which comprises five phases: (i) identification of research questions; (ii) identification of relevant articles; (iii) selection of relevant studies; (iv) data collection and charting; and (v) collating, summarising and reporting the results.

Identification of research questions

This scoping review aims to capture the persuasive gamify elements that could be generated from PBL instruction by answering one research question: What are the persuasive gamify elements related to PBL? For review purposes, the persuasive gamify elements in PBL were defined as gamify elements that have been proven to successfully promote the achievement of desired learning outcomes—either quantitatively or qualitatively—in a

PBL setting. The positive outcome variables include students' and faculty perception of the educational intervention, students' learning experience and task performance after the educational intervention, experts' judgement of learning context, and other indirect variables such as students' attendance rate, participation, interactions and improvement in communication skills in a PBL setting.

Identification of relevant articles

An electronic search was performed using three databases—PubMed, Google Scholar and Scopus. PubMed and Scopus cover a wide range of indexed databases (Balhara, 2012), while Google Scholar is the most comprehensive academic search engine yielding 389 million academic records (Gusenbauer, 2019). By combining multiple databases, the comprehensiveness of the literature could be achieved (Xiao & Watson, 2019). The searches were conducted on articles published in English between 2016 and 2020. Five search terms with Boolean combinations were used, whereby the keywords were identified from the Education Resources Information Center (ERIC) and Medical Subject Headings (Mesh) databases. The search terms were tested and refined using multiple test searches. The final search terms with the Boolean operation were as follows: "problem-based learning" AND "persuasive OR gamify OR gamification OR game". The final search for this study was conducted on 30 January 2020.

Selection of relevant articles

The relevant articles were identified, reviewed and selected based on several selection criteria (Table 1). These criteria were tested on a sample of titles and abstracts to ensure

Table 1 Inclusion and exclusion criteria

Criteria	Inclusion criteria	Exclusion criteria
Abstract selection	The abstract	The study context mentioned in the abstract is primary and secondary education
	Has at least one persuasive gamify element in PBL or collaborative setting in higher education	
	Provides evidence of a robust study design, not limited to randomised controlled trials	
	Provides evidence of evaluation and highlights quantitatively and qualitatively measurable outcomes	
Full article selection	The article	Review articles, published theses, books, research report, editorial and letters will be excluded from the searching process
	Provides elaboration on effective persuasive gamify elements	
	Provides well-designed research intervention with clear methodology on the measurement of the outcome	
	Describes PBL or collaborative learning as the context of study	
	Describes a functional element that has been proven to promote learning	

their robustness in capturing articles related to persuasive gamify elements in PBL. The eligible articles were reviewed by two researchers, and consensus was reached either to accept or reject the articles.

Data charting

The extracted data were charted in a table, and these include author(s), publication year, discipline, intervention performed and outcomes.

Collating, summarising and reporting the results

A thematic analysis was performed to identify the persuasive gamify elements in the literature. The elements were selected based on SDT psychological and social needs and were organised into several themes and subthemes. This process was performed by two independent researchers. The inputs from both researchers were triangulated, and consensus was made either to accept or reformulate the themes and subthemes.

Results

Literature search

Based on the keyword search, 5532 articles were obtained, from which 5343 duplicates and resources that were not original articles were removed. Based on the inclusion and exclusion criteria for abstract selection, the eligibility of the remaining 126 abstracts was evaluated. The abstracts that did not fulfil the criteria were removed, leaving 35 articles for the subsequent evaluation. The 35 full articles were evaluated for eligibility based on the inclusion and exclusion criteria for the full article. Finally, 14 articles were selected for the final review, and important information was extracted. Table 2 summarises the study characteristics. The selection stage is explained using a PRISMA flow chart (Moher et al., 2009) (Fig. 1).

Results of the thematic analysis

The thematic analysis yielded six main themes of persuasive gamify elements: high-fidelity simulation, inquisitive exploration, collaborative learning, interactive instruction, guidance and feedback, and rewards. These themes comprise 16 subthemes, which are described in detail in the next subsections. Table 3 summarises the results.

Theme 1: high-fidelity simulation

High-fidelity simulation involves a simulation that is authentic to the learning context. For instance, students can perform a role-play according to the given scenario and learning objectives of PBL (Duncan et al., 2018). Adopting the clinical scenario into the role-play will make the session more lively, and students could appreciate the learning through verbal and non-verbal acts (Novak et al., 2018). During the role-play, the students can simulate their role not only as a doctor, but also as a patient, family member or even a technician in handling medical equipment (Duncan et al., 2018; Mutter et al., 2020).

In addition, simulation requires the use of real equipment that is normally used in the actual or clinical setting. These include using a sphygmomanometer and cardiac

Table 2 Studies' characteristics

References	Location	Study design	Intervention	Outcome
Mutter et al. (2020)	USA	Randomised control trial	Investigating the effect of high-fidelity simulation on medical students' clinical reasoning skills	Improved reasoning skills
Souza et al. (2020)	Brazil	Period cross-sectional	Examining the effect of brain quiz and games on medical students' cognitive tests	Improved prior knowledge
Shukor et al. (2019)	Malaysia	Quasi-Experimental design (non-equivalent control group posttest-only design)	Measuring the effect of 5S interactive board game on undergraduate student learning process	Improved understanding and knowledge of the 5S practice
Dandge & Desai (2019)	India	Cross-sectional study (period cross-sectional)/study design not mentioned for qualitative approach	Evaluating the effect of competitive elements in project-based and problem-based learning	Improved student engagement, participants employability, problem-solving ability and multidisciplinary teamwork
Shi et al. (2019)	China	Quasi-experimental design (non-equivalent control group posttest-only design and phenomenology)	Evaluating the effect of game mechanics in Pyrus on undergraduate students planning and collaboration skills	Improved planning and collaborative skills
Prochazkova et al. (2019)	Czech Republic	Quasi-experimental design (one group pretest–posttest design)	Evaluating the effect of an e-learning application that utilises problem-solving and gamification on medical students' genetics knowledge	Improved students' knowledge of genetics
Novak et al. (2018)	USA	Quasi-experimental design (one group pretest–posttest design)/study design not mentioned for qualitative approach	Examining the effect of instructional gamified case-based learning and the learning material on educational science graduate student engagement	Improved engagement and achievement of learning outcome
Topalli and Cagiltay (2018)	Turkey	Period cross-sectional	Investigating the effect of real-life problem-based games	Improved students' learner performance in programming course
			Development using Scratch programming environment on engineering students' programming skills and motivation	
Mayer et al. (2018)	USA	Quasi-experimental design (non-equivalent control group posttest-only design)	Examining the effect of notable protagonist patient in clinical case on medical student learning experience	Improved student learning experiences
Duncan et al. (2018)	UK	Phenomenology	Examining postgraduate science students' experience with gamified, mystery-driven and role-playing approaches in problem-based learning	Improved student learning experience
Rozali and Zaid (2017)	Malaysia	Quasi-experimental design (one group posttest-only design)	Evaluating the effect of problem-based learning with mobile games on postgraduate students' motivation	Increased students' motivation to learn

Table 2 (continued)

References	Location	Study design	Intervention	Outcome
Jensen (2017)	Denmark	Quasi-experimental design (one group posttest-only design)/study design not mentioned for qualitative approach	Examining the effect of gamification principle (virtual reality) on problem-based learning process	Increased collaborative and learning skills
Arnab et al. (2016)	UK	Randomised control trial and phenomenology	Evaluating the effect of gamification (competitive) and collaborative environment (social learning platform) on undergraduate sport psychology students' motivational orientation and engagement	Increased studentsengagement
Cusick (2016)	Not documented	Phenomenology	Assessing the effect of using jeopardy-style gamified learning (team clickers and team leader boards) on students' engagement	Improved learning experience

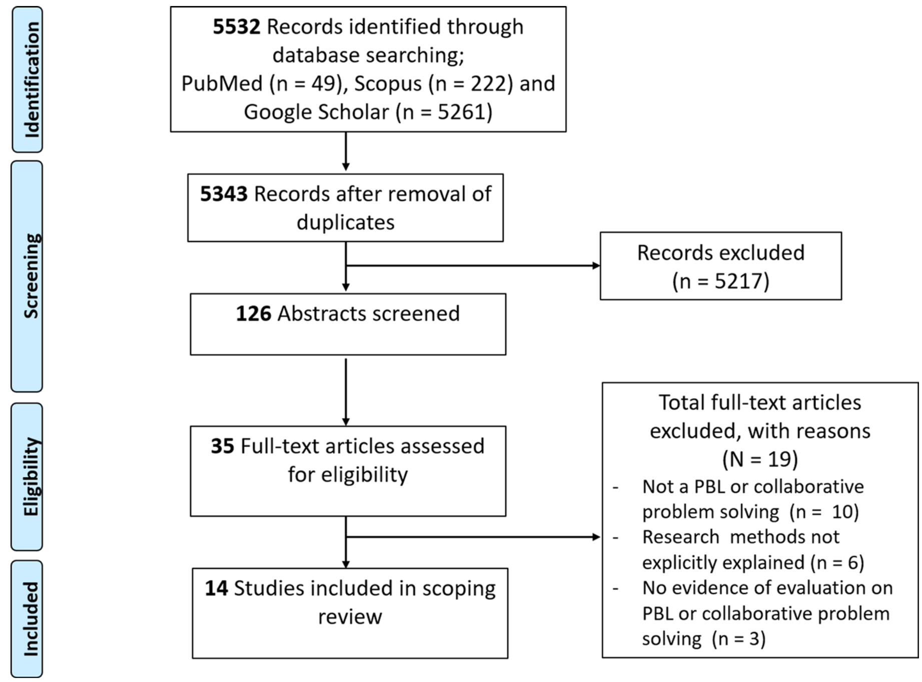

Fig. 1 PRISMA flowchart of the articles selection process

monitoring for cardiovascular-related triggers, intravenous solutions to explain fluid physiology-related cases and oxygen therapy equipment in respiratory-related triggers (Mutter et al., 2020). Plastic manikins that resemble patients can also be used to explain and demonstrate the physical examinations discussed during the PBL session (Mutter et al., 2020).

The authenticity of the case scenario also plays an important role in ensuring the success of the simulation; hence, expert advice should be sought when creating the clinical scenario (Mutter et al., 2020). The case should be constructed using real patient information so that it could mimic patient experience and emotion that they might encounter in their future career (Duncan et al., 2018; Rozali & Zaid, 2017). Nevertheless, these data should be modified and de-identified to ensure anonymity (Prochazkova et al., 2019).

Theme 2: inquisitive exploration

Inquisitive exploration involves the use of gamified instructions that promote discovery of gaps in students' knowledge. Gamified instructions stimulate curiosity in learning through various mechanisms, such as randomness in selecting tasks (Shukor et al., 2019), uncertainty of the task outcomes (Novak et al., 2018), readiness in conducting any unknown task (Duncan et al., 2018) and anticipating consequent tasks after completion of the prior task (Prochazkova et al., 2019). In addition, more emphasis is given to provide a creative problem-solving process rather than finding solutions (Jensen, 2017). The second subtheme that contributed to inquisitive exploration is the provision of positive learning environment which includes the involvement of a secure psychological learning

Table 3 The results of thematic analysis

Theme	Subtheme	Elements
High-fidelity simulation (autonomy)	Role playing simulation	Simulate the role
		According to the given task[g,j]
		Align with learning objectives[g]
		After understanding the content[a]
	Equipment simulation	Equipment simulation via
		Medical equipment[a]
		Manikin[a]
	Authenticity of case scenario	Realistic case scenario that based on
		Real life experience[h,j]
		Modify or de-identify from real data[f]
		Their future practice[j,k]
		Discussion with content expert[a]
Inquisitive exploration (autonomy)	Stimulate curiosity in learning	Adding element of
		Randomness in selecting a task[c]
		Uncertainty or suspense of the outcome[g]
		Readiness in conducting any unknown task[j]
		Anticipating consequent tasks after completion of the prior task[f]
		Emphasize on creating a creative problem-solving process rather than the finding solution[l]
	Provide positive learning environment	Encourage student
		To learn at their own pace[l]
		To comments with an open mind and without criticism[l]
Collaborative learning (relatedness)	Functional group dynamic	Encourage participation by
		Giving equal chance to participate[c]
		Apply turn-taking mechanism[e]
		Visualizing evidence of student participation[m]
		Setting a defined rule to
		Governed individual learning behaviour[l]
		Limit dominant behaviour[c]
	Intergroup competition	Intergroup Compete to Complete a task[m]
	Intragroup cooperation	Intragroup active information sharing[m]
Interactive instruction (autonomy)	Interactive learning tools	Blend the learning with the use of
		Graphical tools such as sketching or data presentation[l]
		Audience response system such as TurningPoint, Kahoot, Socrative[g,n]
		Mobile games[k]
		Virtual reality system visualization[l]
		Live animations[h]
		Facebook or WhatsApp[m]

Table 3 (continued)

Theme	Subtheme	Elements
		Email[m]
		Discussion board[g]
	Challenging instruction	The instructional content is
		Setting multiple levels of goals that align with the learning outcome[a,k]
		Applying various degree of difficulty that align with student levels of knowledge[k]
	Interesting narration	Narrative that based on
		Single long case scenario that is divided into smaller sections of story plots[g,f]
		The use of memorable PBL character[i]
Guidance and feedback (competence)	Immediate constructive feedback	Feedback needs to be
		Immediate[g,h]
		Continuous[g,h]
		Visualized on the displayed board[g]
		Converted into leader board[n]
	Facilitation, task, and resource guidance	Provide students with
		Relevant learning material[f,g]
		Guidance or structure to follow[j,l]
		Hints on how to proceed next stage[k]
		Warning to avoid mistakes[k]
		Tutorial[k]
Rewards (competence)	Task specific rewards	Appreciation given once performing or completing certain task[n,e,d]
	Realtime rewards	Appreciation given instantly[n]

[a] Mutter et al. (2020), [b]Souza et al. (2020), [c]Shukor et al. (2019), [d]Dandge & Desai (2019), [e]Shi et al. (2019), [f]Prochazkova et al. (2019), [g]Novak et al. (2018), [h]Topalli and Cagiltay (2018), [i]Mayer et al. (2018), [j]Duncan et al. (2018), [k]Rozali and Zaid (2017), [l]Jensen (2017), [m]Arnab et al. (2016), [n]Cusick (2016)

environment. The safe learning environments encourage students to learn at their own pace and give students a chance to comment openly without any criticism during the discussion sessions (Jensen, 2017).

Theme 3: collaborative learning

Collaborative learning ensures that all students play their role and fulfil their responsibility in PBL. For instance, students' full participation in PBL can be encouraged by giving students an equal chance to talk or conduct activities through a turn-taking mechanism (Shi et al., 2019; Shukor et al., 2019). Displaying evidence of student's participation can motivate them to interact among themselves during the discussion session (Arnab et al., 2016). In addition, setting up rules in the PBL may govern individual learning behaviour by encouraging contribution from quiet students and limiting the involvement of dominant students. Collaborative learning is also enhanced through intragroup cooperation and intergroup competition. The intergroup competition enhances communication among group members and subsequently increase intragroup cooperation in finding solution for the given problem (Arnab et al., 2016).

Theme 4: interactive instruction

A gamified PBL can be engaging through utilisation of interactive instruction and tools that promote active learning. For instance, an audience response or voting system in online quiz applications (e.g. Kahoot, Socrative and Turning Point) can create competitive learning environment, thus enhancing student's engagement (Cusick, 2016; Novak et al., 2018). The students can present their material or ideas in PBL using graphical tools (Jensen, 2017), a discussion board (Novak et al., 2018), live virtual animations (Jensen, 2017; Topalli & Cagiltay, 2018) or by converting the material into mobile games (Rozali & Zaid, 2017). Students can also utilise social media such as Facebook, WhatsApp and email as a tool for knowledge sharing (Arnab et al., 2016). Besides that, a challenging instruction should be incorporated in PBL to stimulate cognitive skills. The instruction should impose various degrees of learning content difficulty through setting multiple levels of goals that are aligned with the learning outcomes (Mutter et al., 2020; Rozali & Zaid, 2017). Furthermore, the case triggers should also be designed into several story plots that could cover one or two sub-objective(s) (Novak et al., 2018; Prochazkova et al., 2019). To make the triggers more interesting, the names of the subjects involved in PBL can be replaced with unique memorable characters, such as real artists or cartoon characters (Mayer et al., 2018).

Theme 5: guidance and feedback

Constructive feedback in PBL should be given through the application of structured resources and learning task. To ensure constructive feedback is given in real time and to trigger discussions, it was agreed that the output of the discussion should be displayed on the discussion board to let other team members to comment (Novak et al., 2018; Topalli & Cagiltay, 2018). The use of a leaderboard can also be a platform to provide simultaneous feedback (Cusick, 2016). Students should also be given appropriate resources and guidance that can facilitate their learning processes throughout PBL (Novak et al., 2018). For example, students should be provided with clear learning objectives, suitable learning material, detailed instruction, hints, warnings and tutorial to assist them reaching the solution (Mutter et al., 2020; Novak et al., 2018; Prochazkova et al., 2019; Rozali & Zaid, 2017).

Theme 6: rewards

Rewards represent the gamified appreciation to learners for their achievement in PBL. The rewards should be task-specific that focus on the learning process rather than the outcome (Cusick, 2016; Dandge & Desai, 2019; Shi et al., 2019). In addition, the rewards can be given in real time as an instant token of appreciation for the tasks they performed individually or collaboratively (Cusick, 2016). The findings of each selected study are matched with these six persuasive gamify themes and are attached as Additional 1.

Discussion

This scoping review outlines six themes of persuasive gamification elements in the PBL context: high-fidelity simulation, inquisitive exploration, collaborative learning, interactive instruction, guidance and feedback, and rewards. The elements identified in this review have been empirically proven to be effective in promoting student engagement and task performance. An understanding of the mechanisms of these elements provides insights for medical teachers into how to venture into persuasive gamification in the PBL context.

Gamification is usually based on a real-world simulation (Kapp, 2012). Through gamification, the complexity of a real scenario (e.g. a sick patient with many complaints presented to casualty and was attached to all kinds of medical devices) can be replicated for the learning process. These involve setting up a complex backdrop and platform to produce high-quality, engaging and fun simulation medical games. However, the effectiveness of gamification depends on how much the game can precisely abstract the reality and use broad generalisations to represent these scenarios (Yunyongying, 2014). Simulation is an important component of persuasive gamified PBL as it can improve student learning experience and outcomes. In this review, the use of high-fidelity simulations is important for modelling every interaction as authentically as possible. For instance, using a real clinical scenario would result in a meaningful clinical experience for the students, as they can be exposed to the simulation of a workplace learning environment (Kneebone et al., 2005). This element aligns with Azer et al. (2012), who stated that a clinical PBL scenario should reflect the actual practice and common cases in the community. Giving the proximity of the learning experience to the reality of the clinical environment, high-fidelity simulation in PBL provides students with opportunity to appreciate the learning context, critically think and make judgement to the problems given in the triggers. This learning experience would result in the development of learners competency—which is an element of SDT—namely clinical reasoning and application of theories in clinical context (Presado et al., 2018).

Role-playing games are another example of a high-fidelity simulated element that can be incorporated into PBL because they allow the student to produce situations that they are expected to encounter in their career. This element aligns with Wood et al. (2015), who recommended the use of role-play to enhance students' information gathering and deepen the understanding of patients' ideas, concerns and expectations. Chan (2012) who investigated simulated role-play activity in PBL class among first-year nursing students observed that the students constructed their knowledge during preparation and execution phases of the role-plays. The students also demonstrated a high level of participation, showed commitment to self-directed learning and had high motivation for future learning. This element aligns with Wood et al. (2015), who recommended the use of role-play to enhance students' information gathering and deepen the understanding of patients' ideas, concerns and expectations. Role-play can also instil empathy in students, which eventually helps them develop their doctor–patient communication skills (Lane & Rollnick, 2007). Moreover, through PBL simulation, a critical clinical situation can be simulated in a controlled environment, which eventually improves students' confidence in dealing with such cases in the future (Liaw et al., 2010). During a role-play in a PBL session, hands-on active learning activities, such as conducting procedural skills on a manikin or performing physical examination on peers, can be implemented (Nestel et al., 2011). For example, Koh et al. (2010) investigated engineering students learning outcomes by utilising a three-dimensional (3D) simulation in problem-based learning environment that closely resembles the authentic physical system. It was noted from this study that students who were exposed to the 3D simulation-based environment outperformed their friends who were exposed to other types of learning modalities. The 3D simulation enabled the students to explore situations that would have been unattainable or too risky in the real context because they perceived it as being safe to learn. Apart from providing a psychologically safe learning environment, simulation also provides adequate autonomy for the student to explore new knowledge, as it provides variety of option for them to approach in solving the case (Menahem & Paget, 1990). Students will have autonomy in learning if they execute the learning task of their own will and have many learning options during the learning process. Hence, designing a high-fidelity environment would support the development of learning autonomy and intrinsic motivation to learn, which are two important elements of SDT (Stefanou et al., 2013).

The second theme, inquisitive exploration, is a group of elements that stimulate curiosity in learning and provide positive learning environment. The effectiveness of case scenarios in PBL on students' inquisitive exploration could be materialised when students have successfully bridged the gap of knowledge needed to solve a problem. For instance, Loh and Lim (2021) investigated the effectiveness of an authentic PBL (APBL) based on the uncertainty level and learning satisfaction of engineering students studying physics. In this study, the APBL was designed to incorporate elements of uncertainty into well-crafted ill-defined real-world problems. The uncertainty in APBL originated from the lack of knowledge because they are not exposed to the input before the PBL sessions. The element of uncertainty in the APBL acts as a catalyst to provoke real learning by stimulating the students to assess what they know and what they do not know. They were also challenged on how to fill the gap of knowledge uncertainty to construct new meaningful knowledge. This study documented that the student uncertainty level was high at the beginning of APBL and reduced at the end of APBL sessions. This result indicates that in the initial phase of APBL, the students had high intensity in exploring knowledge gaps. However, towards the end of the APBL, the knowledge gap had been filled successfully, thus significantly reducing uncertainty scores. From the student point of view, uncertainty—which is an element of inquisitive exploration—could be stimulated using keywords, real-problem orientation of scenario, appropriate length of cases, encouraging criticality, self-directed problem-solving, stimulate elaboration process, provide suitable clue words, acceptable difficulty level, promote application of knowledge and finally promote teamwork spirit (Sockalingam & Schmidt, 2011). Therefore, carefully drafted PBL scenarios that incorporate gamify elements are important to reveal gaps of knowledge that allow students to advance their learning through inquisitive exploration.

Besides that, inquisitive exploration could be enhanced by adding elements of randomness in selecting a task. For instance, once the students understand the content problems discussed in the PBL session, the identified learning issues can be converted to quizzes, which can be randomly given to students to enforce their understanding. The randomness in giving quizzes can also create uncertainty that evokes suspense, which is considered a core element in a well-designed game (Shute & Ke, 2012). A study by Parmelee and Hudes (2012), which explored the learning impact of team-based learning, reported that quiz modality resulted in a positive learning experience and increased the critical thinking skills of the students. In addition, quizzes that were developed according to learning objectives would be able to direct the students' focus on the important and relevant learning context in a fun and competitive manner. It was argued that the role of quiz modality must not be limited to students' knowledge assessment, but it should be used as another platform for introducing different clinical scenarios in PBL session (Wood et al., 2015). Likewise, inquisitive exploration through quiz modality provides autonomy to explore the problems using multimodal options and cues and thus promotes the development of learning competence and intrinsic motivation to learn.

The third theme, collaborative learning, is important because it ensures a supportive learning environment in a PBL and triggers the feeling of relatedness among the group members (Honkala et al., 2015). Collaborative learning in PBL involves cooperative work among students in solving ill-defined problems and can be enforced through implementing competitive elements. Indeed, collaborative learning instils the feeling of relatedness among students, which has a positive impact on students' intrinsic motivation (Sheldon & Filak, 2008). Providing an equal chance for student to actively participate in the discussion can stimulate the feeling of relatedness—which is an element of SDT—and thus leads to the formation of social integration among them. If the students are socially integrated in the academic environment, their commitment towards academic increases, making them less likely to voluntarily drop out of the learning process (Tinto, 1975).

Lei et al. (2016) who investigated the effect of team-based competition during problem- and case-based learning among 71 medical students reported that students' participation in discussion, initiative to answer questions and ability to challenge or analysing other student's answers were significantly higher than those in classroom-based session. A study by Gutiérrez (2012) that utilised competitive learning environment in a PBL session attended by 60 first-year chemical engineering reported positive students' self-perception on their ability to perform better and achieve personal and group benefits. In addition, Gutiérrez (2012) also identified factors that contributed to "healthy" or non-harmful competition, namely aiming for group achievement, focussing on learning process, execution of short session, selecting of wide range of topic, providing of equal chance to win, balancing workload and adapting communication and group work skills. These studies show that competitive elements used in PBL promote students to be a self-directed learner and equip them with competence to work collaboratively.

Learning through PBL can also be enhanced with the use of interactive learning tools that incorporates elements of gamification. Giving the facts that students are exposed to varieties of learning options when using the interactive learning tools, this form of modality provides students with autonomy to decide and choose the best way to interact during the PBL discussion interesting manner (Elmunsyah et al., 2019). According to Kapp (2013), there are two types of gamification: structural gamification and content gamification. In structural gamification, elements such as badges, points and leader boards are used to gamify the learning process, but the learning content remains ungamified, while in content gamification, the content is gamified by using narrated stories and plot lines. In fact, narrative is listed as the tenth element in Marczewski's

Periodic Table of Gamification Elements (Marczewski, 2017). Although a narrative is an important element in gamification, it is underutilised for the enhancement of adult learning (Kapp, 2013). Our review found that it is important to have interactive instruction that focuses on the use of narrated elements to produce engaging learning material in PBL sessions. For instance, using a single-story narration with a combination of unique characters in a PBL case scenario resulted in high-quality stories (McKee, 1997). A narrated type of case scenario in PBL could enhance students' inner motivation to understand the stories further (Graesser & Ottati, 2014). Students also perceived that the narrative-centric case in PBL had helped them clarify abstract concepts and aided the long-term retention of knowledge (Fischer, 2019).

Moreover, providing a structured instruction to students is pertinent in stimulating their sense of responsibility and feeling of being competent during a PBL session (Sierens et al., 2009). Azer et al. (2012) added that a case scenario must not only tell a story, but its design should include educational principles that encourage the development of higher-level cognitive competency, namely hypothesis making, peer discussion, clinical and critical reasoning, and knowledge retention. Further, ignoring audio-visual elements such as images and recorded audio or video in creating a gamified educational environment might reduce players' overall experience. A rich audio-visual environment might add to the immersive experience of learners. The visual element adds to the overall story of a game and can enhance the learners' learning focus (Toda et al., 2019a). However, many gamification practitioners overlook this vital element, thus causing the experience to be less engaging and compelling. Similarly, most of the case scenarios in PBL are still in the form of a text format with a lack of visual image and audio input, which may not realistically imitate the problem-solving scenario in a clinical environment (Barrows, 1994). Blending an audio-visual modality in the PBL case trigger may enhance students' observation skills, giving them an idea of the severity of the patient's condition and enabling them to discover any contributing factors to the patient's condition (Azer, 2007). Chan et al. (2010) explored the use of video recording as an image trigger in PBL cases, whereby this video recording preserved the original language, promoted active extraction of information and allowed the direct observation of a clinical consultation. Their study showed that video recording triggers improved students' observational and clinical reasoning skills, stimulated students' ability to integrate information and increased students' motivation to learn in the PBL session.

Additionally, providing feedback is also important for facilitating students' learning in PBL. Providing continuous constructive feedback on students' performance during a PBL session does not only improve students' task performance, but it could positively affect students' competence and motivation (García et al., 2019; Sierens et al., 2009). However, to achieve the desired outcome, the feedback should be directed towards students' gap of knowledge rather than the grades, non-threatening, and able to provide suggestions for future improvement (Hattie & Timperley, 2007). Another aspect that can influence students' competence is the introduction of reward system in the PBL. Although reward system is a form of external motivation, ironically it has been proven to instil interest and sense of being capable to solve similar task or problems among students (Cameron et al., 2005).

In addition, a PBL tutor should also provide resource guidance during the learning process. Majority of students depend heavily on the Internet for information searching whenever they are given a task to solve. However, looking at web-based information diversity, a tutor must guide the students in selecting appropriate and reliable learning resources. Wood et al. (2015) reported various ways of providing resource guidance to students, namely by giving a portfolio of additional resource material such as video- or audio-recorded lectures, interactive questions related to the topic discussed and free institutional access to online databases (Wood et al., 2015). In addition, the institution's learning management system (LMS) should be utilised to manage the resources and enable the students to keep track of the learning, even after the PBL session has ended (Azer, 2011).

Likewise, feedback is essential to ensure that students are made aware of their knowledge gap, which drives them to work continuously on achieving favourable improvement (Bernstein et al., 1995). In a gamification environment, players usually receive feedback on their progress towards winning the competition. Aligned with our review findings, any feedback in a gamification environment should be immediate and continuous (Dicheva et al., 2015; Kapp, 2012). The immediacy and continuity of feedback could influence how students internalise and respond to feedback (Fajfar et al., 2012). Hence, feedback related to the gamification environment should also be constant throughout the learning process (Kapp, 2012). In our study context, instant feedback is achieved by having a real-time interactive discussion board during the PBL sessions, aligning with Bartnik and Ćwil (2017), who studied the use of feedback through an interactive society portal discussion board on subjects motivation. The researchers discovered that subjects who received continuous and timely feedback had significantly improved motivation and engagement compared to the control group, which only received financial incentives without continuous feedback. It was postulated that immediate timely feedback given through an interactive discussion board during the learning process imposes less cognitive load on the learners, as the feedback was delivered in a fun and non-threatening manner (Yusoff et al., 2014). Moreover, this method effectively promoted a thorough exploration of the learning issues that arose during the discussion (Ronteltap, 2006). Nevertheless, feedback should be multidimensional, meaning that tutors should also provide feedback to students during and after each PBL session. Feedback from a teacher—as someone that is regarded as an expert by students—is essential because it can provide a feeling of reassurance to the students that they are being supported in learning (Hadie et al., 2018).

Another persuasive element identified in this review is providing rewards to students as an appreciation for their effort in performing the task and encouragement for their achievement in completing the required task. In the context of gamification, this can be done by converting the grading system from traditional marking to a point-based and level-based credentialing system (Cheville, 2016). Fotaris et al. (2016) reported that interactive platforms such as Kahoot!, "Who Wants to Be a Millionaire" and Codecademy also reward their students with achievement credential rather than traditional marking. However, as this form of reward is a source of extrinsic motivation, it should be counterbalanced with intrinsic motivation by stimulating students' interest and sense of responsibility to learn (Muntean, 2011; Viola, 2011). In general, providing rewards, guidance and feedback during a learning process triggers the sense of competence among students, which is aligned with the SDT elements.

Conclusion

This review identified the essential persuasive gamify elements for effective PBL in higher education. Effective persuasive gamify elements for effective PBL in higher education were clustered into six main themes: (1) high-fidelity simulation, (2) inquisitive exploration, (3) collaborative learning, (4) interactive instruction, (5) guidance and feedback, and (6) rewards. All elements must coexist to achieve the desired learning outcomes. It is essential to apply these gamify elements to augment the learning experience in PBL session. For examples, exposing the students with an authentic simulated learning activity can cultivate critical and creative thinking skills and stimulate self-directed learning. Consequently, the students would become familiarised with workplace environment and thus develop competencies required in workplace learning. In addition, working cooperatively in a competitive environment can improve their professional communication skills and teamwork. These lifelong learning skills would equip the students to face future workplace challenges.

Abbreviations
PBL: Problem-based learning; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyse.

Acknowledgements
The author would like to thank the Universiti Sains Malaysia for providing the research fund for this study.

Author contributions
This paper is a part of the PhD project conducted by ASAG. SNHH is his main supervisor and grant holder of this project. MSBY and AFAR are his co-supervisors. ASAG has been working closely with SNHH and MSBY in planning and execution of the review process. All authors read and approved the final manuscript.

Authors' information
Azril Shahreez Abdul Ghani is a PhD candidate at the Department of Medical Education, Health Campus Universiti Sains Malaysia, Kubang Kerian, Kota Bharu, Kelantan. He is also a medical lecturer in the Department of Basic Medical Sciences, Kulliyah of Medicine, International Islamic University Malaysia, Kuantan, Pahang, Malaysia.
Ahmad Fuad Abdul Rahim is a senior medical educationist at the Department of Medical Education, Health Campus Universiti Sains Malaysia, Kubang Kerian, Kota Bharu, Kelantan.
Muhamad Saiful Bahri Yusoff is an Associate Professor and the Head of Medical Education Department, Health Campus Universiti Sains Malaysia, Kubang Kerian, Kota Bharu, Kelantan.
Siti Nurma Hanim Hadie is an anatomy educationist and the Head of Anatomy Department, Health Campus Universiti Sains Malaysia, Kubang Kerian, Kota Bharu, Kelantan.

Funding
This scoping review was supported by Postgraduate Incentive Grant-PhD (GIPS-PhD, Grant Number: 311/PPSP/4404803].

Availability of data and materials
The research data can be retrieved through this link https://tinyurl.com/w5ekrp8v.

Declarations

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Basic Medical Sciences, Kulliyah of Medicine, Bandar Indera Mahkota Campus, International Islamic University Malaysia, Kuantan, Pahang, Malaysia. [2]Department of Medical Education, School of Medical Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Kota Bharu, Kelantan, Malaysia. [3]Department of Anatomy, School of Medical Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, 16150 Kota Bharu, Kelantan, Malaysia.

Received: 20 April 2021 Accepted: 24 April 2022
Published online: 15 May 2022

References

Al-Naggar, R. A., & Bobryshev, Y. V. (2012). Acceptance of problem based learning among medical students. *Journal of Community Medicine and Health Education, 2*(5), 146.

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice, 8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Arnab, S., Bhakta, R., Merry, S. K., Smith, M., Star, K., & Duncan, M. (2016). Competition and collaboration using a social and gamified online learning platform. In *10th European conference on games based learning: ECGBL, 2016* (p. 19).

Azer, S. A. (2004). Becoming a student in a PBL course: Twelve tips for successful group discussion. *Medical Teacher, 26*(1), 12–15. https://doi.org/10.1080/0142159032000156533

Azer, S. A. (2007). Twelve tips for creating trigger images for problem-based learning cases. *Medical Teacher, 29*(2–3), 93–97. https://doi.org/10.1080/01421590701291444

Azer, S. A. (2011). Introducing a problem-based learning program: 12 tips for success. *Medical Teacher, 33*(10), 808–813. https://doi.org/10.3109/0142159X.2011.558137

Azer, S. A., Mclean, M., Onishi, H., Tagawa, M., & Scherpbier, A. (2013). Cracks in problem-based learning: What is your action plan? *Medical Teacher, 35*(10), 806–814. https://doi.org/10.3109/0142159X.2013.826792

Azer, S. A., Peterson, R., Guerrero, A. P. S., & Edgren, G. (2012). Twelve tips for constructing problem-based learning cases. *Medical Teacher, 34*(5), 361–367. https://doi.org/10.3109/0142159X.2011.613500

Balhara, Y. (2012). Indexed journal: What does it mean? *Lung India, 29*(2), 193.

Barrows, H. S. (1994). *Practice-based learning: Problem-based learning applied to medical education*. Southern Illinois University School of Medicine.

Bartnik, W., & Ćwil, M. (2017). Continuous feedback as a key component of employee motivation improvement—A railway case study based on the placebo effect. In *Proceedings of the 50th Hawaii international conference on system sciences* (pp. 4–7).

Bernstein, P., Tipping, J., Bercovitz, K., & Skinner, H. A. (1995). Shifting students and faculty to a PBL curriculum: Attitudes changed and lessons learned. *Academic Medicine: Journal of the Association of American Medical Colleges, 70*(3), 245–247.

Burgess, A., & Ramsey-Stewart, G. (2014). Elective anatomy by whole body dissection course: What motivates students? *BMC Medical Education, 14*(1), 1–6.

Cameron, J., Pierce, W. D., Banko, K. M., & Gear, A. (2005). Achievement-based rewards and intrinsic motivation: A test of cognitive mediators. *Journal of Educational Psychology, 97*(4), 641.

Chan, L. K., Patil, N. G., Chen, J. Y., Lam, J. C. M., Lau, C. S., & Ip, M. S. M. (2010). Advantages of video trigger in problem-based learning. *Medical Teacher, 32*(9), 760–765.

Chan, Z. C. Y. (2012). Role-playing in the problem-based learning class. *Nurse Education in Practice, 12*(1), 21–27.

Cheville, R. A. (2016). Linking capabilities to functionings: Adapting narrative forms from role-playing games to education. *Higher Education, 71*(6), 805–818.

Cusick, J. (2016). A Jeopardy-style review game using team clickers. *MedEdPORTAL, 12*, 1–6.

Dandge, D., & Desai, S. (2019). Adding element of competition to multi-disciplinary PBL: Case study of Robocon competition. *Journal of Engineering Education Transformations, 33*(1), 9–12.

de la Peña Esteban, F. D., Torralbo, J. A. L., Casas, D. L., & García, M. C. B. (2020). Web gamification with problem simulators for teaching engineering. *Journal of Computing in Higher Education, 32*(1), 135–161.

Demirören, M., Turan, S., & Öztuna, D. (2016). Medical students' self-efficacy in problem-based learning and its relationship with self-regulated learning. *Medical Education Online, 21*(1), 30049.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification". In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments* (pp. 9–15).

Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education, 14*(1), 1–36.

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Educational Technology & Society, 18*(3), 75–88. https://doi.org/10.1109/EDUCON.2014.6826129

Dolmans, D. H. J. M., Loyens, S. M. M., Marcq, H., & Gijbels, D. (2016). Deep and surface learning in problem-based learning: A review of the literature. *Advances in Health Sciences Education, 21*(5), 1087–1112.

Duncan, M., Clarke, S., Myers, T., Tallis, J., & Arnab, S. (2018). A hybrid, gamified and mystery-driven approach for facilitating problem based learning in a postgraduate strength and conditioning module. *Practice and Evidence of the Scholarship of Teaching and Learning in Higher Education, 13*(1), 28–48.

Elmunsyah, H., Hidayat, W. N., & Asfani, K. (2019). Interactive learning media innovation: Utilization of augmented reality and pop-up book to improve user's learning autonomy. *Journal of Physics: Conference Series, 1193*(1), 12031.

Fajfar, P., Campitelli, G., & Labollita, M. (2012). Effects of immediacy of feedback on estimations and performance. *Australian Journal of Psychology, 64*(3), 169–177.

Fischer, B. A. (2019). Fact or fiction? Designing stories for active learning exercises. *Journal of Political Science Education, 15*(2), 179–190.

Fotaris, P., Mastoras, T., Leinfellner, R., & Rosunally, Y. (2016). Climbing up the leaderboard: An empirical study of applying gamification techniques to a computer programming class. *Electronic Journal of E-Learning, 14*(2), 94–110.

García, J. A., Carcedo, R. J., & Castaño, J. L. (2019). The influence of feedback on competence, motivation, vitality, and performance in a throwing task. *Research Quarterly for Exercise and Sport, 90*(2), 172–179.

Graesser, A. C., & Ottati, V. (2014). Why stories? Some evidence, questions, and challenges. In R. S. Wyer Jr. (Ed.), *Knowledge and memory: The real story* (Vol. 8, pp. 121–132). Psychology Press.

Gusenbauer, M. (2019). Google Scholar to overshadow them all? Comparing the sizes of 12 academic search engines and bibliographic databases. *Scientometrics, 118*(1), 177–214.

Gutiérrez, I. C. (2012). *Competition as a teaching methodology: An experience applying problem-based learning and cooperative learning*. Universidad Autónoma de Madrid.
Hadie, S. N. H., Hassan, A., Mohd Ismail, Z. I., Ismail, H. N., Talip, S. B., & Abdul Rahim, A. F. (2018). Empowering students' minds through a cognitive load theory-based lecture model: A metacognitive approach. *Innovations in Education and Teaching International, 55*(4), 398–407. https://doi.org/10.1080/14703297.2016.1252685
Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025–3034).
Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045
Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112.
Hendry, G. D., Frommer, M., & Walker, R. A. (1999). Constructivism and problem-based learning. *Journal of Further and Higher Education, 23*(3), 369–371.
Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266.
Honkala, M., Heikkinen, S., Lehtovuori, A., & Leppävirta, J. (2015). Do autonomously motivated students benefit from collaborative learning methods? In *2015 IEEE Global engineering education conference* (pp. 297–300).
Huang, C.-C., Yeh, T.-K., Li, T.-Y., & Chang, C.-Y. (2010). The idea storming cube: Evaluating the effects of using game and computer agent to support divergent thinking. *Journal of Educational Technology & Society, 13*(4), 180–191.
Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development, 59*(4), 529–552.
Jensen, C. G. (2017). Collaboration and dialogue in virtual reality. *Journal of Problem Based Learning in Higher Education, 5*(1), 85–110.
Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. Wiley.
Kapp, K. M. (2013). *The gamification of learning and instruction fieldbook: Ideas into practice*. Wiley.
Karunathilake, I. (2019). Role of problem-based learning (PBL) in postgraduate medical education. *Journal of the Postgraduate Institute of Medicine, 6*(1), 1–5.
Kneebone, R. L., Kidd, J., Nestel, D., Barnet, A., Lo, B., King, R., Yang, G. Z., & Brown, R. (2005). Blurring the boundaries: Scenario-based simulation in a clinical setting. *Medical Education, 39*(6), 580–587. https://doi.org/10.1111/j.1365-2929.2005.02110.x
Koh, C., Tan, H. S., Tan, K. C., Fang, L., Fong, F. M., Kan, D., Lye, S. L., & Wee, M. L. (2010). Investigating the effect of 3D simulation based learning on the motivation and performance of engineering students. *Journal of Engineering Education, 99*(3), 237–251.
Koh, G.C.-H., Khoo, H. E., Wong, M. L., & Koh, D. (2008). The effects of problem-based learning during medical school on physician competency: A systematic review. *Canadian Medical Association Journal, 178*(1), 34–41.
Lane, C., & Rollnick, S. (2007). The use of simulated patients and role-play in communication skills training: A review of the literature to August 2005. *Patient Education and Counseling, 67*(1–2), 13–20.
Lazzaro, N. (2004). Why we play games: Four keys to more emotion without story. *Game Developer Conference, 2004*, 1–8.
Lei, J.-H., Guo, Y.-J., Chen, Z., Qiu, Y.-Y., Gong, G.-Z., & He, Y. (2016). Problem/case-based learning with competition introduced in severe infection education: An exploratory study. *SpringerPlus, 5*(1), 1–8.
Liaw, S. Y., Chen, F. G., Klainin, P., Brammer, J., O'Brien, A., & Samarasekera, D. D. (2010). Developing clinical competency in crisis event management: An integrated simulation problem-based learning activity. *Advances in Health Sciences Education, 15*(3), 403–413.
Loh, K. H., & Lim, Y. P. (2021). Exploring the relationship between learners' uncertainty level and learning performance in an authentic problem-based learning environment. In *Transforming curriculum through teacher-learner partnerships* (pp. 179–198). IGI Global.
Mahmud, S. N. D., Husnin, H., & Tuan Soh, T. M. (2020). Teaching presence in online gamified education for sustainability learning. *Sustainability, 12*(9), 3801.
Majoor, G. D., Schmidt, H., Moust, J., Snellen, H. A. M., & Stalenhoef, B. (1990). Construction of problems for problem-based learning. In Z. Nooman, H. G. Schmidt, & E. S. Ezzat (Eds.), *Innovation in medical education* (p. 144). Springer.
Marczewski, A. (2017). *A revised gamification design framework*. Retrieved from Gamified UK website: https://www.gamified.uk/2017/04/06/revised-gamification-design-framework/
Mayer, J. E., Garg, A., & Carson, S. H. (2018). The use of notable protagonists in dermatology clinical cases: A quasi-randomized controlled trial. *Dermatology Online Journal, 24*(9), 13030/qt8pr6d4xx.
McKee, R. (1997). *Story: Substance, structure, style and the principles of screenwriting. 1997*. HarperCollins Publishers Inc.
Menahem, S., & Paget, N. (1990). Role play for the clinical tutor: Towards problem-based learning. *Medical Teacher, 12*(1), 57–61.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma, G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7), e1000097.
Moust, J. H. C., Van Berkel, H. J. M., & Schmidt, H. G. (2005). Signs of erosion: Reflections on three decades of problem-based learning at Maastricht University. *Higher Education, 50*(4), 665–683.
Muntean, C. I. (2011). Raising engagement in e-learning through gamification. In *6th International conference on virtual learning*, Vol. 1 (pp. 323–329).
Mustard, J. F. (1982). *New trends in health sciences education, research, and services: The McMaster experience*. Praeger Publishers.
Mutter, M. K., Martindale, J. R., Shah, N., Gusic, M. E., & Wolf, S. J. (2020). Case-based teaching: Does the addition of high-fidelity simulation make a difference in medical students' clinical reasoning skills? *Medical Science Educator, 30*(1), 307–313.

Nestel, D., Groom, J., Eikeland-Husebø, S., & O'Donnell, J. M. (2011). Simulation for learning and teaching procedural skills: The state of the science. *Simulation in Healthcare, 6*(7), S10–S13.
Norman, G. T., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine, 67*(9), 557–565.
Novak, E., Librea-Carden, M. R., & Weiszhauz, Y. (2018). I need a training program! Gamification of online case-based learning. In *EdMedia+ innovate learning* (pp. 1011–1017).
Orrill, C. H. (2002). Supporting online PBL: Design considerations for supporting distributed problem solving. *Distance Education, 23*(1), 41–57.
Ott, M., & Tavella, M. (2009). A contribution to the understanding of what makes young students genuinely engaged in computer-based learning tasks. *Procedia-Social and Behavioral Sciences, 1*(1), 184–188.
Parmelee, D. X., & Hudes, P. (2012). Team-based learning: A relevant strategy in health professionals' education. *Medical Teacher, 34*(5), 411–413.
Patiwael, J. A., Douma, A. H., Bezakova, N., Kusurkar, R. A., & Daelmans, H. E. M. (2021). Collaborative testing in physical examination skills training and the autonomous motivation of students: A qualitative study. *BMC Medical Education, 21*(1), 1–10.
Presado, M. H. C. V., Colaço, S., Rafael, H., Baixinho, C. L., Félix, I., Saraiva, C., & Rebelo, I. (2018). Learning with high fidelity simulation. *Ciencia & Saude Coletiva, 23*, 51–59.
Prince, K. J. A. H., Van Eijs, P. W. L. J., Boshuizen, H. P. A., Van Der Vleuten, C. P. M., & Scherpbier, A. J. J. A. (2005). General competencies of problem-based learning (PBL) and non-PBL graduates. *Medical Education, 39*(4), 394–401.
Prochazkova, K., Novotny, P., Hancarova, M., Prchalova, D., & Sedlacek, Z. (2019). Teaching a difficult topic using a problem-based concept resembling a computer game: Development and evaluation of an e-learning application for medical molecular genetics. *BMC Medical Education, 19*(1), 1–8.
Ronteltap, F. (2006). Tools to empower problem-based learning: A principled and empirical approach to the design of problem-based learning online. In M. Savin-Baden & K. Wilkie (Eds.), *Problem-based learning online* (pp. 174–190). McGraw-Hill Education.
Rozali, N. F., & Zaid, N. M. (2017). Code puzzle: ActionScript 2.0 learning application based on problem based learning approach. In *Proceedings of the IEEE 6th ICT international student project conference (ICT-ISPC)* (pp. 1–4).
Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68.
Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380. https://doi.org/10.1016/j.chb.2016.12.033
Schell, K. (1998). Promoting student questioning. *Nurse Educator, 23*(5), 8–12.
Schmidt, H. G., Rotgans, J. I., & Yew, E. H. J. (2011). The process of problem-based learning: What works and why. *Medical Education, 45*(8), 792–806. https://doi.org/10.1111/j.1365-2923.2011.04035.x
Schmidt, H. G., Vermeulen, L., & Van der Molen, H. T. (2006). Longterm effects of problem-based learning: A comparison of competencies acquired by graduates of a problem-based and a conventional medical school. *Medical Education, 40*(6), 562–567.
Sheldon, K. M., & Filak, V. (2008). Manipulating autonomy, competence, and relatedness support in a game-learning context: New evidence that all three needs matter. *British Journal of Social Psychology, 47*(2), 267–283.
Shi, J., Shah, A., Hedman, G., & O'Rourke, E. (2019). Pyrus: Designing a collaborative programming game to promote problem solving behaviors. In *Proceedings of the 2019 conference on human factors in computing systems* (pp. 1–12).
Shukor, J. A., Jamian, R., & Ab Rahman, M. N. (2019). Refining 5S awareness through an interactive game board. In A. Ismail, M. H. Abu Bakar, & A. Öchsner (Eds.), *Advanced engineering for processes and technologies* (pp. 173–181). Springer.
Shute, V. J., & Ke, F. (2012). Games, learning, and assessment. In D. Ifenthaler, D. Eseryel, & X. Ge (Eds.), *Assessment in game-based learning* (pp. 43–58). Springer.
Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The synergistic relationship of perceived autonomy support and structure in the prediction of self-regulated learning. *British Journal of Educational Psychology, 79*(1), 57–68.
Sockalingam, N., & Schmidt, H. G. (2011). Characteristics of problems for problem-based learning: The students' perspective. *Interdisciplinary Journal of Problem-Based Learning, 5*(1), 3.
Souza, J. C., de Sousa, I. F., Penrabel, R. P. M., de Souza, P. A., & Bondarczuk, E. H. (2020). Quiz and games as previous knowledge organizers: A medical training experience report. *Creative Education, 11*(01), 68.
Stefanou, C., Stolk, J. D., Prince, M., Chen, J. C., & Lord, S. M. (2013). Self-regulation and autonomy in problem-and project-based learning environments. *Active Learning in Higher Education, 14*(2), 109–122.
Taylor, D., & Miflin, B. (2008). Problem-based learning: Where are we now? *Medical Teacher, 30*(8), 742–763.
Tayyeb, R. (2013). Effectiveness of problem based learning as an instructional tool for acquisition of content knowledge and promotion of critical thinking among medical students. *Journal of the College of Physicians and Surgeons Pakistan, 23*(1), 42–46.
Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*(1), 89–125.
Toda, A. M., Klock, A. C. T., Oliveira, W., Palomino, P. T., Rodrigues, L., Shi, L., Bittencourt, I., Gasparini, I., Isotani, S., & Cristea, A. I. (2019a). Analysing gamification elements in educational environments using an existing gamification taxonomy. *Smart Learning Environments, 6*(1), 1–14.
Toda, A. M., Oliveira, W., Klock, A. C., Palomino, P. T., Pimenta, M., Gasparini, I., Shi, L., Bittencourt, I., Isotani, S., Cristea, A. I. (2019b). A taxonomy of game elements for gamification in educational contexts: Proposal and evaluation. In *2019b IEEE 19th International conference on advanced learning technologies (ICALT)* (pp. 84–88).
Topalli, D., & Cagiltay, N. E. (2018). Improving programming skills in engineering education through problem-based game projects with Scratch. *Computers & Education, 120*, 64–74.

Torre, D. M., van der Vleuten, C., & Dolmans, D. (2016). Theoretical perspectives and applications of group learning in PBL. *Medical Teacher, 38*(2), 189–195.
Van den Broeck, A., Vansteenkiste, M., De Witte, H., Soenens, B., & Lens, W. (2010). Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the work-related basic need satisfaction scale. *Journal of Occupational and Organizational Psychology, 83*(4), 981–1002. https://doi.org/10.1348/096317909X481382
Van Gaalen, A. E. J., Brouwer, J., Schönrock-Adema, J., Bouwkamp-Timmer, T., Jaarsma, A. D. C., & Georgiadis, J. R. (2021). Gamification of health professions education: A systematic review. *Advances in Health Sciences Education, 26*(2), 683–711.
Viola, F. (2011). *Gamification I videogiochi nella vita quotidiana*. Arduino Viola Publishers.
Wood, D. F. (2003). Problem based learning. *BMJ (clinical Research Edition), 326*(7384), 328–330. https://doi.org/10.1136/bmj.326.7384.328
Wood, S. J., Woywodt, A., Pugh, M., Sampson, I., & Madhavi, P. (2015). Twelve tips to revitalise problem-based learning. *Medical Teacher, 37*(8), 723–729. https://doi.org/10.3109/0142159X.2014.975192
Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education and Research, 39*(1), 93–112.
Yunyongying, P. (2014). Gamification: Implications for curricular design. *Journal of Graduate Medical Education, 6*(3), 410–412.
Yusoff, M. S. B., Hadie, S. N. H., & Abdul Rahim, A. F. (2014). Adopting programmatic feedback to enhance the learning of complex skills. *Medical Education, 48*(2), 104–112. https://doi.org/10.1111/medu.12403

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.