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Preface

Gamification - Analysis, Design, Development and Ludification presents chapters specifically selected to showcase and discuss various aspects of the gamification processes that are actively being implemented today. Introducing game elements and mechanics in non-gaming environments is an application field that requires a deep understanding of those principles and balancing of their functional and narrative components in order to become functional and effective. Many implementations today, particularly in the educational sector, use simple techniques such as rewards, scoring, and simple gamification mechanisms that do not take into account the wide range of capabilities that are available. Hence, in this book, we present several case studies that provide a high-value look at the development of gamification processes and their implementation.

The other parallel dimension that is addressed focuses on the wide availability of transmedia content delivery and interaction modes. Transmedia support delivery mechanisms allow multiple sections of a gamified process to be distributed across different media, each with its own characteristics and unique content and interaction capacity. The lack of standardization in gamification and transmedia results in a continuously expanding ecosystem of media and content-delivering technologies that, on one hand, can offer developers the necessary creative freedom to produce highly technological case studies. On the other hand, however, the choice of technologies may not allow users to experience the full potential of each system.

At some point, most of the available media will be accessible by the majority of users out there, and I do have a short story to tell about the importance of timing. In 2014 we created for a final-year project an augmented-reality gamified experience that included a discovery puzzle involving the identification of physical artefacts at the "Casa Parlante" museum in Corfu, Greece. Its collection features more than 3000 everyday items. The narration used during the guided tour was fictional and revolved around the characters that were present in the form of "mechanically animated human-sized characters" in the house. The story told was based on historical facts and was engineered in such a way as to allow the presentation of the everyday life of the imaginary family in that particular house and city.

We created a gamified scenario and a process that was implemented at the time using image recognition and an end-to-end augmented-reality application system and video for instructions. The gamified process used tablets and recognition of physical objects that had to be identified by the visitors in order to receive their reward. Two sets of tablets were used for teams A and B, who entered the space sequentially. Team A had to find several bottles containing perfume used around the 19th century in Corfu within the thematic living room of the museum and place them on a specially designed mat. When those perfume bottles were placed at specific locations on the mat and the whole setting was scanned by the application, the video provided instructions that revealed a secret drawer to allow visitors to sample a traditional biscuit that was baked during the 19th century and is still being baked today, on the Ionian Islands. Team B was introduced to the opposite scenario where they had to identify the perfume bottle collection on the mat and scatter them at specific locations within the space, matching the scent of each bottle to a fictional family member. When they scanned all three locations and the bottles were placed at the right positions, they received the same reward. This scenario is easy to understand and we can clearly see what each visiting group had to accomplish. However, it was not an easy process to explain to visitors at the time because they lacked prior knowledge of the augmented reality functions. They had to be taught what augmented reality is, how the tablet worked, and then they had to be introduced to the game; a steep learning curve for a three-minute gamified process. In addition, the museum staff often had to explain to the visitors why the tablet would only recognize a small set of items and not everything that was within the museum. This suddenly changed in 2016 when Pokémon GO was introduced and almost instantly, things improved. Visitors were suddenly aware of augmented-reality technologies, their functionality and limitations, and they could play the game without asking questions. Overall, the whole experience was positive and effective. This example demonstrates the competence that is required from the users' perspective in order for a gamified experience to be successful. For this reason, we also introduce the term "Ludification," which can help us add the "fun" part to the process.

The book is organized into two sections: "From Gamification to Ludification" and "Gamification and Learning". I hope that you will enjoy reading the chapters and the valuable research proposals they present. The book is designed to make clear the scope and dynamic of gamification in critical areas of everyday life, a dynamic that sometimes makes it more attractive, meaningful, and therapeutic to get involved in actions and processes that may have lost their attraction over time. However, it is still a book written by technology and media scholars who have every intention and expectation of bringing their research to a cross-disciplinary level in order to identify and fully consider how the exploitation of gamification can be useful, accessible, and naturally integrated into life.

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Section 1

From Gamification to Ludification

Chapter 1

Introductory Chapter: Games, Gamification, and Ludification, Can They Be Combined?

Ioannis Deliyannis, Polyxeni Kaimara, Sofia Maria Poulimenou and Stamatella Lampoura

1. Introduction

The importance of games has been explored by many researchers, educators, and psychologists [1–4]. The word "game" is used to convey both the concept of the game as an object and the experience of the game as an action. In English, the differentiation of concepts is very perspicuous. The word "toy" is used for the object, the word "play" for the game experience, and the word "game" for the structured game. Caillois [5] proposed a two-axis taxonomy of games. The first axis is a continuum between what he called "paidia" (from the ancient Greek word/pe.ðiˈa/) and "ludus" (from the Latin words ludus and ludere, which respectively mean "game" and "to play"). More specifically, on one end of the axis he placed the term "paidia," which refers to spontaneous activity without rules (play) and on the other end he placed the term "ludus," that is, a highly structured game characterized by discipline and directed by rules to achieve specific goals [6]. The second axis concerns the classification of games into four types, based on: (1) competition (agon), (2) luck (alea), (3) imitation or role-play (mimicry), and (4) passion or sense of balance or vertigo (ilinx). According to Caillois [5], all types of games fall somewhere on the continuum between "paidia" and "ludus." Play and games have attracted interest in the natural sciences, social sciences, and humanities [7]. Interdisciplinary research findings from the fields of anthropology, psychology, sociology, and technology demonstrate that "games" are significant mediators between learning and socialization throughout people's lives, and thus game-based learning (GBL) has evolved into a remarkable place of dialog on education, formal and informal, of minors and adults [8, 9]. Regardless of the type of games as objects or processes, the experience of play offers people multiple opportunities to learn and interact with the natural and man-made environment.

In digital age, games get a digital form, with modern research recognizing their potential to engage children's attention and motivate them to explore the limits of their abilities, skills, and knowledge [10–12]. The synergy of technology with pedagogy that utilizes digital games in the learning process is called digital game-based learning (DGBL), a term credited to Marc Prensky [13].

DGBL leverages three elements of game design: challenge, response, and feedback, known as the magic circle of playful learning utilizing fundamental structures, such as rules, purpose and goals, adaptability, outcome and feedback, conflict and competition, problem-solving, interactivity, social interaction, and story and win state [14, 15].

Features of game design, that is, motivation, mechanics, esthetics, narrative, and background sounds, support the learning experience. The dynamics of learning are based on the quality of these features, which are common whether it is classic games or gamified applications [16].

2. The concept of gamification so far

When we refer to less structured game applications, which use some of the games' elements and features, such as rewards, for example, points, prizes, and leaderboards, we define the concept of gamification [17]. Gamification can be considered a subset of applied behavioral psychology because of its deep emphasis on motivation, feedback, progress, and reward, and is an integral part of any game, not necessarily digital [18]. Gamification is applied to many human activities, for example, health services, education, museum, and cultural heritage studies as it presents many advantages for behavioral change and learning [19, 20].

Designing gamification, especially for educational purposes is a complex process that requires the transdisciplinary collaboration of experts from the fields of psychology, pedagogy, game design, and programming [21]. The reason game elements are added to educational material is because they enhance social interaction and improve student performance by motivating them to participate in a learning activity that they would otherwise not engage in due to a tedious, demanding, or boring process [14, 21].

If the goal of educational activity is to learn skills that are valuable in everyday life (e.g., crossing streets), gamification-based rewards can be effective. During the learning process, learners are rewarded and when they apply the targeted skills in real situations, they recognize their value. Thus, the rewards will no longer be needed because learners will continue to practice the skills for their real benefit and not for the rewards. The risk arising from the use of rewards occurs when the goal is to create long-term changes in learner behavior. Although game designers introduce rewards to increase extrinsic motivation, it is preferable to leverage the structural elements of games to rise intrinsic motivation. That is, rewards should quickly be replaced by more substantial elements, such as narrative, plot, and freedom, to choose paths to explore and activities that are themselves mini-games and opportunities for reflection [22, 23]. This process is known as meaningful gamification. In educational environments, "meaningful gamification" is a learner-centered approach that incorporates elements of game design to develop learners' intrinsic motivation [24].

The term "meaningful" is based on Mezirow's [25] "transformational learning" model, where meaningful creation results from connecting educational activities to people's lives, providing them with a variety of experiences and ways of participating. The goal is to increase the chances for each person to find something meaningful in a game-like activity that satisfies their needs and interests. Transformative learning theory fits the principles of universal design for learning and transmedia learning, where learners access content through different media allowing them both to choose their preferred media and to evolve the narrative. The applications directly related to meaningful gamification are simulations.

While DGBL focuses on structural elements of games, such as rules and goals [26], gamification and simulation are based on unstructured game features that are about players' exploration, experiments, and actions within a virtual environment. This virtual environment provides a learning environment free from the pressure and negative consequences that can result from wrong choices [27].

Mitgutsch [26] proposed the term digital play-based learning (DPBL) to describe the learning offered by a circular and nonlinear process of learning and relearning, combined with the unstructured dimension of the game experience. The most dynamic element of gaming activities, whether it is a game, a gamified application, or a simulation, is the experience of playing [14].

3. The concept of ludification

According to Walther and Larsen [18] ludification, although based on the same conceptual framework as gamification, differs in its areas of application. Thus, ludification is connected to both, gamification and transmedia intended for specific nongame purposes, such as contemporary media productions (e.g., interactive fiction) and consumption practices where the coexistence of game structures and mechanics together with modes of storytelling across media become more and more dominant. Consequently, gamified applications are nongame structures and objects using specific game components, while ludified applications are nongame story structures and story objects focusing not just on motivation, feedback, and reward but on ways of designing, developing, and storytelling in new modes and digital media.

4. Can we combine games, gamification, and ludification?

Digital media, such as computer games, have an inherent ludic dimension that is related to multimediality, virtuality, interactivity, and connectivity [7], making the computer-game platforms ideal for the application of all of the above theories. However, creating a successful experience that combines all of the above is not a task that can be simply implemented in a straight forward manner as the most important aspect of the game is the "*flow*" condition that needs to be achieved, where according to Csikszentmihalyi's words: "*flow is a state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will continue to do it even at great cost, for the sheer sake of doing it.*" At this point, it is important to note the power of transmedia storytelling, a term introduced by Henry Genkins [28] that can be introduced within the game world scenario, which may act as the "gluing" material between the three components: games, gamification, and ludification.

5. The "BRENDA: digital gastronomy routes" case study

In order to create a proof of concept, we have already employed such a scenario within one of our research projects that led to the implementation of the "BRENDA: digital gastronomy routes" game publicly available on https://game.brenda.gr, which is a research-based implementation and is cofinanced by the European Regional Development Fund of the European Union and Greek national funds through the operational program competitiveness, entrepreneurship, and innovation, under the call RESEARCH–CREATE–INNOVATE (project code: T1EDK-05099).

The game developed targets the wide area of the Kilkis prefecture in Greece and focuses on visitors or those who wish to explore the local recipes and history. This experience is developed using state-of-the-art web-based technologies and the game is in fact a responsive database that handles the gamified elements: user progression, score, content discovery level, and media delivery. Four main components make up the game experience: the map/point of interest (POI) /questioning component, where users can explore the information, the recipe/restaurants/local products component, the score/user progression section and the storyline/user settings component.

In order to cover the main issues that arise when creating ludified content, developers have to come up with a design that balances out the required end-system functionality and the sense of "flow" described above. In that sense, transmedia content is an ideal choice and can be actively employed to provide a sound platform for the development of narratives that can be combined but at the same time can be totally different. In that sense, and in our case-study scenario, we wish to educate the player with local historical information and at the same time allow them to explore the culinary heritage that exists in the area. Normal games achieve that aim by imposing a strict content discovery approach through the player scenario that governs the experience. The current system proposes that the player can follow a specific method through the call-to-action video, but then users are free to explore the content using their own strategy.

After the call-to-action experienced at the introduction level where the user is asked to help the main character "Brenda" to discover the local recipes and history, the user can approach the task using different strategies. A typical approach supports discovering local information either via the web interface or also by using the WEB-AR scenario, where they discover local hidden information. Both those approaches enable them to gain game credit (coins), which can then be used within the recipe section to uncover local recipes by purchasing their ingredients. They get to keep the recipes forever in their book and a number of other options are also available to them. They can either cook the recipe or try it out at a local restaurant, an action that allows them to earn additional credit (coins) that can be used to reveal more recipes.

This scenario can also be played differently. The restaurant/local products purchaser can use the AR functionality to first sample the recipes and then reveal the recipes, providing a gaming route that focuses mainly on culinary information. However, as the points are not enough to reveal all the recipes, the players have at some point explore the historical information in order to discover the complete recipe collection.

Therefore, we see how a gaming scenario can functionally support ludification by employing various aspects that suit the interests of different target groups. Gamification is also present within the score/user progression section and it is communicated through the interface at the top of the screen by displaying the player's competence.

6. Conclusions

When the terms game, gamification, and ludification are used to describe the playful aspects of processes, it is common for developers to often not use them accurately in order to describe that particular function of their designs. Clearly, a gaming experience contains the gaming process and supports gamification design practices, but those aspects do not guarantee that the end system will be enjoyable. In other words, a gamified process can end up in a highly competitive and stressful task that does not necessarily generate the intended feelings.

In our case study, we have demonstrated how this is achievable by providing a system that combines all three terms. The narrative components allow users/players to experience the breadth and depth of the historical content and culinary experiences that can be either virtually or physically visited. The game components implemented through questions and quizzes on the historical information are clearly the method that allows users to advance the game and reveal the culinary information that is gradually revealed by the system within the cookbook. However, an alternative way to explore the information is to visit the businesses and gain the necessary game points, a process that is actively supported by the gamification design. Ultimately, as the points from one or the other process are not enough to reveal the whole recipe data set, the user is drawn in and completes part of the available tasks to gain access to the information, offering a customizable yet ludified process that builds up dynamically.

Hence, when “ludification” needs to be implemented, we need to be able to describe the design of the enjoyment mechanisms that take place and generate that feeling. This process is still in its infancy and more work is required, in order to produce a method that describes in a deterministic way the functions of systems that focus on enjoyment, as today, this function is overlooked in existing system designs, such as educational software and other application areas of gamified systems.

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References

[1] Dewey J. Democracy and Education: An Introduction to the Philosophy of Education. New York: Macmillan; 1922

[2] Piaget J. Play, Dreams and Imitation In Childhood. (First Published 1951). London: Routledge; 2013. DOI: 10.4324/9781315009698

[3] van Oers B. An activity theory view on the development of playing. In: Children's Play and Development. Netherlands: Springer; 2013. pp. 231-249. DOI: 10.1007/978-94-007-6579-5_14

[4] Vygotsky LS. The role of Play in Development. In: Cole M, John-Steiner V, Scribner S, Souberman E, editors. Mind in Society: The Development of Higher Psychological Processes. 2nd ed. Harvard University Press; 1978

[5] Caillois R. Man, Play, and Games. University of Illinois Press. New York: Free Press of Glencoe; 1961

[6] Lygkiaris M, Deliyannis I. Game Development: Designing Interactive Narrative Theories, Trends and Examples (In Greek: Ανάπτυξη Παιχνιδιών: Σχεδιασμός Διαδραστικής Αφήγησης Θεωρίες, Τάσεις και Παραδείγματα). Athens: Fagottobooks; 2017

[7] Frissen V, Lammes S, de Lange M, de Mul J, Raessens J. Homo ludens 2.0: Play, media, and identity. In: Playful Identities: The Ludification of Digital Media Cultures. Amsterdam University Press; 2015. pp. 9-50. DOI: 10.1515/9789048523030-001

[8] Kaimara P, Deliyannis I, Oikonomou A, Aggelakos K. Learning by playing games or play by learning: A critical review of games in the 21st century school (In Greek: Μαθαίνω παίζοντας ή παίζω μαθαίνοντας: μια κριτική θεώρηση της θέσης των παιχνιδιών στο σχολείο του 21ου αιώνα). In: Anastasiadis P, Kotsidis K, editors. ICT, Distance Education and Creativity in the 21st Century School (Vols 182-219). Lifelong and Distance Education Laboratory [E.DI.B.E.A.]. Pedagogical Department of Elementary Education, Rethymno: University of Crete; 2022

[9] Rieber LP, Smith L, Noah D. The value of serious play. Educational Technology. 1998;**38**(6):29-37

[10] Fokides E, Atsikpasi P, Kaimara P, Deliyannis I. Factors affecting game-based learning experience: The case of serious games. In: Daniela L, editor. Smart Pedagogy of Game-based Learning. Springer Nature Switzerland AG: Springer Cham; 2021. pp. 133-155. DOI: 10.1007/978-3-030-76986-4_9

[11] Kaimara P, Deliyannis I. Why should I play this game? The role of motivation in smart pedagogy. In: Daniela L, editor. Didactics of Smart Pedagogy. Springer Nature Switzerland AG: Springer Cham; 2019. pp. 113-137. DOI: 10.1007/978-3-030-01551-0_6

[12] Kaimara P, Fokides E, Oikonomou A, Deliyannis I. Potential barriers to the implementation of digital game-based learning in the classroom: Pre-service teachers' views. Technology, Knowledge and Learning. 2021;**26**(4):825-844. DOI: 10.1007/s10758-021-09512-7

[13] Van Eck R. Digital game-based learning: Still restless after all these years. Educause Review. 2015;**50**(6):13-28 Available from: https://er.educause.edu/-/media/files/articles/2015/10/erm1561.pdf

[14] Plass JL, Homer BD, Kinzer CK. Foundations of game-based

learning. Educational Psychologist. 2015;**50**(4):258-283. DOI: 10.1080/00461520.2015.1122533

[15] Prensky M. Fun, play and games: What makes games engaging. In: Digital Game-Based Learning. 2nd ed. St Paul, Minnesota: Paragon House; 2007. pp. 105-144

[16] Kaimara P. Design and development of interactive educational-entertainment systems in inclusive education: Interactive educational programs and audiovisual arts as a bridge between typically developing children and children with special educational needs [PhD thesis], Corfu: Audio and Visual Arts, Ionian University. 2022. DOI: 10.12681/eadd/52582

[17] Deterding S, Dixon D, Khaled R, Nacke L. From game design elements to gamefulness. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. 2011. pp. 9-15. DOI: 10.1145/2181037.2181040

[18] Walther BK, Larsen LJ. Gamification and beyond: The case of ludification. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 12517 LNCS. 2020. pp. 125-134. DOI: 10.1007/978-3-030-63464-3_12

[19] Deliyannis I, Kaimara P. Developing smart learning environments using gamification techniques and video game technologies. In: Daniela L, editor. Didactics of Smart Pedagogy. Springer Nature Switzerland AG: Springer Cham; 2019. pp. 285-307. DOI: 10.1007/978-3-030-01551-0_15

[20] Johnson D, Deterding S, Kuhn K-A, Staneva A, Stoyanov S, Hides L. Gamification for health and wellbeing: A systematic review of the literature. Internet Interventions. 2016;**6**:89-106. DOI: 10.1016/j.invent.2016.10.002

[21] Morschheuser B, Hassan L, Werder K, Hamari J. How to design gamification? A method for engineering gamified software. Information and Software Technology. 2018;**95**:219-237. DOI: 10.1016/j.infsof.2017.10.015

[22] Kaimara P, Oikonomou A, Deliyannis I. Design transmedia learning environments for inclusive education (ιn greek: Σχεδιασμός διαμεσικών μαθησιακών περιβαλλόντων για τη συνεκπαίδευση). Dialogoi! Theory & Praxis in Education. 2020;**6**:239-286. DOI: 10.12681/dial.23330

[23] Nicholson S. A RECIPE for meaningful gamification. In: Wood L, Reiners T, editors. Gamification in Education and Business. Springer International Publishing Switzerland; 2015

[24] Nicholson S. A user-centered theoretical framework for meaningful gamification. Games+Learning+Society 8.0. 2012. Available from: http://scottnicholson.com/pubs/meaningfulframework.pdf

[25] Mezirow J. Transformative learning: Theory to practice. New Directions for Adult and Continuing Education. 1997;**1997**(74):5-12. DOI: 10.1002/ace.7401

[26] Mitgutsch K. Digital play-based learning: A philosophical-pedagogical perspective on learning and playing in computer games. Human IT: Journal for Information Technology Studies as a Human Science. 2008;**9**(3):18-36

[27] Fabricatore C. Learning and Videogames: an Unexploited Synergy. 2000 Annual Convention of the Association for Educational Communications and Technology (AECT). Workshop: In Search of the

Meaning of Learning. 2000. Available from: http://eprints.hud.ac.uk/id/eprint/28000/

[28] Csikszentmihalyi M. Flow: The psychology of optimal experience. New York: Harper & Row; 1990

Chapter 2

Right Game, Wrong Place? A Case Study: Using a Gamified AR Application in a Heritage Context to Promote Engagement and Learning

Liam Noah Jefferies

Abstract

This chapter describes an experiment in the use of gamified processes within a downloadable smartphone augmented reality (AR) application situated in a heritage context of national (UK) significance. The AR project incorporated two distinct game modes, both of which were designed to simultaneously provide users with information and motivate continued engagement. The learning gained from the AR project pertains specifically to three core threads; the first, being of fundamental importance to gamification, is that of challenge and how this links to user motivation, audience ability and prior knowledge. The second considers methodology, specifically the observation of 'representative' and 'expert users' and how a comparison of these can provide insight. The final, and most significant, thread reflects upon gamified content in relation to context, user expectation and environmental influences. The conclusion may assist others who seek to use gamification in any context by its exploration of the mistakes made and successes encountered in this case study.

Keywords: gamification, augmented reality, heritage, education, play, observation

1. Introduction

Gamification, as detailed throughout this publication, is a diverse and multifaceted process, which can be applied to many if not all areas of society and industry. The focus here is on the field of the Arts, and more specifically in cultural spaces, such as Art Galleries and Museums. This context offers much to a prospective scholar of gamification; willing audiences, compelling objects and spaces to unveil and hidden narratives to expose [1, 2]. This book chapter explores the development and delivery of a gamified, augmented reality smartphone application called TNAR (Temple Newsam Augmented Reality). The application, being educational in focus and site-specific in nature, was situated within Temple Newsam, a stately home on the outskirts of Leeds (UK), often referred to as the Hampton Court of the north. Here, the intention was to develop gamified mechanics to not only motivate and maintain user engagement, but also to be the vehicle for the delivery of the educational content, thus being at once the medium and the message.

In order to develop and deliver the TNAR application, and subsequently to assess its efficacy, a number of areas are considered. Initially, a consideration of gamification as a means to motivate engagement and the characteristics of gamification that are perceived to foster this motivation will be undertaken, reflecting upon the dichotomy between the mechanistic and experiential perspectives [3] (Sections 2). Following this, an exploration of the relationship between pleasure and motivation when game playing will be undertaken, with a focus on individual play, in which one participant interacts with a gamified system, this being the most common model applied to cultural spaces [4] (Sections 3 and 4). This exploration of the relationship between play and pleasure supports the identification of three distinct characteristics of individual play: challenge, completion and creation. These characteristics are used to reflect upon existing examples of gamified systems placed in cultural spaces, the capacity of each to elicit these characteristics of play, and the impact this had on the experience of the participant (Section 5). This then is the rationale used in the design and development of the TNAR project (Section 6). A description of project implementation and a reflection on methodology applied to capture participant play is provided in Section 7. Finally, a reflection on the results obtained through observing participants engage with the TNAR project is presented in Section 8, with overarching conclusions and closing remarks contained in Section 9.

2. Gamification (1000)

At the time of writing, it is exactly two decades since Nick Pelling is widely attributed with coining the phrase 'Gamification' [5, 6]. He applied the term to an already recognised process of loading particular tasks with game-based mechanisms to enhance motivation, for example the non-computational serious games explored by Clark Abt [7]. Since 2002 the term has been much used and sometimes abused. It has been the focus of often intense scrutiny both within academia and beyond, with ongoing debates about both definition and application from a whole range of fields, and sometimes vehement criticism of both the term and the ideology behind it [8–10].

Gamification has been defined as '*The use of game design elements in non-game contexts*' [11]. This succinct and deceptively simple definition is often used to support a traditional and arguably transactional notion of gamification; the process of harnessing the mechanisms found within games, predominantly but not exclusively electronic, '*such as points, badges, levels, challenges, leaderboards, rewards and onboarding*' [12] and applying them to other contexts, such as manufacturing, distribution or IT services [13]. This is with the intention of encouraging, expediating, improving or prolonging engagement with and progress within the primary activity [14]. For example, awarding data entry clerks points for each entry correctly input, creating a league table and awarding the winner a prize. The gamified component within this system then is intended to act as a vehicle to motivate prompt and accurate completion of the primary task, data entry. This application of gamification has garnered interest from the commercial sector as a means of improving productivity, and from within the research community, with academics seeking to apply gamification to a range of fields, interest peaking in the early 2010s.

During this time there was a significant backlash against this conception of gamification, fermented most notably by Ian Bogost [3] who offered the term 'exploitationware' as a better description. It was argued that it reduces games to the '*incidental properties of their medium, points and leaderboards*' [3] and seeks to parcel up these mechanics into productivity products, which are devoid of the '*playful experiences meant to produce gratification*'. This position was supported by Thibault [9] who viewed gamification as certainly problematic and potentially dystopian, and Dragona [15], who positioned gamification as a mechanism *to 'enable exploitation and control'.* Koster went on to state that gamification misses the point of what a game should be, using '*the trappings of games (reward structures, points, etc.) to make people engage more with product offerings*' ([13], p. 50). Layering these trapping '*on top of systems that lack the rich interpretability of a good game. A reward structure alone does not a game make*' [13]. Nicholson [16] characterises this as a difference between meaningful and (BLAP) gamification with BLAP standing for badges, levels and leaderboards, achievements and points. Implicit in this debate are the opposing ideas of what elements within a game actually create the positive experiences that motivate and engage. On the one hand, this is positioned as the mechanics; the achievement of a certain level, or the accrual of points within the system in and of itself [12]. On the other, it is the more expansive notion of the contextually specific experience of engaging with a complex system in which playful moments are attained to produce gratifications [3].

This debate is essential to an exploration of the efficacy of Temple Newsam Augmented Reality (TNAR), in that the project aimed to create a gamified system that is enjoyable in its own right; to simultaneously educate and entertain. The participants, far from being paid to engage with a task that could be gamified to increase their productivity, had paid to visit the space in which the game was situated. As such it is incumbent on the gamified system itself to evoke pleasure in those engaging with it. To achieve this, an understanding of which characteristics within the gamified system deliver these positive experiences is required. Is it the mechanical or the experiential or a more complicated and context-specific combination of the two as suggested by, for example Tulloch [5]. According to Koster [17], gaming is fundamentally about fun, and that fun, when elicited by playing games, is complex, individual and related to learning and mastery, exploration and rich interpretations.

Bilda [18] aligned positive experience to the notion of 'meaningful play', which is achieved by designing *'experiences that have meaning and are meaningful' (p.34),* with this meaning emerging from *'the interaction between players and the system of game, as well as from the context in which the game is played'.* Two notions are contained in this quote: the first relates to context and will be returned later. The second is the notion of enjoyment, which is at once entirely obvious and often overlooked. The reason players play games is because they are fun. This is the underlying premise of gamification, that it can make a rote or uninteresting task enjoyable or engaging. The perceived enjoyment of the participant is positively related to their continuance intention [19]. Salen and Zimmerman point to the writing of Caillios [20] as proving a model to understand this, offering characteristics of play and pleasure through which positive experience can be understood, designed for and measured. This provides a potential way forward that bypasses the rhetoric of the above debate and looks at the fundamentals of play, *'the task is to find how this potential can be translated to actuality'* [21]. To do this, a wider exploration of the history and theory of game playing and the pleasure it offers is needed, this being the focus of the next section.

3. Playing games

In this section, a brief consideration of games and play from a social and, to some extent, historical perspective will be made to support the identification of the characteristic forms and types of pleasure that are elicited when one engages in play. This will provide the means and measure by which the efficacy of the TNAR project can be assessed.

The playing of games has served an important function across much of human history, with board games being discovered in the tombs of the Pharaohs [22], in Roman archaeological digs [23] and evidence of game play and in particular adversarial or gambling games emerging from many ancient civilisations [24, 25]. The vast majority of these games are competitive in nature, being played between two or more participants who seek to defeat their opponents. Well-known examples of ancient games that are still played today are Chess, Backgammon and Go [26]. In relation to the function these games played this is seen to be largely social, with the players deriving satisfaction from interacting, competing, collaborating with and hopefully overcoming their peers [27]. Game playing was often associated with monetary gain through gambling [28] although the focus here is necessarily on non-financial motivations as TNAR has no financial or monetized dimension.

Malaby [29] and Walsh et al. [30] coined the term gaming capital, an extension of cultural capital [31], with a player's skill and mode of play contributing to or reducing their perceived capital in relation to their peers. Thus, an individual's gaming abilities define their position within the community of players and to an extent in wider society, an idea taken to its limits in Ian, M Bank's novel *The Player of Games* [32].

Turning to a consideration of electronic games, pre-C2000 gameplay was primarily designed as a solitary activity, and whilst there are notable exceptions to this, for the most part, the mechanism was one of a single player interacting with a system to achieve specific goals. This dichotomy between multiplayer analogue games and single-player electronic games was highlighted by Zegal et al. [25, 33]. Whilst this certainly is not the case now, with the proliferation of mass multiplayer online games, and arguably was not entirely true even in 2000 if commercial video games are included in the gaming array [27], it is certainly still the case for gamified systems placed in cultural spaces. Here *'the model places the individual and the individual's interaction with the artefact or system at the heart of the agenda'* [34].

It is essential then to consider what motivates a single player, and whilst the single-player model does not necessarily preclude all social incentives, there are certain impetuses that are notably more significant in solo play. To move forward we must explore the experience of play, and more particularly the characteristics or categories that can be used to define it. Fortunately, a number of theorists, not least Roger Caillois [20], Mihaly Csikszentmihalyi [21], Marc Leblanc [35] and Brigid Costello [36], have committed much thought to this, and whilst a detailed examination of the categorisations posited is not possible, a broad overview will provide much of use. Some of these categories are primarily related to social, multi-participant play such as 'fellowship' [35], 'friendship' [21] or 'Competition' [21]. However, others are fundamental to the perceived pleasure and motivation of participants of single-player games, and the gamified systems placed in cultural spaces. These are categorised from the above literature here as challenge, creation and completion and are explored in more detail in the following section.

4. Single-player mode(s) of engagement

> *'Play is a total activity. It involves a totality of human behaviour and interests'.*
> *R Caillois: [20]*

In the previous section, three key characteristics of single-player play were suggested: challenge, creation and completion and a detailed consideration of these three aspects of gaming pleasure is the substance of this section. These characteristics will then be employed to evaluate the case study to follow and as a vehicle to assess the effectiveness of the TNAR-gamified application central to this chapter.

4.1 Challenge

According to Costello [37] challenge is largely analogous to difficulty; participants derive this form of pleasure '*from having to develop a skill or to exercise skill in order to do something*', and '*an activity can often be more fun if it is not too easy*' (p. 66). Csikszentmihalyi's ([18], p. 74) example of rock climbing, as '*a private experience rather than a public event*', is of relevance here, as it allows the participant to '*choose the level of challenge that best suits one's level of skill*' ([18], p. 79) or mood for challenge at the time. In his example, there is a grading system for potential climbs that allows the climber to compare their inherent ability to the potential future challenge. The successful completion of sufficient challenge is found to produce both pleasure and self-fulfilment, with the activity of engaging providing its own intrinsic reward. Similar entirely non-social pleasure is present in other game-playing activities, such as playing solitaire or attempting to solve a crossword puzzle; pleasure is derived from using skill and/or perseverance to tackle the challenges presented by the system being engaged with.

> *'Games that are too hard kind of bore me, and games that are too easy also kind of bore me'. Koster ([13], p.10).*

Koster's position, as defined in the above quotation, supports Csikszentmihalyi's argument that in order for a single participant to derive pleasure from engaging with a gamified system it must present the correct level of challenge. As in the Three Bears story, for every Goldilocks gamer, the beds should not be too hard, or too soft… they should be just right. Of course, as shall be seen in the studies below, games, like beds, do not always have a hardness level or degree of difficulty indicator to usefully guide us through our challenges. In the arena of electronic games, this raises the spectre of the potential for a mismatch between desired and offered challenges.

4.2 Completion

This characteristic is to an extent akin to challenge in that it forms part of the same process of engaging with the game or system to achieve an end: reaching the top of the cliff and finishing the jigsaw. However, there is an important difference, which relates fundamentally to the specific pleasure derived. Challenge is conceived as the embodied experience of the encounter; that moment of pleasure in the effective application of skill, the achievement of a 'flow state' [21] that can only occur whilst actively engaging. Completion is generally the goal at the game's start, but the pleasure derived from challenge is not dependent upon completion. Completion is seen more as a lasting sense of achievement, residing in memory rather than in the instant. Whilst this sense of satisfaction can be related to the challenge faced in attaining completion—the *'process'* to take an Aristotelian view [38, 39]—it is not necessarily dependent upon it. Sizar [40] summarises this position succinctly as the one being the 'excited engagement during activity' and the other the 'satisfaction and contentment at their completion'.

4.3 Creation

> *'Creation is the pleasure participants get from having the power to create something while interacting with a work. It is also the pleasure participants get from being able to express themselves creatively'. Zagal, Rick and Hsi ([33], p. 65).*

The final characteristic of the pleasure derived from play is that of creativity. Unlike challenge and completion, for creativity to exist the system being engaged with must offer the opportunity to express creativity for this pleasure to be elicited. This distinction is perhaps not immediately clear, as the definition of creativity is somewhat ambiguous; for example, it could be argued that a chess player displays creativity when playing, taking an unexpected approach to certain game situations. However, for our purposes here we will make the following differentiation, which links to notions of opportunity and uniqueness. Our chess player demonstrates skill and understanding when choosing an unexpected move, but does so in a system with clearly defined set outcomes. This differs from the experience of the painter, where the artist has the opportunity 'to make exist that which didn't' [41]. To return to the example of rock climbing, when the climber climbs an existing route that someone else has defined and laid out, the pleasure of challenge and completion are elicited, but when the climber looks at a virgin cliff and defines a new route from scratch the pleasure of creation is also a factor and can predominate. Or, to take an example from commercial video games, in Minecraft™ the player can create something entirely unique from the varied building blocks provided, with pleasure derived from the creative process, which is non-defined and open-ended. Creativity within gaming then provides a distinct form of pleasure that may or may not be experienced depending on the game and perhaps on the skill of the player.

5. Gamification in cultural spaces

> *'Digital technologies, in particular interactive storytelling and gaming, have a great potential for assisting both the education and entertainment of visitors in museums'. Danks et al. [42]*

In this section, we will consider the ability of gamified systems situated in cultural spaces to elicit the forms of pleasure posited above, with this by extension providing a method to assess the capacity these games offer to motivate and prolong engagement. Testing the hypothesis of Danks et al. above, there is now a growing repository of papers that explore gamification applied to cultural spaces, predominantly museums ([43–47] e.g. with [48, 49] both offering literature reviews). Beyond this, Scheuer [50] offers a useful study relating to the form the vast majority of projects take, this being an 'add-on' game, which augments an existing exhibition rather than being developed as part of it. Furthermore, there is the consideration of purpose when applying these games, which the literature positions as almost universally related to learning, with motivations, when given any attention, generally seen to be derived from the act of learning. This is a position disputed by Martens et al. [51] who see the game as providing pleasure distinct from the wider goal of learning, with that pleasure providing the motivation to engage. However, in order to consider the characteristics of pleasure posited here, a reflection on specific gamified systems which have been, for the most part, directly experienced by the author will be most valuable to our purposes, with due effort made to offer examples in a representative range of forms.

5.1 High tea

The first example is '*High Tea*' (Welcome Collection 2011). This browser-based strategy game was commissioned as part of the web presence for the 2010/11 Welcome Trust exhibition *High Society* with the '*aim of establishing new and meaningful engagement with the themes of the exhibition*' [52] and is still available to play at https://preloaded.com/work/wellcome-collection-high-tea/. In this game, users were asked to take on the role of the nineteenth century opium smuggler, developing a strategy to sell enough opium to the Chinese of the Pearl Basin to fund the purchase of tea to supply the expanding UK market. The clear intention here is to develop a compelling game whose mechanics not only motivate but also educate, with the motivating factor—the accrual of tea—being fundamental to the educational narrative. Exposing the dubious ethics of Victorian England and the historical appetite for narcotic substances—Opium or Caffeine—was key for the curatorial intentions of the wider exhibition.

This is a useful example for two reasons: the first relates to the mechanism of gamification in that the educational goal—the learning that is the primary task—is seamlessly integrated into the mechanics of the game. Points and scores are awarded in the form of currency or products (tea or opium), and levels and outcomes can be attained through the collection and distribution of these, but the process the player undertakes to achieve these goals is based on historical events and interactions. The game itself is thus the lesson. The playable moments that offer pleasure, primarily through achieving the increasingly challenging levels, simultaneously motivate continued engagement and deliver the educational goals of the game itself. The second is the distribution method chosen by the designers, who did not situate this within the gallery space, but made it available *via* online gaming platforms and their own proprietary web presence. This had the dual purpose of both widening, and making international, opportunities to consume, and of allowing players to interact in a context of their choosing, rather than being constrained to play during a visit to a cultural space.

5.2 CHESS project

> *'Museums have graduated from the mere display and presentation of collections to the creation of experiences that respond to their visitors' evolving needs and expectations'.*
> *Katifori et al. [53]*

The second example only arguably fits into the game category. The Chess Project, however, has many of the characteristics of a game, such as challenge and completion.

The CHESS project, situated at the Acropolis Museum in Athens (CHESS: Cultural Heritage Experiences through Socio-personal interactions and Storytelling), is a long-running, part EU-funded research project that seeks 'to enrich museum visits through personalized interactive storytelling' [54]. The project uses interactive narratives delivered *via* mobile-augmented reality to engage and educate participants about the historical artefacts on display, with participants being required to follow clues and locate physical objects in order to progress through the on-screen narratives. The story is intended to motivate players to explore the museum and gain a deeper understanding of the historical context of the physical exhibits.

What is of note here is the direct approach the authors took to the notion of challenge, and their evident desire to respond to each participant's individual level of prior knowledge and understanding. This recalls Nicholson's [16] concern that '*the challenge in creating something meaningful is that the concept of what is meaningful is defined by each individual'.* In the CHESS project, pre-engagement questionnaires were used to create personalised narrative experiences, designed to reflect the individual participant's interests and knowledge [55]. The designers used this mechanism to address the issue that level of difficulty is both individual and context-specific, as raised above. Using this approach, players were able to access tailored narratives that provided sufficient challenge to motivate, without being too easy or too hard, and took into account the varied ages, backgrounds, interests and enthusiasms presented by a diverse visiting public.

This reiterates the importance of challenge level for a challenge to be a motivating pleasure within gamified applications in cultural spaces. As per Nicholson: *'small differences in age or interests of visitors may have considerable impact on the appropriateness of the digital activities and the delivered experiences' (Ibid [55], p. 16).* Personalisation needs to be 'dynamic and highly targeted' to be effective which poses considerable challenges to designers as such a level of personalization can require detailed understanding of the age, interests and motivations of individual game players [56].

5.3 If you go away

> '*We wanted to know if you can move people emotionally through an augmented digital experience. It turns out you can, but only a some of them!' [57]*

The final example offered here is *If You Go Away,* created by UK-based arts organisation Invisible Flock (2015). This interactive, site-specific game sought to explore ideas of loneliness and isolation in urban settings, using GPS and augmented reality to offer a reimagination of the cities in which it was hosted including Leeds, Nottingham and Manchester (UK). The game offered an '*augmented reality journey through the streets made strange and new*' [58]. The game used a point-click model of gaming, inspired by titles such as Monkey Island™ and combined this with augmented reality to provide a games mechanic that required players to interact simultaneously with both physical and digital features in order to solve puzzles and progress. Players were required to, for example, place a digital (on-screen) beer can in a physical (real world) bin.

An interview with the creative director of Invisible Flock, Ben Eaton [57], found a number of relevant concepts that both relate to, and were to some extent the inspiration for, the measures of pleasure explored in this chapter. With reference to completion, for example, 240 participants began engaging with the game, which took about 2 hours and culminated with a digitally mediated dance on a bridge at sunset.

Of those 240, only around 10 reached this culmination, which '*from a publicly funded piece of art perspective, you could argue is slightly problematic in terms of access. But as a game with a certain amount of win or fail state built into it, it is less problematic, it's actually part of the medium*' [57].

To turn to the second pleasure concept, the pleasure of challenge, Eaton says of the puzzle element of the point and clicks mechanic in his game: '*..it was hard, and for people who understood what they were doing, they enjoyed it and it was fun*', but '*a lot of people didn't.* It is reasonable to assume an interrelationship here; the level of challenge was either greater than expected and implied by the context of the offering, or those participating did not recognise the puzzle mechanism and thus found it difficult to progress. This will be considered in more detail in the context of the main project.

What of course the eagle-eyed reader will have realised is that the pleasure of creativity as defined above is not found in any of the above examples. A search for examples of gamified applications, situated in cultural spaces, seeking to, or capable of eliciting, the pleasure of creativity as defined here has been unsuccessful to date, despite all the models, both from within game design and more broadly, emphasising its efficacy. Indeed, there are only limited examples to be found in the wider literature (see Refs. [59–61]) primary motivation for exploring this form of pleasure and in seeking to employ it in the TNAR project described below.

6. Project motivation and description

6.1 Motivation

The TNAR project was informed by all the research findings summarised above and its objectives are their product. To summarise: firstly, the opposing ideas of what motivates player engagement with a gamified system emerged; these being either transactional metrics [16] or emotive playable moments [3]. The second consideration relates to outcome and gamified mechanism, and how their alignment can be used to simultaneously motivate engagement and deliver outcomes, with this being effectively demonstrated in the High Tea game example. The third is the tension between eliciting the pleasure of challenge and that of completion, in particular when games are played by diverse incidental audiences. The final consideration relates to the pleasure of creativity as described in Section 4, with this being potentially impactful but underexplored within the wider literature. The development of the TNAR application was then, a project to enhance understanding of the operation of these four aspects of game-playing pleasure.

6.2 Description

TNAR was a gamified augmented reality application located in the Picture Gallery, an historically significant space in Temple Newsam, a stately home near Leeds (UK). The augmented reality application used two distinct game mechanics with the aim of explaining the social and economic factors that influenced the construction and decoration of the physical space, the primary goal being the education of participants. The educational content was intended to offer context about two important characters from Temple Newsam's history; Sir Arthur Ingram, who commissioned the original construction of the Picture Gallery and his descendant, Viscount William Ingram, who was instrumental in its renovation. This educational information is not readily available within the physical space itself.

The first games mechanic was modelled upon text-based adventures such as Planet Fall (1983), which are in turn based upon earlier adventure gamebooks like the Fighting Fantasy series. As in these, players are required to make choices based on real historical events and navigate conflicting pressures to obtain enough money to either build the picture gallery in the first place or to refurbish it. Through this means a series of historical scenarios are encountered, with the player required to make choices between different courses of action in order to progress. The challenge element derives from the imperative to navigate these historical encounters, with each choice made having repercussions and only certain paths leading to successful outcomes. The player is required to use their judgement and to develop understanding of the historical and political influences at play, using this knowledge to inform their choices, learning from mistakes and accruing knowledge about the characters involved, their personalities and the pressures they faced. The mode of play is intended to align the educational goals with the motive influence of the game mechanic (**Figure 1**). Scenarios are sequential in nature, growing in both complexity and difficulty as the player progresses, with intervals in which the second games mechanic (below) is deployed, to offer a sense of completion, and to illustrate and mark progress.

The second game mechanic is most analogous to computer games such as Sims™ (2000) or SimCity™ (1997) with the player asked to construct and decorate a digital version of the physical picture gallery in which the game is being played. This digital model was overlaid and mapped onto the physical space, offering a direct comparison between the current physical reality of the space and the presented historical recreations. These recreations were the bare walls and architectural features followed by a representation of the Tudor space and finally a faithful digital recreation of the space as it is currently seen, with this becoming a digital souvenir the player can take away with them and revisit at their leisure (**Figures 2** and **3**).

The game incorporates a number of functions germane to this chapter. Primarily, it aims to offer the opportunity for the player to exercise creativity, giving them

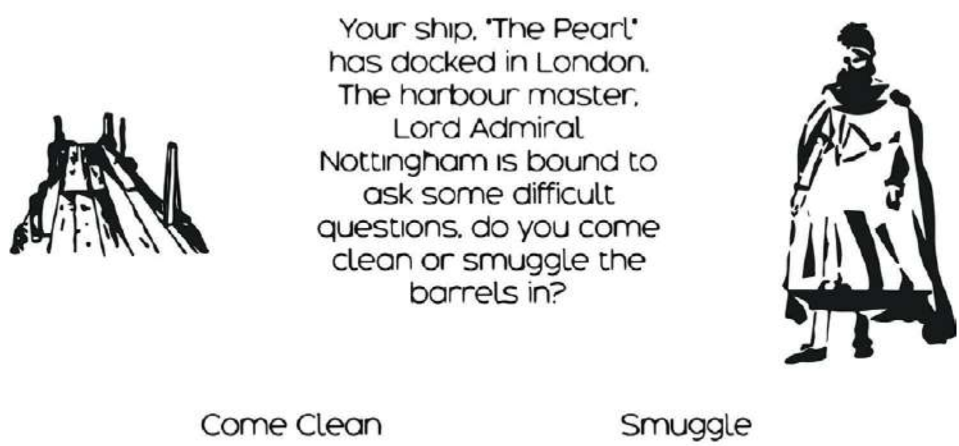

Figure 1.
TNAR: (2018).

Figure 2.
Early redecoration scenes (2018).

Figure 3.
Final redecoration scenes (2018).

choices on how to apply the various elements of decoration and construction, with a large variety of potential outcomes being available. The second function relates to progress and completion, with the building and redecoration of the digital space operating to illustrate and reward player progression in the text-based game, but doing so in a way that is directly related to the educational goals rather than using arbitrary points or levels. The third function also relates to this imperative to align method and mechanism of play through playable moments, such as completing the gallery and comparing it with the original, and through the overarching goal of the application, to wit, the dissemination of contextual and educational information relating to the hidden histories of the space itself.

7. Methodology and dissemination

7.1 Dissemination

The intention was to offer TNAR to the general public, but this proved unworkable due to accessibility concerns and the potential alienating effect of this on incidental

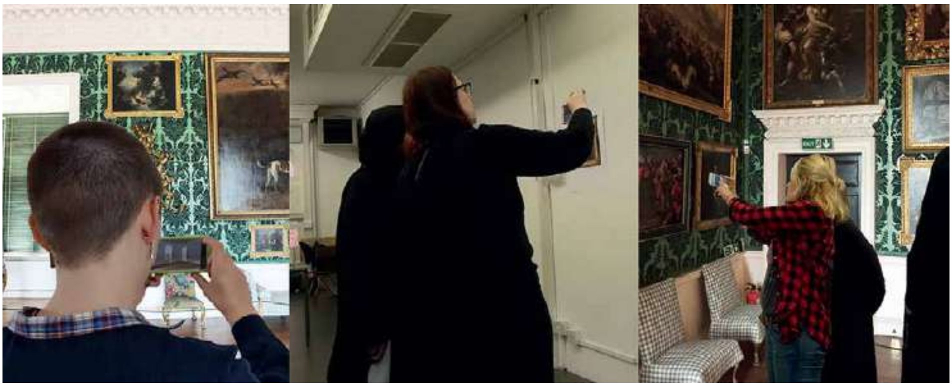

Figure 4.
TNAR In-use (2019).

audiences, related to WIFI™ availability and software compatibility. Therefore, seven participants were invited to take part at Temple Newsam, with their experience designed to model those of an incidental audience as far as possible (**Figure 4**). Of the seven observed, two were deemed to be expert users, in that they had significant previous experience engaging with mobile augmented reality applications. These participants were included as a form of control in a bid to understand the impact of technological familiarity on the engaged experience [62, 63]. The TNAR application was also displayed, in the form of a 2-hour workshop, to 20 invited guests. In this scenario, participants were given contextual information relating to the project, their interaction was recorded, and written feedback was obtained post-participation.

7.2 Methodology

Two primary approaches, or paradigms to use Hein's [4] phrase, dominate methodological discourse around the capture of audience experience with interactive or indeed gamified systems. One approach is principally quantitative, focusing on measurable metrics, for example 'use time', participant progress or click count, and the other is principally qualitative, seeking to capture individual experience or subjective responses [48, 64, 65]. Much of the contemporary literature suggests that the purely quantitative is insufficient in capturing the nuances of engagement, with many advocating an ethnographic model, employing naturalistic methods as better equipped to offer experiential insight [66–72]. Moving away from methods derived from the 'behavioural and cognitive sciences', models founded in the 'cognitive and educational sciences' [68] are exemplified by the following quote: '*Observation, in some sense, of an interactive system in action is the only way to understand it*' [71]. This position is supported by many in the fields pertaining to audience studies in cultural spaces [73–75]. Refs. [76–78] highlight qualitative observation as being the best method of assessing complex behaviours or subjective emotions such as satisfaction or enjoyment.

With this in mind, a methodology primarily employing narrative participant observation was selected as being best positioned to capture and understand the capacity of the TNAR application to elicit the forms of playful engagement that are our focus. These observations were undertaken by the author and describe the participant's engaging experience as a narrative, in which evidence, both verbal and physical, pertaining to the gaming experience, is captured. This employed, as far as possible, a total of one observer model [79, 80] in which interactions between participant and observer are limited. The observational narratives were augmented with post-engagement, semi-structured interviews and written feedback. This aligned to methods successfully applied by, that is Costello, Edmond or Muller [36, 71, 81], when seeking to understand the pleasure participants experience when engaging with interactive artworks.

These observations, and other evidence, including verbal and written feedback were subjected to systematic review [82] seeking interpretive commonalities, which were then categorised; these form the basis of the results and discussion to follow. This data can be viewed here.

8. Results and discussion

In this section, an examination of the key finding that emerged through the systematic review of the participant observations and supporting feedback will be offered. These findings largely align with considerations outlined in Section 6.1 and coalesce around the following headings: challenge, creativity, completion and alignment. A reflection on methodological appropriateness and application is also offered.

8.1 Challenge

As discussed in Section 4, the pleasure elicited through the challenge of engaging with a game or gamified system such as TNAR is perceived to have significant bearing on the ability of that game to motivate participants to continue to engage. Observations of those using the TNAR application support that thesis, but possibly the motivation was less pleasurable than per the model. Five of the seven participants presented verbal or physical signs of frustration when engaging with the text-based game, with comments, such as 'How am I supposed to know the right answer?', 'Oh no, I have to start again!' and 'Oh this is ridiculous!' as representative examples of the range of emotional responses observed. Whilst some of the observed frustration was directed specifically towards the system and interface, with technical issues and unfamiliarity with modes of engaging with AR accounting for this, four of seven participants, including the expert users, were observed to be demotivated by the text-based game mechanism specifically. Comments indicated that this is related to two factors: degree of difficulty caused too many failures and repetitions, and this was insufficiently mitigated by the motivational boosts of perceived incremental progressions and rewards. Secondly, failure and repetition—exploring different avenues in order to progress—is a tried and tested mechanism in text-based games, but failure and the need to repeat in the context of an educational game in a stately home were received extremely negatively, indicating a misalignment between expected mode of play and what was offered.

8.2 Creativity

Creativity is identified as one of the key components of pleasurable play; however, with very few examples of this form of play being present in the literature, exploring this was one of the primary objectives of the TNAR project. It is interesting from a research perspective and gratifying from a creative one, then, that the creative game mechanism was the most successful element of the project in stimulating positive responses. All those who successfully progressed through the game to this component, and had a device capable of rendering it successfully, (4/7) were observed to derive pleasure from building and decorating the digital rendition of the picture galley. Players were seen to experiment for prolonged periods with the different options, and there was evidence that the creative process had an educational dimension, with comments from participants about the effectiveness of their recreation and expressions of interest about the historical decorative options. The TNAR project then was, in this component, effective both as an educational tool and as a motivational mechanism in that players were motivated to continue playing. There is evidence that gameplay *via* augmented reality also provided meaningful playable moments through comments, such as 'Visually, very cool, I felt very much part of the experience', and 'It's magic'. Motivation was not, it was observed, necessarily sufficient, however, for players to re-engage with the text-based game.

8.3 Completion

The pleasure offered by completion—that lasting sense of achievement and satisfaction when a challenge is overcome successfully—was not a significant feature in the players observed as only one of the seven participants completed the game. The creative scene decorating component of the game was open-ended with no clear point of completion. The text-based game did have a definite completion point, but this proved too challenging for the majority of the participants to achieve. Participants were observed to become demotivated and disengaged. What is of note is the length of time players were willing to commit to persevering in the text-based game; a matter of 5–10 minutes in most cases before giving up. This engagement time was significantly less than expected during design and testing, and again suggests differing expectations set by the context of the experience. Would the players have been prepared to commit more time to play the game in a setting such as their own front room for example? Is attention span necessarily short in an environment that offers so much to engage with in a limited timeframe? There was of course one exception; one super-participant navigated the text-based game with fluency and enthusiasm. In this case, the challenge level was appropriate and completion—a sense of achievement—was experienced.

8.4 Alignment

Alignment refers back to the concept initially discussed when examining the High Tea project in Section 5 and specifically the alignment of a game mechanism with an educational goal. In the case of the High Tea project, the medium was very much the message and this was intended to be the case with the TNAR project in both game modes but was, for the majority of participants, only observed to be effective during the creative decoration scenes. In this section, the participants were observed to make tangible and visible links between the historical content and the real work context of the space, with the redecoration scenes unveiling the hidden histories in a way that had real meaning for the participants. The text-based game, however, despite being more contextually and educationally rich, proved less interesting to participants and they seemed to derive less pleasure from navigating these choices. It was intended that during the text-based game participants would come to emotionally respond to characters and their predicaments, with this being key to the motive power of the game mechanism. However, this did not occur, and while a clear rationale for this does not emerge from the evidence, there were references in the participant feedback related to the aesthetic experience with the text-based game being described as 'text heavy', overly 'educational' and 'confined'.

8.5 Method

The final area of note from this process is related to the methodology used. This is seen as effective, but raises some interesting points, particularly in relation to the efficacy of qualitative observation. This is inherently subjective and reliant on the observer being able to interpret the external evidence of internal emotion in an unbiased way. To combat this potential, observed perception of emotional experience was not included without physical evidence of this occurring. Generally, this took the form of verbal comment or non-verbal utterance or other easily interpreted physical action, such as feet stamping, gesticulation or subdued or introverted behaviour. This led to sometimes descriptive narratives of observation being produced, in which what was happening is clear, but not what the participant was feeling. It was at this point that the other methods of feedback capture became useful to corroborate, inform and augment the impression garnered from the observations (which were by and large more negative than the written feedback).

9. Conclusions

When reflecting upon the topics covered in this chapter, a number of conclusions have been reached. These are summarised here in the hope that they accrete in some small way to the research discourse pertaining to gamified systems in cultural spaces.

Firstly, challenge has been identified as a key characteristic of play within gamified systems and has been observed to exert a powerful motive influence on participants in terms of continued participation and enjoyment. This has both positive and negative implications. For challenge to have a positive impact upon engaged experience, it must fall within a Goldilocks Zone, at a point, between boredom and anxiety, being not too hard, or too soft, but just right. Achieving this is complicated by the diversity of audiences present within a visiting public. The CHESS project, above, developed strategies to align interest with topic offered: a similar strategy would be possible with a menu of challenge levels although there are barriers to achieving this such as time and potential bias, which make this a difficult proposition.

Arguably, one in seven is a reasonable statistic for completion of a challenge game in a heritage setting within a limited timeframe and where the individual has numerous competing priorities vying for their attention. The High Tea project worked around the negatives of the heritage context by making the game accessible outside of the setting, so that the visitor could navigate the game in their own time and space. As above, context is everything. Game player motivation and perseverance levels are very different when sitting on a comfortable sofa at home with plenty of time and few distractions than when playing a game in a culturally significant space with a myriad of competing experiential offerings. The game designer can factor in levels as in the Chess Project, allows the game to be played beyond the heritage context as in the High Tea setting above or incorporate game elements where completion is not defined by the designer but is the subjective decision of the game player—by the incorporation of creative elements.

Creation was observed to be the most significant pleasure in the case of the TNAR project, with participants at their most engaged when creating their own spaces. It was also at this point that the mechanism of the game most succinctly aligned with the educational intention in that the pleasure the participant experienced, and which motivated them to continue, was also the mechanism by which the educational information (the task) was delivered. This is perhaps the key conclusion here, and one that has relevance to the debate about what gamification is and should be. One in which a nuanced appreciation of the desired outcome, the pleasure the player is expected to experience and the gamified mechanism used to achieve this is required. This is in part a response to the debate outlined in Section 2, in that gamification is not a silver bullet to motivate, and that a mismatch between mechanism and outcome can in fact do the reverse; demotivate and disengage or even make it more difficult or confusing the attainment of the learning goal, as perhaps, for novice gamers, was the case with the text-based sections of TNAR.

When all the above factors align, when the game is suitably presented for its context, when participants are time confident, when the participant is challenged to the correct degree, motivation to play and to continue playing to the end is achieved and the educational goals embedded in the experience will be delivered; then, the task is gamified. The alternative is a gamified creative gameplay that can, as in the TNAR project creative component, deliver meaningful educational content. In either case, the task being gamified must be integrated into the system itself, for points and leaderboards do not an effective game make. As with the High Tea project, when the playable moments within the system that elicit pleasure at the same time constitute the task these things align and positive experience and positive learning outcomes are achieved.

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References

[1] Tillon AB, Marchal I, Houlier P. Mobile Augmented Reality in the Museum: Can a Lace-Like Technology Take you Closer to Works of Art ? IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities. Switzerland, Basel: Institute of Electrical and Electronics Engineers; 2011. pp. 41-47

[2] Matuk C. The learning affordances of augmented reality for museum exhibits on human health. Museums & Social Issues. 2016;**11**(1):73-87. DOI: 10.1080/15596893.2016.1142815

[3] Bogost I. Why gamification is bullshit. In: Walz SP, Deterding S, editors. The Gameful World: Approaches, Issues, Applications. Cambridge, MA, US: MIT Press; 2015. pp. 65-79. Available from: https://books.google.co.uk/books?id=KDxTBgAAQBAJ

[4] Hein GE. Learning in the Museum. Vol. 47, Assessment. New York, New York, USA: Routledge; 1998. p. 203. Available from: http://books.google.com/books?id=Yz4pflj1jMoC&pgis=1

[5] Tulloch R. Reconceptualising gamification: Play and pedagogy. Digital Culture & Education. 2014;**6**(December):317-333

[6] Marczewski A. Gamification: A Simple Introduction. London, UK: Andrzej Marczewski; 2013. Available from: https://books.google.co.uk/books?id=IOu9kPjlndYC

[7] Abt CC. Serious Games. Illustrate. Lanham, US: University Press of America; 1987. p. 176. Available from: https://books.google.co.uk/books?id=axUs9HA-hF8C

[8] Bogost I. Persuasive Games, A Decade Later. In: de la Hera T, Jansz J, Raessens J, Schouten B, editors. Persuasive Gaming in Context. Amsterdam, NDL: Amsterdam University Press; 2021. p. 29-40. Available from: http://www.jstor.org/stable/j.ctv1hw3z1d.5

[9] Thibault M. Punk Gamification. In: Proceedings of GamiFIN Conference 2019. Levi, Finland; 2019

[10] Woodcock J, Johnson MR. Gamification: What it is, and how to fight it. The Sociological Review. 2018;**66**(3):542-558

[11] Deterding S, Dixon D, Khalad R, Nache L. From game design elements to Gamefulness: Defining "gamification.". In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, MindTrek 2011. Tampere, Finland: Association for Computer Machinery (ACM); 2011. pp. 9-15

[12] Zichermann G, Cunningham C. Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. Sebastopol, US: O'Reilly Media; 2011. p. 208. Available from: https://books.google.co.uk/books?id=zZcpuMRpAB8C

[13] Narayanan A. Gamification for Employee Engagement. Birmingham, UK: Packt Publishing; 2014. Available from: https://books.google.co.uk/books?id=Pc4GBgAAQBAJ

[14] Bahr W, Mavrogenis V, Sweeney E. Gamification of warehousing: Exploring perspectives of warehouse managers in the UK. International Journal of Logistics Research and Applications. 2022;**25**(3):247-259. DOI: 10.1080/13675567.2021.1892042

[15] Dragona D. Counter-gamification: Emerging tactics and practices against the rule of numbers. In: Rethinking Gamification. Lüneburg, Germany: Meson Press; 2014. pp. 227-250. Available from: https://mediarep.org/bitstream/handle/doc/2957/Rethinking_Gamification_227-250_Dragona_Counter-Gamification.pdf?sequence=1

[16] Nicholson SA. Recipe for Meaningful Gamification. Gamification in Education and Business. Cham, Switzerland: Springer; 2015. pp. 1-20

[17] Koster R. Therory of Fun for Game Designers. Sebastopol, US: O'Reilly Media; 2013. 299 p. Available from: http://oreilly.com/catalog/errata.csp?isbn=0636920029236

[18] Salen K, Zimmerman E. Rules of Play: Game Design Fundamentals. London: MIT Press; 2004 (ITPro collection). Available from: https://books.google.co.uk/books?id=UM-xyczrZuQC

[19] Sharma TG, Hamari J, Kesharwani A, Tak P. Understanding continuance intention to play online games: Roles of self-expressiveness, self-congruity, self-efficacy, and perceived risk. Behaviour and Information Technology. 2022;**41**(2):348-364

[20] Caillois R. Man, Play, and Games (Translated by Meyer Barash). New York, US: The free press; 1961

[21] Csikszentmihalyi M. Beyond Boredom and Anxiety. New York, US: Whiley, Jossey-Bass Publishers; 1975 (Jossey-Bass behavioral science series). Available from: https://books.google.co.uk/books?id=afdGAAAAMAAJ

[22] Crist W, Dunn-Vaturi AE, de Voogt A. Ancient Egyptians at Play: Board Games across Borders. London, UK: Bloomsbury Publishing; 2016

[23] Austin RG. Roman board games 1. Greece & Rome. 1934;**4**(10):24-34

[24] Donovan T. It's all a Game: A Short History of Board Games. London, UK: Atlantic Books; 2018. Available from: https://books.google.co.uk/books?id=ceNVDwAAQBAJ

[25] Zagal JP, Nussbaum M, Rosas R. A model to support the design of multiplayer games. Presence: Teleoperators and Virtual Environments. 2000;**9**(5):448-462. DOI: 10.1162/105474600566943

[26] Piette E, Stephenson M, Soemers DJNJ, Browne C. General board game concepts. In: IEEE Conference on Computatonal Intelligence and Games. Copenhagen, Denmark: CIG; 2021

[27] Stenros J, Paavilainen J, Mäyrä F. The Many Faces of Sociability and Social Play in Games. MindTrek 2009 - 13th International Academic MindTrek Conference: Everyday Life in the Ubiquitous Era. New York, US: Association for Computing Machinery (ACM); 2009. pp. 82-89

[28] David FN. Games, Gods and Gambling: The Origins and History of Probability and Statistical Ideas from the Earliest Times to the Newtonian era. New York: Hafner Publishing Company; 1962

[29] Malaby T. Parlaying value: Capital in and beyond virtual worlds. Games and Culture. 2006;**1**(2):141-162

[30] Walsh C, Apperley T. Gaming capital: Rethinking literacy. In: Changing Climates Education for Sustainable Futures in Proceedings of the AARE 2008 International Education Research Conference 30 Nov 4 Dec 2008. Milton Keynes, UK: Open Research Online (ORO). 2009. pp. 1-12

[31] Bourdieu P. Forms of capital. In: Richardson JG, editor. Handbook of

Theory and Research for the Sociology of Education. Westport, Connecticut, US: Greenwood; 1986. pp. 60-74

[32] Banks IM. The Player of Games. London UK: Orbit; 2009. (Culture). Available from: https://books.google.co.uk/books?id=4TtHAQAAQBAJ

[33] Zagal JP, Rick J, Hsi I. Collaborative games: Lessons learned from board games. Simulation and Gaming. 2006;**37**(1):24-40

[34] Heath C, Lehn D v. Interactivity and collaboration: New forms of participation in museums, galleries and science centres. In: Parry R, editor. Museums in a Digital Age Routledge. London: Routledge; 2010 [cited 2015 Mar 3]. Available from: https://books.google.co.uk/books?hl=en&lr=&id=-SBmGtwekr4C&oi=fnd&pg=PA266&dq=new+forms+of+participation+in+museums&ots=sWlXpKDwFH&sig=J2FEM8yhCDR88qPN5C0lfRTs7Gg

[35] Leblanc M, Hunicke R, Zubek R. MDA: A formal approach to game design and game research." In Proceedings of the AAAI Workshop on Challenges in Game AI. Vol. 4. no. 1. Menio Park, US: Association for the Advancement of Artificial Intelligence (AAAI); 2004. p. 1722

[36] Costello B. Play and the Experience of Interactive Art. Sydney: University of New South Wales; 2009. Available from: http://epress.lib.uts.edu.au/dspace/handle/2100/984

[37] Costello B. A pleasure framework. Leonardo. 2007;**40**(4):370-371

[38] Arnheim R. From pleasure to contemplation. The Journal of Aesthetics and Art Criticism. 1993;**51**(2):50-53

[39] Joseph HWB. Life and pleasure. Philosophy. 1945;**20**(76):117-128. Available from: https://www.jstor.org/stable/3748317

[40] Sizer L. The two facets of pleasure. Philosophical Topics. 2013;**41**(1):215-236

[41] Garneau PA. Fourteen Forms of Fun. Gamasutra.com. 2001 [cited 2022 Jul 17]. Available from: http://accad.osu.edu/~pgarrett/730/gamasutra/Gamasutra-Fourteen-Forms-of-Fun.html

[42] Danks M, Goodchild M, Rodriguez-Echavarria K, Arnold DB, Griffiths R. Interactive Storytelling and Gaming Environments for Museums: The Interactive Storytelling Exhibition Project. Technologies for E-Learning and Digital Entertainment. Berlin, Germany: Springer; 2006. pp. 104-115. DOI: 10.1007/978-3-540-73011-8_13

[43] Vitkauskaitė I. Opportunities for innovation adoption in art galleries. European Journal of Interdisciplinary Studies Opportunities. 2016;**8**(02)

[44] Noreikis M, Savela N, Kaakinen M, Xiao Y, Oksanen A. Effects of gamified augmented reality in public spaces. IEEE Access. 2019;**7**:148108-148118

[45] Corallo A, Fortunato L, Renna C, Sarcinella ML, Spennato A, Blasi C d. Mobile app for promoting cultural heritage: Geostatistic and textual analysis. In: MEKO International Conference on Metrology for Archaeology and Cultural Heritage. Lecce, Italy: International Measurement Confederation (IMEKO); 2017. pp. 194-201. Available from: https://www.researchgate.net/publication/324170311_Mobile_app_for_promoting_cultural_heritage_geostatistic_and_textual_analysis/citations

[46] Paliokas I, Patenidis AT, Mitsopoulou EE, Tsita C, Pehlivanides G, Karyati E, et al. A gamified augmented

reality application for digital heritage and tourism. Applied Sciences (Switzerland). 2020;**10**(21):1-18

[47] Liarokapis F, Petridis P, Andrews D, Freitas S d. Multimodal serious games Technologies for Cultural Heritage. In: Al MI, , editors. Mixed Reality and Gamification for Cultural Heritage. New York City: Springer International Publishing; 2017. pp. 371-392. DOI: 10.1007/978-3-319-49607-8

[48] Marques D. The Visitor Experience Using Augmented Reality on Mobile Devices in Museum Exhibitions. Doctoral dissertation, Universidade do Porto (Portugal); 2017

[49] Madsen KM. The gamified museum - a critical literature review and discussion of gamification in museums. In: T. Jensen, O. Ertløv Hansen & CAFR, editor. Gamescope: The Potential for Gamification in Digital and Analogue Places Aalborg. Aalborg: Aalborg Universitetsforlag; 2020. p. 343-354

[50] Scherer KR. What are emotions? And how can they be measured? Social Science Information. 2005;**44**(4):695-729

[51] Martens A, Müller W. Gamification. In: Nakatsu R, Rauterberg M, Ciancarini P. Handbook of Digital Games and Entertainment Technologies. Singapore: Springer; 2017. pp. 909-931

[52] Birchall D, Henson M. High Tea: Evaluation Report. London: Welcome Trust; 2011

[53] Katifori A, Karvounis M, KourtisV,KyriakidiM.CHESS:Personalized Storytelling Experiences. Singapore: ICIDS; 2014. p. 8832. Available from: http://www.chessexperience.eu/v2/publications-and-media/scientific-papers/category/14-2014.html

[54] Vayanou M, Katifori A, Karvounis M, Kourtis V, Kyriakidi M, Roussou M, et al. Authoring Personalized Interactive Museum Stories. Cham: Springer; 2014. pp. 37-48. DOI: 10.1007/978-3-319-12337-0_4

[55] Roussou M, Katifori A. Flow, staging, wayfinding, personalization: Evaluating user experience with Mobile museum narratives. Multimodal Technologies and Interaction. 2018;**2**(2):32. Available from: http://www.mdpi.com/2414-4088/2/2/32

[56] Katifori A, Karvounis M, Kourtis V, Perry S, Roussou M, Ioanidis Y. Applying Interactive Storytelling in Cultural Heritage: Opportunities, Challenges and Lessons Learned. Springer, Cham: Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics.)2018;11318 LNCS(August). pp. 603-612

[57] Jefferies LN. When Space Becomes Interface: Mobile Augmented Reality, Audiences and Engagemtent in Cultural Insitutions. (Doctoral Thesis). Sunderland: University of Sunderland; 2020

[58] Eaton B. If you Go Away. [cited 2022 Apr 6]. Available from: https://invisibleflock.com/portfolio/ifyougoaway/

[59] Dennis AR, Minas RK, Bhagwatwar AP. Sparking creativity: Improving electronic brainstorming with individual cognitive priming. Journal of Management Information Systems. 2013;**29**(4):195-216

[60] Agogué M, Levillain K, Hooge S. Gamification of creativity: Exploring the usefulness of serious games for ideation. Creativity and Innovation Management. 2015;**24**(3):415-429

[61] Roth S, Schneckenberg D, Tsai CW. The ludic drive as innovation driver: Introduction to the gamification of innovation. Creativity and Innovation Management. 2015;**24**(2):300-306

[62] Bilda Z, Edmonds E, Candy L. Designing for creative engagement. Design Studies. 2008;**29**(6):525-540. DOI: 10.1016/j.destud.2008.07.009

[63] Bilda Z, Costello B, Amitani S. Collaborative analysis framework for evaluating interactive art experience. CoDesign. 2006;**2**(4):225-238. DOI: 10.1080/15710880601008026

[64] Schreiber JB, Pekarik AJ, Hanemann N, Doering Z, Lee AJ. Understanding visitor engagement and Behaviors. The Journal of Educational Research. 2013;**106**(6):462-468

[65] Brieber D, Nadal M, Leder H, Rosenberg R. Art in time and space: Context modulates the relation between art experience and viewing time. PloS One. 2014;**9**(6):1-8

[66] Lehn DV, Heath C, Hindmarsh J. Exhibiting interaction: Conduct and collaboration in museums and galleries. Symbolic Interaction. 2001;**24**(2):189-216

[67] Lehn D v, Heath C, Hindmarsh J. Rethinking interactivity: Design for participation in museums and galleries. In: Work, Interaction & Technology. London: Kings College; 2005 [cited 2015 Mar 3]; Available from: http://www.eng.cam.ac.uk/DesignOffice/cmt/resources/pdf/vom_lehnetAl.pdf

[68] Heath C, vom Lehn D, Osborne J. Interaction and interactives: Collaboration and participation with computer-based exhibits. Public Understanding of Science. 2005;**14**:91-101

[69] Dourish, P. Implications for design. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. New York: Association for Computer Machinery (ACM); 2006. pp. 541-550

[70] Dindler C, Iversen OS. Motivation in the Museum - Mediating between Everyday Engagement and Cultural Heritage. In: Proceeding of the Nordes Conference. Oslo: Engaging Artifacts; 2009. pp. 1-10

[71] Edmonds E. The art of interaction. Digital Creativity. 2010;**21**(4):257-264. Available from: http://hdl.handle.net/2086/7909

[72] Nekhvyadovich LI. The Possibilities of Ethnomethodology in modern art studies. In: Terra Sebus: ActaMuseiSabesiensis, Special Issue; Sebeș, Romania: Muzeul Municipal; 2014. pp. 187-199

[73] Stoica A, Fiotakis G, Cabrera JS, Frutos HM, Avouris N, Dinitriadis Y. Usability evaluation of handheld devices: A case study for a museum application. Proceedings PCI. 2005;**2005**:11-15. (e124d2a1-686a-2a3b-46d0-4da7cc526eb2)

[74] Shettel H. How to DEFINE EXHIBIT EFFECTIVENESS ? Curator The Museum Journal. 2001;**44**(4):327-334

[75] Turkle S. Along Together. 2nd ed. London: Basic Books; 2011. p. 496

[76] Graham B. A Study of Audience Relationships with Interactive Computer-Based Visual Artworks in Gallery Settings, through Observation, Art Practice, and Curation. Vol. 0 [Phd, Doctoral Thesis]. Sunderland: University of Sunderland; 1997

[77] Bradbury V. The Performativity of Code in Participatory New Media Artworks. [Doctoral Thesis].

Sunderland: University of Sunderland; 2015

[78] Bradburne JM. Interaction in the Museum: Observing, Supporting, Learning. [Doctoral Thesis]. Amsterdam: University of Amsterdam; 2000

[79] Williamson JR, Williamson J. Understanding Public Evaluation: Quantifying Experimenter Intervention. In: CHI 2017 Conference Proceedings. Denver; 2017. pp. 3414-3425

[80] Williamson J, Sundén D. Deep cover HCI: The ethics of covert research. Interactions. 2016;**23**(3):45-49

[81] Muller E. The Experience of Interactive Art: A Curatorial Study. Sydney: University of Technology; 2008. Available from: https://opus.lib.uts.edu.au/bitstream/10453/21803/1/01Front.pdf

[82] Snelson CL. Qualitative and mixed methods social media research: A review of the literature. International Journal of Qualitative Methods. 2016;**15**(1):1-15

Chapter 3

Research on the Design of Interactive Games of Intangible Cultural Heritage Based on HTML5

Jie Zhou and Ziyi Kong

Abstract

In the context of digitalization, it is particularly effective to export and disseminate cultural content in the way of game interaction. In particular, the emergence of HTML5 new communication carrier is favored by the digital display and dissemination of intangible cultural heritage in a more lightweight way and accepted easily by users. It can not only show difficult and old content, but also add interest and audio-visual interaction through small games. This chapter discusses this topic. Firstly, this chapter analyzes the interactive characteristics of the current functional intangible cultural heritage games applet based on HTML5,and summarizes its technical characteristics. Secondly, it makes a case analysis about the interactive framework of intangible cultural heritage games based on HTML5. Finally, it refines and summarizes the main art design process of HTML5. The chapter is committed to giving full play to the advantages of HTML5-based large user base, convenient communication, and open operation mode, so as to meet the users' experience of intangible cultural heritage and game interactive experience, so as to promote the inheritance of intangible cultural heritage.

Keywords: HTML5, interactive design, Chinese intangible cultural heritage, applet, art design

1. Introduction

All nations and countries have intangible cultural heritage in various forms, which is an exact manifestation of diverse human civilization. In the context of global integration, many intangible cultural heritages are facing many common difficulties in inheritance and development. Network communication is an important way for the popularization and diffusion of intangible cultural heritage, among which HTML5 has become a common style in the digital communication of intangible cultural heritage due to its portability, compatibility, multimedia, and other characteristics [1]. This chapter focuses on the applet of HTML5 and the design practice of China's intangible cultural heritage as the main research theme, hoping to provide a preliminary view for the interactive design of intangible cultural heritage based on HTML5 from the perspectives of type, case, and design process.

2. Basic research of HTML5

2.1 Basic overview of HTML5

HTML5, the fifth-generation hypertext markup language, is the most widely used language on the Internet. HTML5 technology has great advantages in supporting the display of various dynamic effects such as image, sound, video, and animation, which, therefore, is widely used in modern Internet advertising and is referred to as “HTML5” by Chinese people. With the popularity of instant messaging in the recent years, the function of browser has been integrated into WeChat, microblog, and other apps, so that HTML5 pages spread by such terminals can be directly browsed and involved by code scanning. The huge number of users and social attributes provide a convenient platform for the dissemination of HTML5 pages.

From the technical point of view, HTML5 is characterized by easy search, local storage, compatibility, connectivity, multimedia features, etc. It holds more prominent multimedia features than HTML4, shifting the dominance of flash and integrating process audio and video functions to facilitate audio and video processing in the network. Moreover, HTML5 is more effective in 3D effect rendering, which provides technical possibilities for further virtual reality applications.

At present, common HTML5 performance types are Visual, Audio, and Games. Among them, interaction, which integrates visual presentation and interactive behavior, is the most popular, and this kind of HTML5 has a higher focus on user experience. The addition of interaction technology enables users to participate in HTML5, not just passively and simply accept information [2]. The user interaction under the guidance of HTML5 audio-visual promotes the development of them, arousing their emotional resonance and making users willing to forward and share, thus further improving the dissemination scope and effect of HTML5 content.

HTML5 is widely used in information dissemination and brand marketing due to its various characteristics such as short cycle, low investment cost, convenience, easy dissemination, strong interactivity, time-consuming fragmentation, and strong interest. Therefore, HTML5 technology, a representative of new media technology, is combined with intangible cultural heritage, and with the support of multisensory design in vision, hearing, and touch, it contributes to the visualization and active inheritance of intangible cultural heritage culture, gives users a comprehensive experience for cognition, and makes cultural exchange more possible.

2.2 Significance of integrating HTML5 with cultural heritage communication

Intangible cultural heritage is produced in a specific environment and culture. The emergence of digitization provides a new idea for the protection of national cultural heritage. In the past, intangible cultural heritage was widely spread among the elderly in the community. With the development of the Internet, an increasing number of new things have emerged on the Internet. A variety of network resources and foreign cultures attract young netizens and occupy their daily life, resulting in their lack of understanding and interest in their own traditional culture [3]. Therefore, to make the ancient intangible cultural heritage younger and be accepted, recognized, and loved by the public, it is of great importance to cultivate cultural confidence.

The development of new media technology has brought a number of new media, and the change of media has changed the way people understand the world. In the context of mobile Internet, the demand of network audience shifts from active acceptance to participation, from desire to become the disseminator of information to the disseminator of information and from superficial participation to deep participation. Their demand for participation is the driving force for the development of communication technology [1].

In the context of digital media, intangible cultural heritage can be spread in more interesting and diverse forms, especially by using HTML5 technology. Various forms such as animation, interaction, and games can be interspersed in the page, attracting young people to learn about intangible cultural heritage. The increased interactivity reduces the distance between culture and people, which allows users to experience intangible cultural heritage from inside to outside in the new media era from a new perspective, feels the spiritual power contained in intangible cultural heritage, and has a sense of identity with the value behind intangible culture, thereby making intangible cultural heritage more accessible to the younger generation. At the same time, with the help of HTML5 pages of WeChat, microblog, and other terminals, cultural heritage can be rapidly loaded and disseminated online, and its communication scope and channel be effectively improved. The interactivity of HTML5 technology not only makes two-way communication between input and output possible, but also achieves the twice in communication effect with half the effort.

3. Case study on the combination of HTML5 and cultural heritage

3.1 HTML5 visual interactive work “digital provider”

HTML5 “the king’s glory x digital provider program” was jointly launched by Tencent and Dunhuang Research Institute to spread Dunhuang culture and advocate the protection of Dunhuang murals. It has excellent performance in visual design, music and sound effects, interaction, and user experience (**Figure 1**). HTML5 focuses on the disappearing colorful Dunhuang murals that are fading their brilliant colors. The video is slowly unfolded in words, and with the animation of broken and peeling rock walls, it pulls users into the space and time of Dunhuang. Users come to mural selection interface, and then browse and enjoy 10 Dunhuang murals by sliding the screen horizontally, and then re-color and re-produce one of their favorite murals that have lost their color into the most beautiful Dunhuang in everyone’s heart. They may enter their names to generate your own Dunhuang murals after painting and then freely choose to share or donate money for Dunhuang murals, becoming a digital provider and contributing to the protection of murals (**Figure 2**).

This kind of HTML5 focuses on feeling the charm of culture in the viewing process by satisfying users’ audio-visual experience. The key to the success of this case is the appropriate connection between the expression form of creativity and emotion. The first is creativity. By clicking on the interactive form of color for the lost murals, users can achieve a sense of creative achievement in this process and personally feel the beauty of Dunhuang murals. In terms of expression form, the entire HTML5 adopts slow pace and simple tone. The visual design perfectly fits the gravel texture of Dunhuang murals and the traditional color matching of murals, enabling users to have an immersive experience. Secondly, sound and picture are combined in the program. In terms of design, bells and flutes in line with the theme tone are used, which greatly enhances the authenticity and beauty of HTML5 and generates the resonance between users and the disappearing Dunhuang murals.

Figure 1.
Digital provider interactive interface 1.

Figure 2.
Digital provider interactive interface 2.

3.2 Audio HTML5: Quyi

This kind of HTML5 applet mostly outputs and transmits the content in the form of loading video and audio. Quyi is an important category of intangible cultural heritage [4]. The Organizing Committee launched mobile terminal HTML5 in the 2020 national intangible cultural heritage Quyi week, intending to further publicize and popularize Quyi-related knowledge, enhance the visibility of Quyi intangible cultural heritage, and promote its inheritance and development [5].

The background sound Pipa performance "ugly end and Yin beginning" is always accompanied with the opening of the applet. The animation is loaded, and the representative string Pipa patterns and cloud patterns are selected. After entering the main interface, there will be a male and female dulcimer and erhu performance scene. The HTML5 program will spread the folk art knowledge to the public in the form of question and answer. Many knowledge points are assessed by loading audio for the purpose of interactive assessment with the audience. The answer results of all the questions will be presented in the form of different interface sounds, and correct answers and relevant expanded knowledge will be displayed on the screen for knowledge assessment and publicity, achieving the original intention of HTML5 production. In the loading process of specific audio, we should pay attention to intercepting the most representative part of the audio, so that the audience can quickly grasp the key points of audio in the shortest time and make rapid and accurate judgment on specific knowledge points such as musical instruments, playing places, and Quyi categories. At the same time, the audio should also be as realistic as possible to achieve auditory pleasure.

Similar video loading can also be seen in the publicity of intangible cultural heritage activities such as HTML5 Tai Chi and Sending a king ship. This kind of audio loading needs to intercept the activity as part of the essence in a short time, so as to more accurately convey the main characteristics of intangible cultural heritage to the audience.

3.3 HTML5 interactive games: Qwaken the "sense of ceremony" of the spring festival

Leading game companies, represented by Tencent, Netease, and Panax notoginseng mutual entertainment, start from small games and display Chinese traditional culture by combining games and culture. With custom display as the theme, Wake up the "sense of ceremony" HTML5 produced by Sanqi mutual entertainment company adds interactive links to allow players to complete multiple spring festival customs through their own actions (**Figure 3**). Take pasting Spring Festival couplets as an example, players need to select words and fill in the blanks to pull the correct words into the couplet. When these blanks are all filled, the blessing words of the gate will be reversed, and the gate will be opened, which implies "happiness."

The scene connection is embedded with intangible cultural heritage elements to make the interface transformation more smooth and ingenious such as setting off firecrackers and lion dance. The lion will appear after the firecracker burst effect. The red happy lion jumps out from the far right of the picture. You may click to accumulate strength, and the lion can jump up the plum blossom pile one by one, and pull down the hydrangea at the top, so as to pop up the blessing of good luck. The cheerful New Year music and pictures with red as the main tone not only restore the most Chinese New Year flavor, but also incisively and vividly express the sense of ceremony that the whole HTML5 wants to convey.

Similar interactions can also be seen in the publicity of movable-type printing. Wood movable-type printing is one of the main forms of movable-type printing in ancient China after movable-type printing invented by Bi Sheng in the Northern Song Dynasty. At present, it is mainly distributed in Ruian City, Zhejiang Province, but rooted in Chinese clan concepts and a thriving local genealogical culture. It is mainly used for genealogy printing, with strict consistency with ancients skills and very

Figure 3.
Spring Festival H5 game interactive art interface.

exquisite process. In addition to the preparatory work of genealogy opening, audit, and grading in the early stage, its processes include font making, word picking, typesetting, printing, post-production and online binding, which retains both the traditional process of Chinese movable-type printing and the characteristics of thread bound books.

In order to further publicize and popularize Chinese movable-type printing, improve the visibility of ancient printing techniques, and promote their inheritance and development, the Intangible Cultural Heritage Research Institute launched the HTML5 special page on the mobile terminal of "fun to play wooden movable type and send blessings in the new year." HTML5 small game adopts the wooden movable-type font library provided by Dongyuan village, Ruian City. By clicking on the nine-palace grid to extract blessings, users can select words independently and personally experience wooden movable-type printing technology. Users can also enjoy the simple and solemn charm of the old song style in the processes of writing, engraving, picking up, typesetting, and printing. The HTML5 theme makes it possible to enjoy the micro-video of wood movable-type printing taken in Dongyuan village [6].

4. Art design process of intangible cultural heritage applet based on HTML5 technology

4.1 Clarify the design purpose and theme

Firstly, whether HTML5 design communication of intangible cultural heritage is conducted for the purposes of science and education, brand publicity, drainage, or promotion are determined. Tencent's "visit you through the Forbidden City" produced an ancient costume rap HTML5 with the characteristics of ridicule and crossing. The orientation of making traditional culture live, as well as the art style and narrative mode of the whole HTML5, has taken into account the initial appeal. In such a young, popular, and entertaining way, it targets at college students and aims to arouse their attention to traditional culture.

Before design, we should first read a large number of documents, watch documentaries, and conduct necessary field investigations according to the target theme. Intangible cultural heritage activities are mostly a cultural form created based on thousands of years of social production, life practice, and cultural exchange. Behind the complex and elaborate production process of many kinds of intangible cultural heritage is the portrayal of regional culture and human spirit. Therefore, in addition to the essence of production skills, basic knowledge, and performance activities, intangible cultural heritage HTML5 projects should also take into account the multidimensional influence of regional culture and customs, which should be jointly reflected in the design positioning of HTML5.

The innovation of communication forms relies on cultural carriers. The local storage, compatibility, and multimedia features in HTML5 technology can express the living face of intangible culture through various forms of media such as audio, video, and interactive games. Interaction design helps intangible cultural heritage categories convey cultural images, so as to deepen the impression of the audience and improve the communication effect.

4.2 Work conception and determination of artistic style

After the investigation and analysis of environment and theme, we can further determine the final form of HTML5: In terms of form, it can be roughly divided into visual, audio, interactive, game, and other categories. In terms of performance style, it can be divided into real shooting, dynamic illustration, long picture, audio, etc., according to performance object. There are many ways to narrate the script of HTML5, which can be roughly divided into event narration, emotion narration, function narration, science and education narration, game narration, and other different types. The choice and determination of form should be coordinated with technology, art, and copywriting to identify the most appropriate expression method.

After the basic style is determined, the HTML5 project is considered as a whole and the basic framework is drawn up. Generally, it is necessary to introduce the historical origin, production technology, and formal expression of intangible cultural heritage. In addition to the background introduction by using pictures and narration, production technology and display process can be the main content of HTML5. Each scene represents one step. Considering cultural differences and other factors, many users may be exposed to intangible cultural heritage for the first time and lack basic cognition and understanding, making them feel obscure when watching HTML5 and not knowing what to show, and thus affecting the communication effect. Therefore, the design of copywriting and narration is very important in the planning of HTML5. Each scene is equipped with a simple and general narration, which can not only help users understand, but also makes the connection between scenes more coherent, and then improves user experience.

When the whole planning and creativity are focused on special festivals, new forms for festival characteristics can be developed to enrich HTML5. Many intangible cultural heritage HTML5 are executed by shooting video and special effect synthesis. In the design process, appropriate forms of expression should be selected to highlight the content to the greatest extent. When the form is determined, the prototype drawing shall be designed at the same time, which is similar to the mirror splitting script, and can also be understood as the preliminary sketch.

4.3 Visual design

It is necessary to determine art style in the stage of specific design. The designer needs to judge what kind of expression form to use, what tonality to need, what elements to match, and how to match the music and dynamic effect, which requires strong control ability.

Intangible cultural heritage has certain popular science characteristics in the process of reproduction and dissemination. Therefore, from the perspective of visual design, it follows certain objective practical laws. If it has a certain narrative or plot, we need to find the corresponding reference to design the picture, conform to the theme in tonality and content, and find the appropriate soundtrack and sound effect.

In the HTML5 small program of Tibetan medicine mud mask, the author selects the colors with strong contrast and visual expression. In addition, some Tibetan elements are also used in the picture, such as Scripture barrel and prayer flags, which add distinctive regional characteristics to the picture (**Figure 4**). From understanding the small medicine mud mask to understanding the breadth and depth of Tibetan culture, this HTML5 is not only a way to promote a Tibetan skill, but also an opportunity to popularize Tibetan culture [7]. At the same time, these elements can also help the scene to be more coherent and smooth.

In terms of color matching, as the main content follows the traditional bright and exaggerated color matching of Tibetan style (**Figure 5**), in order to highlight the main body, distinguishes primary and secondary, and avoids the adverse experience of visual fatigue caused by watching high saturation colors for a long time, the author selects dark colors such as black, Tibetan blue, and red brown as the background color of HTML5, and appropriately uses materials such as gold thread to outline points and lines to enrich the composition of the picture, and prevent the background from being too monotonous and dull, so as to improve the texture of the whole HTML5.

4.4 Specific interaction or play design

In specific links, users can set levels or playing methods [8]. Generally, its type can be divided into customs clearance, award, selection, sharing, etc. The settings of activity name, activity time, and number of participants can be made in the basic settings of small games. The first, second, and third prizes can be set in the award

Figure 4.
Illustration design of Tibetan cultural elements, by Ziyi Kong.

Figure 5.
Creative illustration performance of medicine mud mask, by Ziyi Kong.

setting. The awards include gifts and coupons. It is particularly suitable for both online and offline activities. The cashing address can also be set for offline activities. Points can be drawn. Award setting, such as product score and winning probability, can be set.

In the winning setting link, in addition to setting the basic lucky draw limit and winning rate, advanced settings assisted by friends are also added. Only after successful sharing and invitation can users get an additional chance of lucky draw, making it easier to achieve activity fission.

In the sharing setting link, in addition to the QR code and links, users can also set up near open screen advertisements and brand advertisements, add pictures and external links, click to view the example effect, and display only the preview on the WeChat. Taking the game “Dragon Boat Race” as an example, users click the left and right buttons in turn to move the dragon boat forward. If they click the wrong button, the dragon boat will not move. The game time is 30 seconds. When the time is up, “time is up” will pop up and the game results will be displayed. Through lottery and interaction, users can finally set up sharing and invite more users.

4.5 Dynamic effect design

With the development of digital media technology, people are no longer satisfied with the visual impact brought by static pictures. The addition of dynamic effect can add interest to HTML5 and improve the overall viewing experience of users. HTML5 project needs a certain time to load materials. Therefore, expressive or transitional pages can be set on the loading page, which can not only attract users’ attention and help them alleviate the boredom and anxiety caused by waiting, but also quickly and intuitively help users make their first impression of non-heritage categories, mobilize users’ curiosity, and lay a foundation for the development of later contents. The dynamic effect of the design mostly serves the whole, highlights the focus of the picture, and makes the picture more vivid and HTML5 more expressive.

In addition, the dynamic effect of shaking of small elements in some scenes can be designed to add interest. There should be a proper number of dynamic effects. Too many dynamic effects will make the screen lack focus and dazzle users. And dynamic effect should not be independent of the picture, but should consider the whole and maintain the overall rhythm of HTML5.

4.6 Sound effect design

The design and creation of HTML5 works mainly focus on vision, hearing, and touch, among which vision and hearing are the easiest to achieve the effect and give feedback of digital screen. However, sound effect design is often ignored in HTML5 creation. The sound effect of HTML5 mainly includes background and auxiliary sound effects. Background sound effect is an important means to lay the emotional tone of the whole HTML5 and create an atmosphere. It needs to be targeted at the theme following the principle of audio-visual consistency. Auxiliary sound effect is a detailed design added according to the needs of the content, which plays a role in setting off the description of the content and can bring users an all-round audio-visual experience.

To sum up, it is necessary to combine the design object and theme, and appropriate rhythm and melody in the sound effect design of HTML5. In terms of auxiliary sound effect, in addition to adding key sound effects in line with tonality, we can also add narration to expand the knowledge of intangible cultural heritage beyond the scene, including the history of specific intangible cultural heritage activities and the spiritual and embodied cultural connotation, which enables users to feel the appeal brought by music and enjoy a more immersive experience when appreciating the exquisite and simple cultural heritage.

4.7 Integration and realization

HTML5 integration can be specifically achieved in two ways. One is by code. The prepared layered map, including PSD file, PNG cut, appropriate file, MP3 audio, and video file, is packaged to the front-end engineer. The engineer places these contents on the server and combines the elements into HTML5 web page by code editing. After the code editing is completed and tested, the whole HTML5 web page will be pushed to the Internet. The other is codeless implementation. At present, there are a large number of HTML5 page generation tools on the Internet, most of which appear in the form of Web sites, and are named as third-party platforms, which provide assistance for designers without front-end resources. The designed materials can be uploaded to the server of the third-party platform for editing and publishing. The disadvantage of such platform includes single function and limited effect, while the HTML5 page generated by engineers can be customized.

5. Follow-up work

In terms of publicity channels, WeChat official account and short video can be combined online to improve the initiative and convenience of users' browsing. In addition, the jump feature of HTML5 allows users to not only browse the intangible cultural information of the current HTML5 page, but also jump to other pages according to the prompts, so as to learn more relevant information [9]. Therefore, online and offline links can also be adopted to cooperate with local museums to develop relevant cultural and creative products and build local cultural brands. And small e-commerce programs can be connected to broaden product sales channels, and promote regional economic development to a certain extent.

At present, trendy cards and trendy toys are deeply loved by young people. Cross-border cooperation and joint branding between intangible cultural heritage culture and such fields is an effective means to quickly promote ancient culture among young groups, and the form of HTML5 is also very consistent with the "trendy" concept of these brands. It can be used as a means of publicity to promote goods and make the consumption behavior of the audience accompanied by cultural communication.

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References

[1] ya Z, Xin X. A review of the research on the digitization of intangible cultural heritage. Library and Information Work. 2017;**61**(02):6-15

[2] Shen J, Jian W, Rui J. Application of interactive technology in digital popularization of intangible cultural heritage. Science and Technology Communication. 2021;**13**(01):81-83

[3] Yaqing T, Jie Z. Practice and breakthrough of HTML5 technology in cultural heritage communication. Art Research. 2020;**04**:92-93

[4] yanru LV, Li Z. Innovative application of new media technology in digital display of intangible cultural heritage. Packaging Engineering. 2016;**37**(10): 26-30 + 10

[5] Available from: https://mp.weixin.qq.com/s/660-Nch0gF-eBjpSqdaapQ. [Accessed: April 21, 2022]

[6] Available from: https://mp.weixin.qq.com/s/h_7aChTotGn5cR9aBWlF4A [Accessed: April 21, 2022]

[7] Fan W. Model text religious connotation and aesthetic intention of Tibetan mask. Sichuan Drama. 2005;**05**:51-52

[8] Liping L. Research on new year picture website design based on HTML5. Satellite TV and Broadband Multimedia. 2019;(17):46-47

[9] Xin D. On the role of H5 in the publicity of intangible cultural heritage. Art and Technology. 2018;**31**(06):93

Chapter 4

A Usability Analysis of the DAO Concept Based on the Case Study of a Blockchain Game

Lars Karbach, Moritz Korte, Nils Orbat, Daniel Muschiol and Marc Jansen

Abstract

Games based on a blockchain exist in all variants and facets, mostly as single- or multiplayer games. This chapter deals with the implementation of a multiplayer strategy game (Connect Four), using blockchain technology for decentralized data storage and the entire game logic. The focus is on the use of the decentralized autonomous organization (DAO) principle, for coordination and voting within the teams. The chosen game just stands as an example; other games or gamification approaches in which users can take decisions collaboratively can be used here. A web application was implemented acting as a central interface between players and the blockchain. Hence, it was possible for players to compete against each other in teams and to collectively decide the next move by participating in a roundly voting. With the help of a standardized questionnaire, answered by each player after each match, possible impacts of the voting mechanism on the usability were determined.

Keywords: decentralized autonomous organization (DAO), blockchain, blockchain gaming, system usability scale (SUS) score, usability.

1. Introduction

In 2008, the white paper for peer-to-peer payments was published by Satoshi-Nakamoto [1]. Various blockchains have been developed since then and are always discussed as *financial innovation*. Besides the FinTech aspect, however, there are also other possible purposes.

As Vitalik Buterin described in 2014, blockchains can also serve as decentralized autonomous organizations (DAOs) [2]. DAO refers to an association of like-minded members who control and manage it. A DAO is based on a set of rules in which the basic rules of the organization and its financial management are defined. Once this set of rules—for example, in the form of a smart contract via a blockchain—has been made accessible to members, these publicly visible rules can no longer be changed, except by a vote of the members [2].

A DAO is, therefore, not controlled by a central authority, but by the member collective itself. It can, for example, be a donation organization in which the donors can vote on to whom the collected sum should be donated. Voting can be viewed in a similar way to stock corporations. The weighting of the votes depends on the amount of money previously paid in. The voting can be executed via the so-called governance tokens [3].

The goal of this thesis is the investigation and implementation of a multiplayer game based on the DAO principle. The main idea is that a collective of players makes decisions together. Using the example of "Connect Four," in which two teams with any number of players compete against each other, the next move of each team is decided democratically by voting using governance tokens.

To add excitement to the game, the winning team should be rewarded with the deposits (governance tokens) of the opposing team at the end of a match. A key aspect to consider when implementing such a community game is that a game is chosen where all the moves can be made public and there is no need for additional encryption of data on the blockchain. This is deliberately chosen so that the focus of this work is only on the implementation of the community game and more complex problems regarding data encryption are avoided, which could affect the implementation of the project in terms of time or even prevent it. The game "Connect Four" fulfills these requirements and is, therefore, a suitable candidate for this elaboration. Another challenge is to implement the game in a completely decentralized way so that all the calculations, data transformations, and game moves can be publicly viewed via the blockchain at any time, thus ruling out any manipulation of the game flow. Another key aspect to consider when implementing such a community game is whether both the specific nature of decision-making and the use of a blockchain can lead to unforeseen problems in the game flow for the participating players. Therefore, the research question can be described as follows:

RQ: What difficulties arise with regard to the usability of the game due to the use of the DAO principle and how do they affect the players' experience?

To answer this question, a *webapp* will be developed, which implements the multiplayer game and communicates with the blockchain. Blockchain applications offer the advantage of creating pseudoanonymity between participants. More precisely, this means that although all the transactions and rules are visible within the blockchain, the transaction partners are anonymized by unique keys [1]. In this way, a blockchain offers a high level of transparency and, at the same time, a high level of anonymity [4].

This work is divided into four parts. In addition to related work and the architecture of the decentralized application (in short: dApp), the implementation and a subsequent evaluation are described. There, the usability of the application is evaluated and discussed by using a questionnaire. A conclusion and an outlook conclude this work.

2. Related work

Games based on blockchains, such as Bitcoin or Ethereum, are already popular today and do not represent a novelty. They are particularly popular because their rules are stored within the blockchain and are, therefore, transparent for all the participants [5]. There is a distinction between fully decentralized implemented games and a traditional game design approach paired with blockchain technology [6]. The former is characterized by a simple game structure, with clear rules and low complexity. An example is the game *CryptoKitties* [7]. A hybrid approach is often used, consisting of a combination of traditional methods and the blockchain.

As described earlier, the DAO approach is not a fundamental innovation within the blockchain environment (see Section 1). For example, Soichiro Takagi describes numerous use cases for DAOs in 2017. Among them are approaches such as *Arcade City*[1] (a ride-sharing platform), *Open Bazaar*[2] (an e-commerce platform), and *The DAO*, which is an investment fund that invests in various companies while letting shareholders (DAO token holders) participate in votings [8]. *The DAO* has since been discontinued due to security vulnerabilities and the resulting loss of trust toward the DAO [9].

At the time of writing, no references to a game that uses the DAO principle as a central game feature could be found; therefore, it can be assumed that the influence of the DAO principle on usability has not been investigated so far. Thus, this relation represents an innovation within blockchain games as well as a clear differentiation from other papers.

3. Architecture

For the implementation of a DAO game based on a blockchain, several components are needed, which are described below. As shown in **Figure 1**, the user first communicates with a web server to obtain the required static files that provide the presentation logic in the browser. The business logic is split into three different dApps on the Waves blockchain.

3.1 Web application

All the files implementing the presentational logic are delivered via a static web server. To maintain a fully decentralized approach, no business logic is implemented at this point.

This strategy allows a fully decentralized implementation of the game, but can be extended for new platforms, such as iOS or Android, if needed.

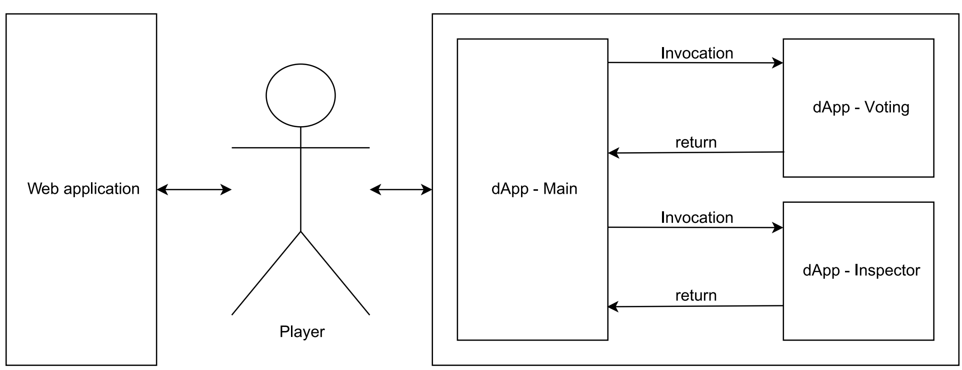

Figure 1.
Architecture of the DAO game.

[1] https://arcade.city/
[2] https://openbazaar.org/

3.2 Blockchain

Since low transaction fees and fast processing speed of business logic are the primary concerns when implementing a multiplayer game, the Waves blockchain was chosen, which offers significantly shorter confirmation times and lower transaction fees than conventional blockchains, such as Ethereum or Bitcoin.[3]

Each dApp may have a maximum script complexity of 10,000 and script size of 32,768 bytes.[4] For this reason, the business logic was divided into three different dApps.

3.2.1 dApp - main

The Main dApp acts as a unified interface and persistent data store. To perform an action within the game, players must communicate directly with this dApp. Each time the dApp is called, various checks are performed to verify the correctness of the request.

3.2.2 dApp - voting

The Voting dApp is called exclusively from the Main dApp and calculates the final result of the current round based on all votes that have been submitted. If there is no clear result, the first vote submitted will be used to decide which move will be made for the respective team.

The result of the calculation is then transferred and written to the data storage of the Main dApp.

3.2.3 dApp - inspector

The Inspector dApp is called by the Main dApp at each completed turn and then checks whether a team has fulfilled all criteria for a win or whether a draw has occurred. The result is also transferred and written to the Main dApp's data store.

4. Implementation

Owing to the decentralized implementation of the game, different problems arise within the individual components. This section will give a general overview of the implementation and will address particular problems that occurred during the implementation.

4.1 Web application

The following section will mainly address the frameworks used for implementing the user interface (see **Figure 2**).

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[3] https://docs.waves.tech/en/blockchain/waves-protocol/waves-ng-protocol (13.02.2022)

[4] https://docs.waves.tech/en/ride/limits/ (13.02.2022)

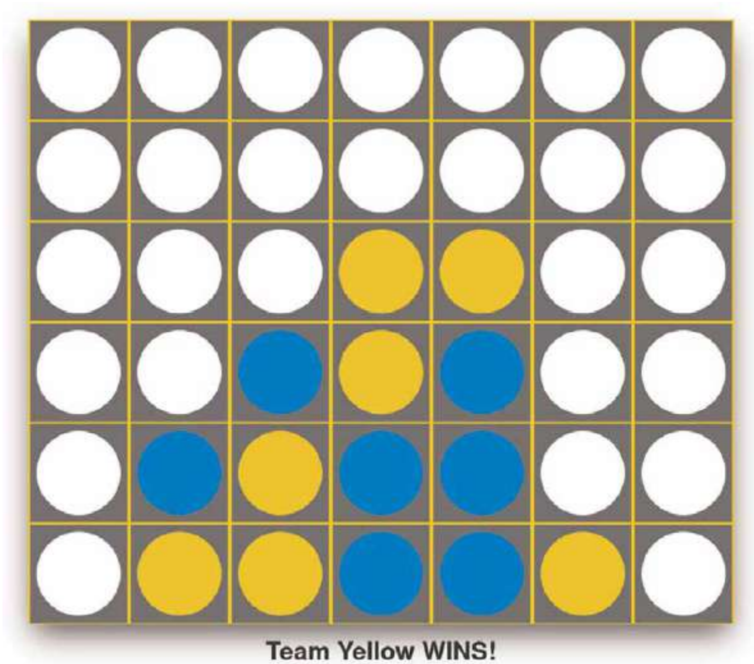

Figure 2.
User interface.

4.1.1 Next.Js

Since a game based on modern browser technologies requires a very dynamic display logic, the Next.js framework was used for this specific use case. With the aid of this framework, the implementation of very dynamic and interaction-intensive user interfaces can be greatly simplified. To ensure that each player always has a current state, the current game state is regularly queried via the Waves Node REST API and transferred to the player's local cache. Next.js displays the current game board based on this data.

4.1.2 Waves-transactions

For the interaction of the individual players with the game, the library "waves-transactions" is used. With the help of this library, transactions to the Waves blockchain can be created and signed in the browser.

4.2 Blockchain

This section covers the specifics of the Waves blockchain. A special focus lies on the problems of the individual dApps. It is noticeable that there were frequent problems with control structures such as loops during the implementation. Since Ride is not Turing-complete, some steps within the game logic had to be implemented in a completely different way. The following section will give an insight into some of these problems.

4.2.1 dApp - main

Since there is no way to perform event- or time-based actions on a blockchain, a mechanism had to be developed to determine if a team had exceeded the maximum allowed round duration.

To do this, each transaction, regardless of which team it came from, was checked to see if the team currently taking its turn had taken longer than the current block height + 5 blocks (1 minute per block). If this is the case, the current team's turn will automatically end as soon as a player from the other team makes a new transaction. The user interface calculates these values in real time and automatically indicates to the waiting team that it may now vote again if the other team timed out.

4.2.2 dApp - voting

The Voting dApp must calculate how many times a single field has been voted for each players submitted vote. This is problematic because Ride does not implement a native counting function.

First, all votes are collected in a single entry in the data store with the following format: "walletId_fieldNumber, walletId_fieldNumber." After all players have voted, the previously generated entry is split by the delimiters "," and "_" into a new list containing only the voted field numbers. Up to this point, it has not been necessary to use a loop, since Ride provides native functions for splitting strings. Since the new list can only be as large as the number of players, the FOLD function can be used to determine which field got the most votes. This value is returned to the Main dApp after the calculation.

4.2.3 dApp - inspector

The inspector must check at each completed turn whether a team has won the game or whether it has come to a draw. In doing so, he must examine the entire board for the previously defined victory conditions. As soon as there is a sequence of four game tokens from the same team on the board, the team has won the game.

To realize this requirement, the entire board is split into a multidimensional array (seven rows, six columns). This array is then traversed with two nested FOLD functions, and it is checked on a horizontal, vertical, and diagonal levels whether a team has won or whether there is a draw. For this purpose, each of these conditions is checked using index queries. By using index queries, the need for an algorithm that is entirely based on loops is eliminated and, thus, can be implemented in Ride.

5. Evaluation

This section presents the evaluation strategy and explains how it will be conducted. Subsequently, the research results are presented and discussed.

5.1 Evaluation strategy

Typically, the usability for human-technology interaction is described by means of ISO 9241-11 [10]. Since this is difficult or poorly measurable, the system usability scale questionnaire (short *SUS*) is used to answer the question of whether the DAO principle has an impact on usability [11, 12]. This questionnaire was provided to each user in the follow-up of each game.

Each participant was asked to state whether the DAO principle had an impact on usability and if so, what that impact was. For this purpose, a mixture of quantitative (Likert scale of the SUS questionnaire incl. SUS score) and qualitative (free text fields for a question) questions had to be answered within the questionnaire.

After all participants had completed the questionnaire, the questionnaire was evaluated descriptively in order to be able to measure the influence. The qualitative statements were evaluated and presented by a quantitative content analysis (SUS score for usability classification).

The results of this survey will be discussed within the upcoming sections after the successful completion of the statistical analysis.

5.2 Results

The following section will describe, evaluate, and then discuss the results of the evaluation. In the period from January 31, 2022 to February 13, 2022, the questionnaire was answered. Within this period, 42 persons answered the questionnaire, of which 34 were male and 8 were female. Twenty-seven of the 42 respondents were under the age of 30; the remaining were evenly distributed up to the age of 64. Approximately 83% of the respondents had at least a general qualification for university entrance (e.g., A-level).

The SUS score is determined from all the answers given in the questionnaire and is intended to provide a quick overview on the usability of the project. Its reliability, measured in the Cronbach's alpha, is 0.92 (out of a maximum of 1). This means that the questionnaire has a very high reliability and, thus, fulfills one of the most important quality criteria that a questionnaire must fulfill [11, 13]. Questions are asked about the ease of use, the feeling of security, the complexity of the application, and the need for any support during use. The SUS score is a number that can have a value between 0 and 100. Basically, the higher this value, the better the usability. As shown in **Figure 3**, all values smaller than 50 are to be considered as *awful*. From 68 onwards, usability is considered *okay*. Everything else after that is rated as *good* or *excellent*. In this work, a score of 70 could be achieved. Thus, the usability of the *Connect Four* game can be rated as *good*. In addition to the questionnaire for the SUS score, free text fields were also evaluated. For example, 17 of the 42 respondents stated that they liked playing as a team. Likewise, the fun of the game (12 out of 42) as well as the design (four out of 42), the handling (four out of 42), and the low requirements for participation (one out of 42) in the game were explicitly emphasized. Four people did not provide any further information.

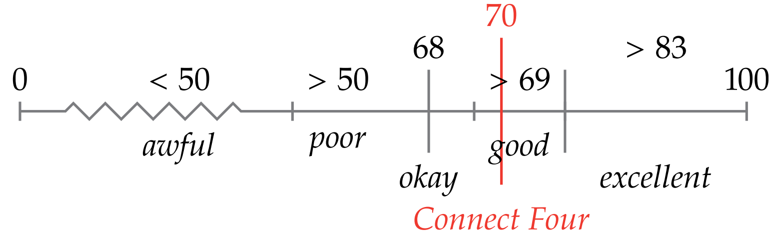

Figure 3.
SUS score.

Thirty-four people used the free text fields to indicate what could be improved. It is striking that 16 of the 42 people found the long delay after placing a vote to be annoying. Communication within the teams (two out of 42) and the design (seven out of 42) and the cryptic user names (six out of 42) were also rated as poor. Three people found playing in teams to be not good and would have liked to play on their own.

5.3 Discussion

As the results show, the DAO concept can be integrated very well into games that are based on a blockchain. Thus, the application was able to achieve an SUS score of 70 points and can be considered good, as already described. The score is comparable to the Facebook app for iOS from 2018, as described in [14]. Many of the respondents stated that the collaborative decision-making approach had been the most exciting and fun aspect.

The evaluation of the free text fields shows that there is potential for improving usability in the way communication is handled within the teams. A chat could satisfy this need and make the game more fun. Likewise, assigning user names would simplify the identification of players. As a result, the SUS score can be sustainably improved after the implementation of these functions. Since the game has been implemented almost entirely in a decentralized manner, as described in Sections 3 and 4, the long waiting times after a vote has been submitted cannot be prevented or can only be prevented with difficulty. This is because the performance of the game correlates with the performance of the blockchain.

When evaluating this application, it should always be kept in mind that it is a minimum viable product (MVP) whose goal has only been to investigate the DAO concept with regard to the usability of a game.

Moreover, as described in Section 5.1, the population of respondents consisted of known individuals. Similarly, the number of respondents was so small, 42, that the representativeness of the quantitative survey could be questioned. In addition to the size of the population, the homogeneity of the group may also have played a role. As described, it consisted mostly of people who were under the age of 30 and male. All these factors could have contributed to the good SUS score. Thus, it is not possible to clearly assess whether the created application could achieve an SUS score of 70 with a different constellation of respondents.

6. Conclusion and outlook

Based on the previously described sections, both a conclusion and an outlook are now presented. A description is given of how the application could be further developed and also which difficulties might have to be expected.

6.1 Conclusion

The goal of this work was to create a blockchain-based game that uses the DAO concept as a central element. The aim was to investigate the influence of the DAO concept on the usability of the game. For this purpose, the game was implemented in a fully decentralized way using the Waves blockchain. Based on a survey of the players, it was found that the DAO concept has an influence on usability that can be considered positive. The game achieved an SUS score of 70 points, which can be classified as *good*. Likewise, it was stated within the free text fields that the game, which is typically played as a two-person strategy game, definitely has potential with its multiplayer approach. It remains questionable whether the game would achieve a consistent score with a different group of players. The group of people surveyed was very homogeneous and known to the authors of this work. Nevertheless, it can ultimately be stated that the DAO concept has a positive influence on the gaming experience.

6.2 Outlook

The causal relationship of the DAO concept on the usability of games was answered within this manuscript. The game selected for this purpose has the property that all information is always available to all the players. Since all information is always on the blockchain, visible to all, the DAO concept cannot be applied to games such as *sink ships* or *hangman* without endangering *cheat safeness*.

It is, therefore, necessary to investigate which properties these games must fulfill, especially with regard to aspects of security, respectively, the encryption of data, so that they can be implemented in a practical way. This aspect is particularly important because, as described in Section 1, the winning team receives the stake of the opposing team.

Other areas of application for the DAO are also to be investigated. Can entire elections for municipalities, states, and the federal government be implemented via a DAO without the possibility of election manipulation? For this, the performance of the blockchain and the guarantee of voter anonymity must be carefully investigated. It, therefore, remains to be seen how and in what form the DAO principle will be used in the future.

Abbreviations

DAO	Decentralized autonomous organization
dApp	Decentralized application
SUS	System Usability Scale
MVP	Minimum viable product

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References

[1] Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System. 2009. Available from: http://www.bitcoin.org/bitcoin.pdf

[2] Buterin V et al. A next-generation smart contract and decentralized application platform. White Paper. 2014; **3**(37)

[3] ethereum org. Decentralized autonomous organizations (DAOs). 2021. Available from: https://ethereum.org/en/dao/

[4] Redaktion. Blockchain und Datenschutz. Informatik Spektrum. 2018;**41**(2):144-153. DOI: 10.1007/s00287-018-1099-9

[5] Min T, Wang H, Guo Y, Cai W. Blockchain games: A survey. In: 2019 IEEE Conference on Games (CoG). London, United Kingdom: IEEE; 2019

[6] Du M, Chen Q, Liu L, Ma X. A Blockchain-based random number generation algorithm and the application in Blockchain games. In: 2019 IEEE International Conference on Systems, Man and Cybernetics (SMC). IEEE; 2019. pp. 3498-3503. Available from: https://www.semanticscholar.org/paper/A-Blockchain-based-Random-Number-Generation-and-the-Du-Chen/eee3f781cb62c64066776f428c80272ca1f6d89e

[7] Chohan UW. The Leisures of Blockchains: Exploratory analysis. SSRN Electronic Journal. December 4, 2017. Available at SSRN: https://ssrn.com/abstract=3084411. DOI: 10.2139/ssrn.3084411

[8] Takagi S. Organizational impact of blockchain through decentralized autonomous organizations. International Journal of Economic Policy Studies. 2017;**12**(1):22-41

[9] Ragnedda M, Destefanis G. Blockchain and Web 3.0 - Social, Economic, and Technological Challenges. New York: Routledge; 2019

[10] Standardization IOF. ISO 9241-11 - Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs): Part 11: Guidance on Usability. Berlin: ISO; 1998

[11] Bangor A, Kortum PT, Miller JT. An empirical evaluation of the system usability scale. Journal of Human–Computer Interaction. 2008;**24**(6): 574-594. Available from: http://dblp.uni-trier.de/db/journals/ijhci/ijhci24.html#BangorKM08

[12] Brooke J. "SUS-A Quick and Dirty Usability Scale." Usability Evaluation in Industry. CRC Press; 1996. Available from: https://www.bibsonomy.org/bibtex/222828ba84252e85947031f087684d9fb/dzeneralen. ISBN: 9780748404605

[13] Kreutzer R. Praxisorientiertes Marketing: Grundlagen-Instrumente-Fallbeispiele. Gabler. 2022

[14] Calısır F. Industrial Engineering in the Big Data Era: Selected Papers from the Global Joint Conference on Industrial Engineering and its Application Areas, GJCIE 2018, June 21–22, 2018, Nevsehir, Turkey. Cham, Switzerland: Springer; 2019

Section 2

Gamification and Learning

Chapter 5

Activity Based Learning (ABL) Using Gamification (GBL) in Mechanical Engineering Design Education: A Studio-Based Case Study

Mike Mavromihales and Violeta Holmes

Abstract

In our research, we aim to introduce Game-based learning (GBL) activity as part of a holistic approach to supporting knowledge acquisition within a Mechanical Design module. Our case study evaluates Activity Based Learning (ABL) by use of GBL as a tool to drive collaborative student learning. The activity described targets students' ability to engage in hands-on practical collaborative learning, utilising existing skills in order to collectively share and reinforce knowledge. It relies on knowledge acquired from several subject topics thus consolidating applications through a studio-based activity in the form of a game bringing about its own benefits in teaching and learning. Widely used in a range of subjects, the application of GBL in Engineering and Technology and its effectiveness is less explored and reported as a learning tool in Engineering education. We present an approach to underpinning engineering education as part of a studio-based activity for Mechanical Engineering Design. We explore the options and potential for collaborative learning whilst offering students the opportunity to compete with peer teams for ranked positions on a leader board. We report on the level of student engagement and the extent to which learning outcomes were met through the introduction of such an activity.

Keywords: game based learning (GBL), activity based learning (ABL), group collaboration in learning, team based learning, game design

1. Introduction

With a significant rise in published work on the subject of gamification for the enhancement of teaching and learning in engineering education [1, 2], a number of question remain open. These concern the effectiveness of such methods with a distinct lack of empirical evidence [3] on the value of such games. The potential for such ABL can span over several positive facets including

- Collaborative learning
- Games Based Learning with all the spin-off benefits [4]
- Improved engagement and participation
- A holistic approach to consolidating subject area curriculum/knowledge and is referred to as Integrated Concurrent Engineering Education (ICEE)

In order to evaluate the effectiveness of Activity Based Learning in Mechanical Design a Game has been designed and incorporated as part of an intermediate module delivery (year 2 of engineering undergraduate study) on a BEng Mechanical Engineering course. The aim of the game is to partly fulfil the learning outcomes of a module in Mechanical Design whilst also reinforcing prior knowledge in associated topics such materials and process selection and detailed design.

In this paper we report on the outcomes of conducting such an activity based on direct feedback from students along with their level of engagement and participation. We shall also explore possible improvements for furthering the outcomes in ABL particularly in Collaborative learning as part of group work.

There were three module learning outcomes that we aim to fulfil through the application of this ABL activity and these are as follows:

- Abilities in graphical communication and possess an intermediate understanding of the design process.
- To identify key areas of product design analysis and choose appropriate methods for their solution in a considered manner (cognitive and intellectual skill)
- To select and use a range of communication methods appropriate to the product design analysis

2. Facilitating the activity within the curriculum

Mechanical Design is a core module for undergraduates in Engineering and Technology studies. Reinforcing engineering scientific principles and elements of design through the application of studio based design projects has long been recognised and acknowledged as an effective means of achieving higher order cognitive thinking in mechanical engineering education [5].

Several core modules precede the Mechanical Design module that form a fundamental part of the curriculum for the Mechanical Engineering Bachelor's Degree at the University where this cases study was conducted. The content of these modules is interlinked through theory and application in which the theory is reinforced by application. The modules used as examples and detailed in this paper intend to demonstrate how Activity Based Learning (ABL) and Game-Based Learning (GBL), in a group context (Team-Based Learning or TBL), could improve the learner experience during intermediate modules (studied mid-way through a program of undergraduate study) delivery. All modules will be defined in terms of content and learning outcomes and the way in which the content of these modules interlink will be clarified. The three modules to which reference will be made for the application of ABL, GBL, and TBL are:

- Manufacturing Technology
- Engineering Communications and Materials
- Mechanical Design

The profiles of undergraduates that join the Bachelor's Degree are of diverse educational and training backgrounds which can vary from school leavers with GCSE (General Certificate of Secondary Education) Advanced level subjects, international school leaving certificates/diplomas or baccalaureate to mature apprentice trained or experienced students. GCSE Advanced level subjects are the common route of entry by UK school leavers, into university undergraduate courses.

Mechanical Design as a formal module in Mechanical Engineering undergraduates programs is usually introduced at the intermediate level once students have acquired prior knowledge in subjects such as graphical communication and use of Computer-Aided Design (CAD), materials, manufacturing processes and engineering science and analysis. The dilemma that many engineering educationalists are faced with is that too often students regard these subjects in isolation. Once they have met the learning outcomes of each and have passed the subjects at different stages of study, the context is lost. This is why engineering education is often labelled as being too linear. Any thought of application becomes vague. Design aims at bringing together the application science-based subjects through an initial process of synthesis. This requires a systematic approach or disciplined method of thought through which the creator creates, analyses, and eliminates solutions prior to embarking in the detail. This process is referred to as the design methodology. As an initial part of the module, students are encouraged to practice by following through the design methodology process. It is a pursuit that challenges their creativity using analytical abilities. It is a complex process where extensive relationships need to be sub-divided into a series of simple tasks. The complexity of the process requires a sequence in which ideas are introduced and iterated.

Students usually embrace this process even though some struggle to systematically and methodically follow it.

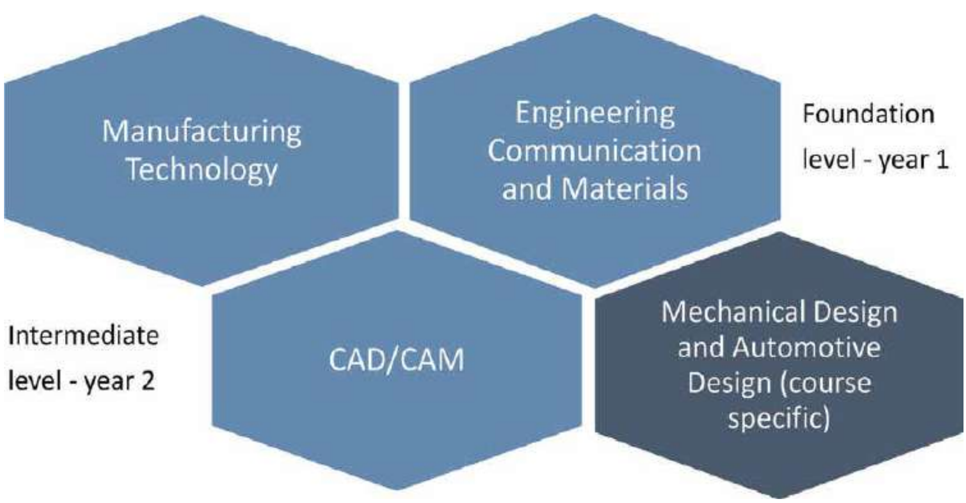

Figure 1.
Positioning and timing of various modules for embellishing student knowledge for design application.

In the later part of the module, students are expected to consolidate prior knowledge and apply it in the detailing stage. For this, they need to consider detail such as concise and unambiguous graphical representation, design for manufacture and assembly, materials selection and design validation though analysis.

It is through such a consolidation process that it becomes evident how past knowledge is either forgotten, overlooked or sporadic.

The aim of the activity is therefore to prompt learners on how prior knowledge is applied through examples in which they are assisted by collaboration with peers and guidance of the tutor whose role is as facilitator. **Figure 1** indicates where the activity is positioned in relation to knowledge gained in other modules.

3. Key research questions and outcomes

Several questions were posed prior to, during and after the Activity Based Learning Activity. Guidelines for good practice in both ABL and GBL were followed [4]. The research questions to be addressed were aimed at establishing the following:

- Were students applying knowledge gained from formal didactic delivery sessions leading to the activity and was knowledge reinforced partly through collaboration with their peers?
- What were the motivating factors driving the students to perform better than their peers in the activity?
- Which students had performed better and why?
- How do students overcome gaps in knowledge through application of other skill sets and collaborative learning?
- Had collaboration enhanced or hindered certain participants and why?
- Did the activity serve as an effective means of formative self-assessment, to gauge the standards of students against their peers?
- Was the activity enjoyable and was attainment improved as a result?
- Would the activity lead to improved performance in assessment?

4. The challenge and motivation of this work

The challenge and motivation of this work lie in educating undergraduates and enabling them to think outside their traditional engineering subjects by applying knowledge in a more practical manner. The approach is a holistic one in that it links prior knowledge by bringing it together to be encompassed and applied in examples as part of a GBL challenge. The activity was intended to trigger learners' inquisition as to how and why a wide range of engineering artefacts are designed and made in a certain way. Inquisition is a great tool for acquiring wider knowledge and the activity was partly intended to inspire learners to do this by firstly undertaking this collaboratively as part of GBL.

A further challenge lay in providing a thoroughly 'robust' education to engineering undergraduates in order to equip them with the knowledge and skills to apply in a 'real world' environment. In order to achieve this, motivation and engagement are key. By facilitating them with the appropriate blend of teaching and learning techniques such motivation and engagement could be achieved and evaluated through both metrics and qualitative results.

5. Consolidation of prior learning leading to the activity

The activity was designed to integrate prior knowledge from several modules through collaboration amongst learners. The learning outcomes for each of the modules were as follows:

- Manufacturing Technology—knowledge and understanding

- Understand a range of the processes required for the manufacture of engineered products.

- Engineering Communications and Materials—knowledge, understanding and abilities

    1. Have a working knowledge of 2D draughting in BS 8888 by both manual methods and using a standard CAD package and a basic working knowledge of 3D CAD.

    2. Understand and use common engineering vocabulary and terminology.

    3. Appreciate the differences in the basic mechanical properties of materials and basic strengthening mechanisms for metals.

    4. Make informed decisions on the selection of materials.

    5. Design a basic engineering artefact including the selection and use of common engineering components and materials and to create engineering drawings which could be used for its successful manufacture.

- Mechanical design—knowledge, understanding and abilities

    1. To understand the design decisions taken by others by studying existing products.

    2. Possess the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.

    3. Be able to use creativity to establish innovative solutions and represent those solutions in the form of 3D and technical drawings whilst demonstrating the ability to select a number of bought-out parts.

4. Ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include production, operation and an awareness of the product's eventual environmentally sensitive disposal.

5. Develop the ability to work in a team, understand design management issues and evaluate outcomes.

6. Structure of delivery of Mechanical Design and rationale.

Mechanical design as a formally delivered module on the BEng Mechanical Engineering course in an intermediate subject delivered in year 2. This is because students require certain prerequisite knowledge and skills prior to embarking on a design process and ultimately communicating a carefully considered solution with validation. Included in prior learning are skills such as effective graphical communication using both manual (technical and creative) illustrations as well as tools such as 3-dimensional (3D) Computer-Aided Design (CAD). They must be able to refer to and apply relevant Technical Drawing skills in accordance with standards such as those that relate to technical representation of engineering components. They must be aware of how to validate a design through appropriate analysis using correct procedure, for instance, the selection of a simple rolling element bearing or the analysis of a structural member using the Finite Element Analysis (FEA) method. Awareness of available materials and the production methods used to process these is also an important aspect of design for manufacture. With such skills and knowledge gained through prior learning, learners are able to apply and extend their depth of cognition [5] through design synthesis. The Mechanical Design module at intermediate level offers learners the opportunity to further hone their learning and understanding of the detailed design process once they have been guided through the creative design phase. This is achieved by means of a combination of lectures and by examining existing products in order to attempt the early stages of the design process in assignment work. The complete process will lead them from the conceptual stage to the final engineering design which will be represented by technical engineering drawings. The process may commence from identifying a need for a product through concept to detail design for manufacture.

Students are assessed on the following criteria:

- Further exploration of design options making systematic step by step decisions based on the application of morphological charts

- Concept to reality conversion

- Detailed product definition through technical graphics

- Consideration to and appropriateness of manufacturing processes

- Consideration of materials and selection of suitable materials based on a process of elimination

- Design evaluation through the application of tools such as calculations, including stress simulation

Learning Outcomes of the Mechanical Design Module.
Evidence is sought through five key learning outcomes:

a. To understand the design decisions taken by others by studying existing products and ability to apply the methodology to their own design challenges.

b. Possess the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.

c. Be able to creatively establish innovative solutions and represent those solutions in the form of 3D and technical drawings whilst demonstrating the ability to select a number of bought-out parts.

d. Ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include production, operation and an awareness of the product's eventual environmentally sensitive disposal.

e. Develop the ability to work in a team, understand design management issues and evaluate outcomes.

6. Related work

Two clusters of collaborative learning are identified [6] which are of practical value to teaching and learning facilitators. Credible alternatives, such as well-designed whole class instruction are evaluated in one of Ross's clusters. Other studies have demonstrated that collaborative instructional methods lead to cognitive and affective gains for students at different levels, including undergraduate and postgraduate levels [4, 7]. Such studies have confirmed that different collaborative structures have different effects.

It has also been recognised that there are amplifying and suppressing factors in collaborative learning which would render them ineffective for certain learners. Low ability learners with poor social or interaction skills form a good example. In our case the experimental group consisted of mature and motivated undergraduate learners. It can therefore be safely assumed that the poor social or interaction skills did not hinder their learning. All learners possessed good communication skills which was evident from their interaction within particular smaller social groups to which they gravitated.

The other cluster of collaborative learning research, which is useful to educators, focusses on mediators or mechanisms that explain why collaborative learning is effective. It is necessary to consider practical observations and findings focus on what learners say to each other and how they say it during joint tasks. This will include implicit and explicit requests for help and contributions to their work, spontaneity in order to resolve a solution jointly (or to arrive at joint understanding) [8, 9]. Such questions could also be addressed to the facilitator. Explicit answers would not be provided but further explorative questions would be offered as a form of guided assistance in order to arrive at a conclusion. Explanation and solutions are more frequently arrived at when students are working in structured collaborative groups than when not [10]. Instrumental or mastery-oriented help seeking is characterised by students alternating between giving help and receiving it.

Many of the student conversations during the activity were very naturally occurring in structured and therefore more like tutoring sessions than basic information exchanges. Webb [11] reported six studies in which the ability to give explanations to peers correlated strongly with general ability. This resulted in dominance within a group by upper ability students. This is especially the case in collaborative learning classrooms [12]. This dominance is even stronger when the group is required to produce a single product or arrive at a single solution. The danger here is that as an activity is task-driven, pressure from more able students can create a case of 'helpers system' in which there is reduced participation by the less able in order not to slow down the group in the target driven activity. This can lead to a situation in which lesser contributors who believe that their offerings are of little value may respond by withdrawing from the task [13]. This will inevitably nearly always offer a challenge to the facilitator of such collaborative learning activities. This was minimised in our study through grouping individuals within learning and social groups that they were already accustomed to working within. Furthermore, the required attributes for successfully completing the activity relied on more than just knowledge alone as they included skills in information finding as well as a small element of luck (as games usually require).

There are potential dangers with collaborative learning. Where help is needed and requested from peers, requests have to be explicit, focused, repeated and directed to an individual who is willing and able to provide the help. Excessive help seeking reduces peer esteem as such students are viewed to be 'passengers' or free riders rather than contributors to group efforts. The skill set required to successfully complete this activity was multifaceted as it included the ability to search for information. This is a skill that most young learners are capable of doing through extensive use of search engines and the web as a whole.

It has been argued that creating classroom structures that promote interdependence and provide explicit training is a prerequisite to student willingness to help each other. This approach has been central in studies by Johnson and Johnson [14] for Learning Together. Developing a positive climate strategy for group learning is also documented in [15, 16].

There is a wealth of information available to assist teachers in the instructional challenges of group work. The work considered includes practical strategies with persuasive evidence about their effectiveness through:

- Frequency of high quality help giving

- Balancing student participation in group deliberations

- Encouraging learners to ask for explanations (a functional help seeking strategy)

- Improve the quality of student explanations

These points alone (direct teaching of helpfulness, improving the social climate of the classroom, strengthening teacher interventions, and implementing reciprocal roles) amplify the positive effects of collaborative learning. One of the most accessible methods of achieving this is by providing students with generic prompts. This approach was demonstrated as part of our investigation in the ABL activity.

Such prompts force students to think about the material to be learnt in different ways. Whilst exploring the material further through a structure of deeper processing, they are facilitating more effective learning than non-elaborative questions like 'who', 'what', 'where' and so on [17]. This prompt-based structure can be extended to student-generated questions without the guidance of elaborative prompts [18]. In addition to enhancing student discourse in small groups, these prompts can be used to structure teacher interventions in small group deliberations and to move whole class discussions to deeper understanding.

7. Game development and applied pedagogy for enhancing game-based learning

At the root of development, Gagne's defined nine elements of instruction [19] serve as a useful guide. The nine events are listed in **Table 1**. These are also discussed and applied by Becker, [20], Becker [21] and more recently by Mavromihales et al. [4].

The nine events can be embodied, directly or indirectly, in game elements. They are widely used as a benchmark for evaluating educational games [20].

Reference was also made to generic guidance of Gamification of Learning: good versus bad practice, which can be seen in **Table 2**.

Some of the key questions that were addressed related to the following:

- Application of skills and knowledge gained prior to the game
- Fun in participation
- Collaboration with peers (beneficial, fun or hindrance?)
- Gauging of self-performance (formative feedback of 'how am I doing' compared to my peers)

Leading up to the end of year submission of individual projects, students are invited to take part in studio based group activities. Such activities may include writing a comprehensive Product Design Specification (PDS) with customer

1. Gaining attention (reception)
2. Informing learners of the objective (expectancy)
3. Stimulation recall of prior learning (retrieval)
4. Presenting the stimulus (selective perception)
5. Providing learning guidance (semantic encoding)
6. Eliciting performance (responding)
7. Providing feedback (reinforcement)
8. Assessing performance (retrieval)
9. Enhancing retention and transfer (generalisation)

Table 1.
A list of Gagne's nine events interpreted through game design.

Gamification of Learning: Good versus Bad		
© K.Becker	**Good**	**Bad**
Point Values for Quests	Reflect level of difficulty & engagement. *EG. 10 XP for small quiz; 250 XP for term project*	Assigned arbitrarily. *EG. Everything has point values in the 1000's*
Scoring System	Strictly Cumulative. EG. All scores are simply summed for the final grade.	A simple mapping from traditional compartmentalised system. EG. Each scored task fills a specific scoring "slot".
Quests	Wide variety, large and small.	Simple translation of traditional system. EG. 6 assignments, 1 midterm, 1 final exam.
Quests	Varied tasks. More tasks to choose from than needed for full score.	The SAME assignments, quizzes, and exams, just now called "quests".
Competition	Students compete against themselves (previous scores) or have access to anonymized class rankings.	Students compete against each other.
Leaderboards	Anonymized. Students can see where they rank, but others cannot see who ranks where. NO ONE is singled out.	Student identities known. Winners and losers obvious.
Narrative	Theme and approach complements subject matter, student level and interests.	Imposed from above. Connection to subject matter thin, contrived, or completely non-existent.
Badges	Awarded for genuine achievements. Publicising badges optional (i.e. students choice)	Awarded for trivial acts. EG filling out a form, wearing a hat on Hat Day, etc.
Practice & Mastery	Re-do's encouraged. Resubmission allowed. Some tasks repeated in different ways.	Every task is a one-off. No resubmissions.
Path to End	Customised. Allows for multiple routes to success. Clear. Defined at beginning of term.	Lock-step. One path for all. Every task is revealed JUST before it is given out.
https://www.researchgate.net/project/A-new-book-Gamification-A-Practical-Guide-for-the-Classroom Accessed 2/11/2020. Reproduced with permission of the author (K.Becker).		

Table 2.
Good versus bad gamification in the physical or virtual classroom.

requirements and applying the 6-3-5 creativity technique (https://www.youtube.com/watch?v=TR1i1PPd8ZU) Accessed 1-2-2022.

Studio assigned time gave opportunity for the introduction of a new GBL activity. Gagne's Nine Events of Game Design (**Table 1**) were used as a guide to formulate the game.

Gillies et al. [22] present a strategy that structures the interaction within a collaborative group to stimulate the cognitive and metacognitive processing appropriate to complex learning tasks. In metacognition processing, learners are given the opportunity to monitor, regulate and evaluate their own thinking and learning. The process is realised through interaction with peers during which they use existing knowledge, like building blocks, in order to deduce an answer to a question or solution to a problem. If knowledge is lacking in individual members, a process of self-awareness becomes apparent. Whilst knowledge from peers is gained, weaknesses in individual participants become apparent. This strategy helps in monitoring comprehension. So, although some of the questions encouraged collaborative learning in which learners combined their knowledge to answer a clear-cut question or reviewing and retelling material already covered in class, other questions encouraged cognitive advanced goals which called for learners to achieve a deeper comprehension of material and construct new knowledge. The latter requires interaction with higher-order thinking which results in complex learning. This is known as 'Guided Reciprocal Peer Questioning' (King [12, 18]) and is intended for structuring interaction that promotes higher-order thinking and complex learning. Its effectiveness has been demonstrated in a number of controlled research studies conducted in classroom settings. According to socio-cognitive learning theory [23], cognitive change is strongly influenced by interaction and activity with others. Different interactions promote different kinds of learning [24]. Fact-based interaction is ineffective for complex tasks, which involve analysing and integrating ideas, constructing new knowledge and solving novel problems as they seldom elicit responses that are sufficiently thoughtful [25].

Webb et al. [24] have shown through their research that when learners are given instructions to work collaboratively, they generally fail to interact at a planful level unless they are guided and prompted explicitly by the teacher, or facilitator. Learners also fail to activate and use their relevant prior knowledge without specific prompting.

This is further supported by [26] on constructionist theory of comprehension. It builds coherent highly-integrated mental representations [27].

Examples of how some basic comprehension questions may be formatted are:

'What does … mean?

What causes … to occur?

Describe … in your own words.

Whilst questions that pose more thought-provoking may be formatted like this:

What is the significance of … ?

How are … and … similar?

What is a new example of … ?

What is the difference between … and … ?

The quiz questions offered as part of this activity were combined to include both 'memory' or 'review' questions as well as 'thinking questions' which provoked thought. Guided Reciprocal Peer Questioning that uses thought-provoking questions to induce cognitive processes in learners has been shown to be effective, particularly with more mature learners where a better understanding of content was demonstrated by learners at University level, particularly in small study groups.

8. Design studio quiz game design

The comparison of good vs. bad practice summarised in **Table 2**, was used as a guidance to evaluate practice of gamification activity, in the 'Design studio quiz game' presented in this case study:

- Questions varied in difficulty and marks were awarded accordingly as 2, 4 or 6 (point values for quests and scoring system).

- Some questions were awarded a negative score if answered incorrectly. The points system (including particular questions that were negatively scored for incorrect answers) were not disclosed to students.

- There was a large choice of questions due to the number of game cards incorporated as part of the game.

- Competition existed between teams who strived for a place on the leader board which displayed the top 50% of groups.
- All subject matter was linked to existing and previously studied modules (narrative).

The top three winning teams are announced upon completion of running the game over a duration of at least 2 weeks, as part of module delivery. Some of the key questions contained on the quiz cards were addressed at a stage post-completion of the gamification activity (practice and mastery).

9. Sample questions and significance to higher order thinking

Figure 2a and **b** show examples of components featured on two of the quiz cards. The associated questions were as follows:

Figure 2a images were associated with the tasks/questions:

1. Identify the surface finish indicated by 'A' and show it would be represented on a technical drawing.
2. What is the most likely method of manufacture of the complete component?
3. By what machining method is the surface finish at 'A' achieved?

Figure 2b images were associated with the tasks/questions:

1. Identify the surface finish indicated by 'A' and show how it would be represented on a technical drawing.
2. How may this surface finish achieved?
3. Define the nominal roughness number range achievable by your answer to Q.2.

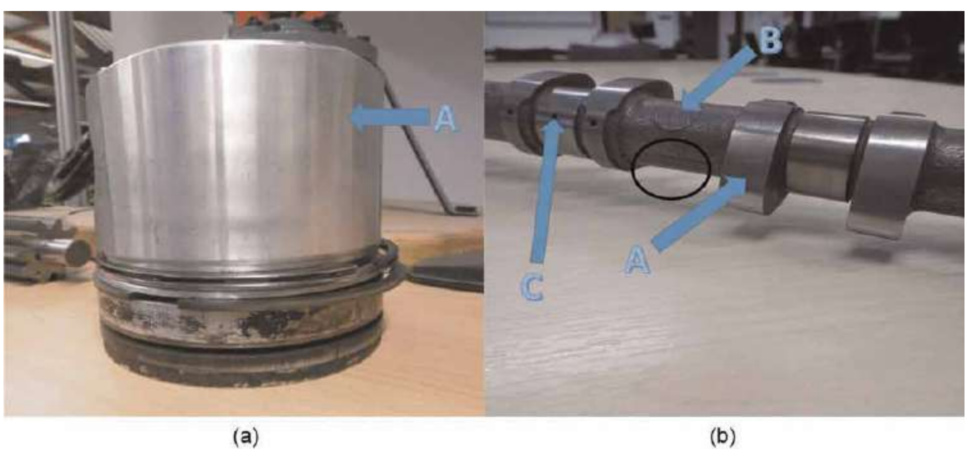

Figure 2.
(a), left and (b), right, illustrate the components featured on the quiz game cards. Associated questions relating to these components have been given above.

4. What can we deduce from the features shown by arrow 'B' and the area within the black oval line?

5. What is the significance of the holes as shown at arrow 'C'?

One of the challenges in planning the ABL activity was careful consideration of the wording of questions. This was important because, as the activity required cooperation between peers, the intent was to partly challenge small groups of participants in higher order cognitive thinking whilst promoting group interaction to achieve those goals. To do this, certain questions, but not all, had to go beyond mere information retrieval of previously-acquired knowledge but to engage in thinking analytically about that knowledge. Learners were therefore encouraged to use what they already knew, often collectively, in order to construct new knowledge. This will encourage the learners to solve new problems and address new issues.

It was for this reason that in this case study, learners were encouraged or guided to engage in a particular pattern of dialogue. For example, if a question required that a small group of collaborating learners explore possible methods of manufacture for an identified artefact, the choice may have been choosing from a wide range of possible methods. To avoid the blind recollection of as many manufacturing methods they could identify between them (using basic memory and knowledge), they were encouraged to consider materials limited to process but also the surface finish achievable by each process and associate the information collected to the artefact in question. This guidance, therefore, encouraged higher-order cognitive thinking and making connections between new explored material (by searching during the activity) and relevant prior knowledge. This interaction induces learners' sophisticated cognitive processes such as inferencing, speculating, comparing and contrasting,

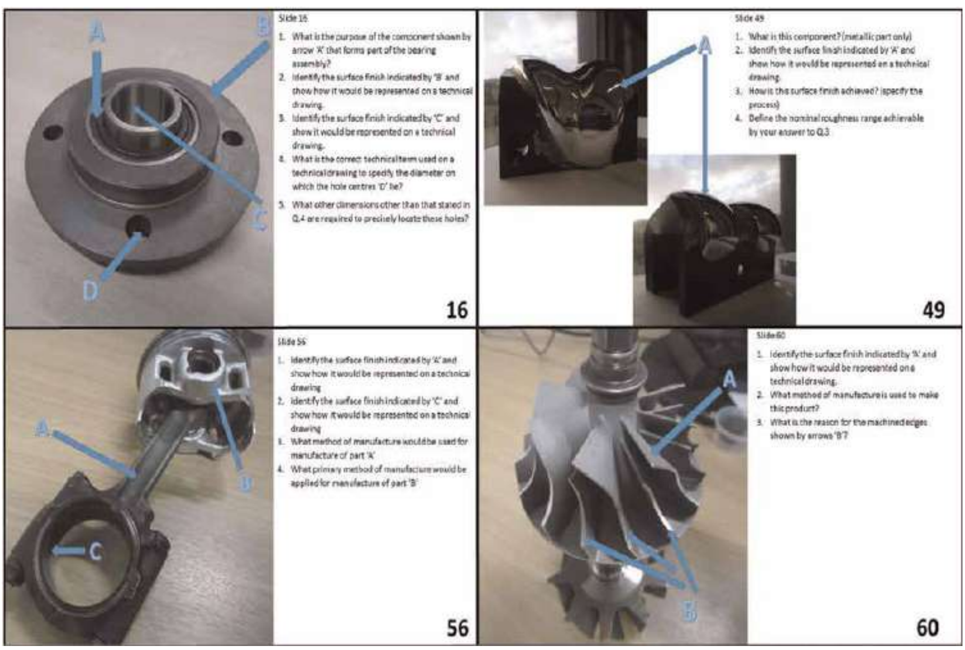

Figure 3.
Illustration showing samples of four quiz game cards containing component image and associated questions.

justifying, explaining, questioning, hypothesising, evaluating, integrating ideas, logical reasoning and evidence based argumentation.

10. Game specifics: mechanical design studio activity game

A large number of existing engineering components (that are freely accessible in physical form in order to allow for exploration) were identified. These components all existed and were located within certain accessible areas of the Department (including the workshops, the design studio, display areas and research laboratories). The components were photographed and catalogued onto game quiz cards. Each component image had a number of questions associated with it. Examples of four such quiz cards are illustrated in **Figure 3**.

11. Game definition and rules of conduct

During a scheduled studio session individual participants would form groups of no more than three and no less than two members. The activity was time-limited and entailed collective and collaborative knowledge and skill. Like most games, there was also an element of luck depending on the cards drawn, the number of questions per card and the level of difficulty of questions. The required knowledge was expected to have been obtained from delivery of lectures in the Mechanical or Automotive Design and other modules (both at foundation and intermediate levels) and gave the opportunity to apply and reinforce knowledge through collaborative learning. The skill element would be evident in the manner in which the participants would explore or deduce the required information by using sources of information available to them (including the internet and reference lecture notes within the Virtual Learning Environment) and through collaborative reasoning.

Participants would blindly draw three cards at a time and once these were completed, they could then request more cards. Each question would have points associated with it, the precise weighting of which was not known to the participants. One in three questions would carry a negative score, or penalty, which was not disclosed to the participants. This would only be applied to easier questions that the students were expected to know. Questions carried either 2, 4 or 6 points depending on level of difficulty, but were not disclosed to participants. All questions had to be attempted before the quiz cards could be returned to the facilitator and participants had to identify and physically handle the part on the quiz card (guidance and direction as to the whereabouts of the part were provided for this).

Specifically, the questions covered certain aspects of mechanical design including:

- Surface finish
- Applied manufacturing technology associated with processes
- Materials
- Technical graphical communication
- Tolerances

Some of the topics such as surface texture definition, tolerances and elements of mechanical design (i.e., definition and selection of bearings) were covered as part of lecture-based delivery for the same module. The game offered further opportunities for reinforcing knowledge through application by collaboration.

As part of the rules, groups were required to work collectively and not to fragment to work independently, even if they considered this to be advantageous. They were also not allowed to exchange quiz cards. To break the rules (including segregation and exchange of cards) they would risk group disqualification.

The activity would be run over consecutive weeks and at the end of each session the tutor would sum up the points scored by each team across several group sets. The activity would run over a duration of 2 weeks. Once proven to be successful, there was no reason why it could not be run over a longer duration. An online leader board would display the ranking order for each team but only for the top 50% of teams. The leader board would be revised following each session that the activity was run thus introducing an element of competition and an attempt for a top 50% positioning. An example of the leader board is shown in **Table 3** where the names of individual students are omitted are replaced by group letters, for the purpose of this paper.

It was evident from student attendance, engagement and participation that the activity was well-received by all the students. Attendance was generally excellent for

Date:19/3/2018								
Team	**Day of attendance**	**Tutor**	**Score**	**Week**	**Score**	**Week**	**Total**	**Overall ranking**
GROUP J	Tuesday	MM	29	1 of 2	23	2 of 2	52	**1**
GROUP M	Tuesday	MM	20	1 of 2	11	2 of 2	31	**5**
GROUP C	Thursday	MM	19	1 of 2	11	2 of 2	33	**6**
GROUP N	Tuesday	MM	18	1 of 2	11	2 of 2	29	**7**
GROUP K	Thursday	MM	16	1 of 2	15	2 of 2	31	**5**
GROUP G	Thursday	MM	16	1 of 2	12	2 of 2	23	**8**
GROUP A	Tuesday	MM	15	1 of 2	27	2 of 2	42	**2**
GROUP T	Tuesday	MM	13	1 of 2	26	2 of 2	33	**3**
GROUP S	Tuesday	MM	11	1 of 2	ABS	2 of 2	11	**11**
GROUP D	Thursday	MM	10	1 of 2	14	2 of 2	24	**9**
GROUP H	Thursday	MM	9	1 of 2	ABS	2 of 2	9	**11**
GROUP B	Tuesday	MM	7	1 of 2	16	2 of 2	23	**10**
GROUP P	Thursday	MM	7	1 of 2	31	2 of 2	33	**4**
GROUP F	Thursday	MM	7	1 of 2	1	2 of 2	3	**13**
GROUP M	Thursday	MM	3	1 of 2	ABS	2 of 2	3	**16**
GROUP R	Tuesday	MM	ABS	1 of 2	9	2 of 2	9	**12**
GROUP E	Thursday	MM	ABS	1 of 2	5	2 of 2	5	**15**
GROUP L	Thursday	MM	ABS	1 of 2	6	2 of 2	6	**14**

Note: ABS indicates that a member of the group was absent during that particular session.

Table 3.
Final group ranking table.

the activity sessions. Students were further enticed by being offered a minor score that would contribute towards their overall score for the module, for attending and actively participating. Even though this score was insignificant, it appeared to have resulted in good overall activity involvement.

Other than introducing a learning activity with an element of fun and competition, there were several other objectives:

- For students to be more aware of engineering artefacts that they come across on a day-to-day basis and question their related engineering attributes (raise awareness and inquisition)
- To apply and reinforce existing knowledge obtained through various engineering modules
- To encourage them to think in greater detail and concise definition with regard to their own individual mechanical design assignment

A short feedback questionnaire was issued at the end of term in order to gather qualitative feedback from participants on how they perceived the activity from various aspects including,

- Applying previous knowledge
- Whether they regarded the Activity Based Learning event as being fun, despite of, or especially due to, the element of competition
- Effective collaboration with peers
- Formative self-assessment
- Clarity relating to requirements and rules of engagement
- Relevance of activity to course content

The initial appraisal of the answers to the above questions is encouraging and students have indicated that they are satisfied with the format of this learning activity. Detail analysis of both the qualitative feedback and impact on their individual design work are reported in later in this chapter.

Table 3 shows the final rankings of groups (with names disguised by assigning to groups). Participants could follow their progress and compete for a place on the rankings table. Only the top 50% of the participating groups would be displayed on the league tables. Positions could change during consecutive weeks of game deployment. This introduced an element of competition in an effort to be part of the top 50% of participating groups (**Figure 4**).

12. Evaluation

The design studio quiz game was included in the delivery of the Mechanical Design module and its 'sister module' of Automotive Design. It was conducted over a period

Figure 4.
Studio ABL with gamification in action.

of 2 weeks and included activities associated with engineering artefacts as illustrated in **Figures 2a** and **b**.

Once the activity had been completed and the top-scoring teams had emerged, learners were given formative feedback on performance and how this could have been improved. Discussion sessions helped resolve queries that arose regarding certain questions relating to artefacts used as part of the activity. During the evaluation, certain questions were addressed through a feedback questionnaire in order to establish whether the activity had generated a positive learning experience or had the activity succeeded in achieving the following?

1. Encouraged learners to apply skills and knowledge previously gained on the course and were these further reinforced during the game?

2. Was the GBL activity fun to participate in and did it introduce an element of competition amongst peers within a GBL environment?

3. Encourage effective collaboration with peers in order to address key quiz questions?

4. Did the activity provide a means of formative assessment (a means of gauging self-knowledge against that of peers)?

5. Was the activity a refreshing and welcome activity during studio sessions?

6. Were participant requirements made clear prior to the game and were the rules of conduct also made clear?

7. Did team working help in completing the tasks effectively?

8. Should ABL be more widely applied?

9. Was the activity interesting and relevant to the module and course (as perceived by learners)?

The feedback questionnaire consisted of nine questions. A copy of the questionnaire is included in the appendix and the analysis by students' selected answers to the given questions is also detailed.

The basis of the questionnaire was to establish the views as to whether students had perceived to have gained from the overall learning experience. One of the longer term research questions is whilst students may respond positively to an ABL approach to teaching and learning, do they actually benefit to a greater extent, beyond the activity. Question 8 was included to enable the quantification of students who desired for more sessions to be delivered in this manner whilst Question 9 tried to establish the students' perceived relevance of content, to their course. Questions 3 and 7 referred to aspects of Collaborative learning whilst questions 2, 5 referred to aspects of gamification design [8, 10].

13. Summary of findings, analysis and conclusions from feedback questionnaires

Figures 5 and **6** correspond to the responses of questions 1 & 2. These indicate that 96% of learners felt that they had applied previously gained skills and knowledge which were further underpinned during the activity. A small number of students felt that this was not the case. Although unclear, these responses may have been from a minority of students who had entered the course directly into year 2 and thus not have studied specific modules in manufacturing technology, materials and engineering communications delivered in the first year of the course. Differences in courses between various institutions can hinder continuity and link with prerequisites. The 82% response to the game being fun and competitive was again positive, however, effort was required by participating learners and the pressure to perform as a result of

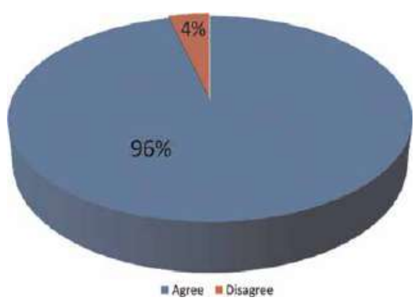

Figure 5.
I applied skills and knowledge previously gained on my course and these were further underpinned during the game.

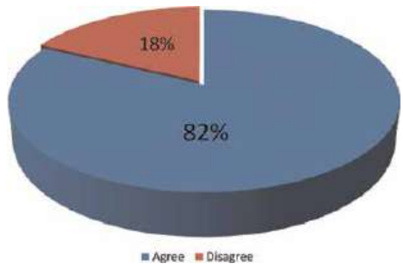

Figure 6.
The game was fun whilst it also introduced an element of competition against my peers within an activity based environment.

gaining a place on a leader board may have dampened the enthusiasm of the 18% of respondents who disagreed with this statement.

Figures 7 and **8** correspond to the responses to questions 3 & 4. 94% of learners indicated that they collaborated effectively with peers to address the quiz card questions. The high score of success indicated by this question regarding collaborative learning was higher than expected. Collaborative learning has been well established and proven to be successful in numerous educational empirical studies, time and time again [28]. Johnson and Johnson [7] base it on social interdependence theory that underlies the most widely used collaborative learning procedures. It has been validated by hundreds of research studies [14]. Social interdependence exists when the accomplishment of each individual's goals is affected by the actions of others. They, therefore, promote each other's efforts to achieve their goals. Negative

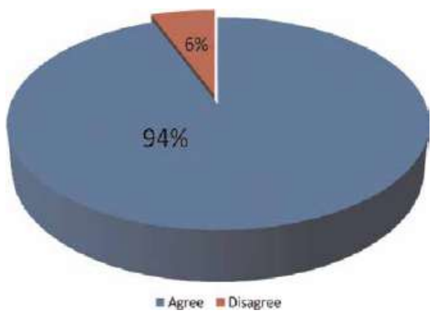

Figure 7.
I collaborated effectively with peers to address the quiz card questions.

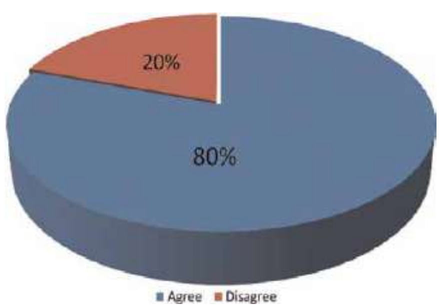

Figure 8.
It provided a means of formative self assessment, to gauge my own knowledge against my peers.

interdependence exists when individuals perceive that they can obtain their goals if and only if the other individuals with whom they are collaboratively linked fail to obtain their goals. Based on interdependence theory, the high percentage score (94%) is believed to be attributed to groups (of maximum of three members) that were self-assigned in the knowledge that they were able to collaborate. The small number (6% of respondents) that disagreed with this statement was likely to have had a member absent during part of the activity. **Figure 8** indicates that 80% of participants felt that they had gained a means of formative feedback as to the level of their knowledge as compared to their peers.

Figure 9 indicates that the majority (86%) of students regarded the activity as a welcome change from studio sessions. The 14% that disagreed may have done so due to the required effort and competitive element necessary to partake in active learning sessions. The question was straightforward without ambiguity. **Figure 10** indicates that nearly a third of participants were not entirely clear of the rules of conduct. This may have been due to absenteeism from a class based session during which the rules were covered. These were also displayed throughout the duration of the game. Questions regarding rules of conduct were addressed during the activity.

The results indicated by **Figure 11** directly correlate with the responses to question 3 (see **Figure 7**), in that 96% of respondents agree that cooperation with peers was of benefit in completing the activity. The responses to question 8 are indicated in **Figure 12** which correlate closely with question 5 (see **Figure 9**), indicating that 88% of participants would like more Activity Based Learning.

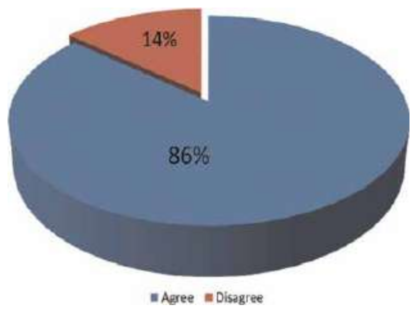

Figure 9.
The activity was refreshing and welcome during studio sessions.

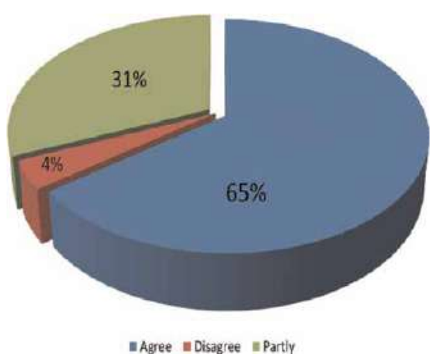

Figure 10.
I was clear what was required in order to participate in the activity and the general rules were clear.

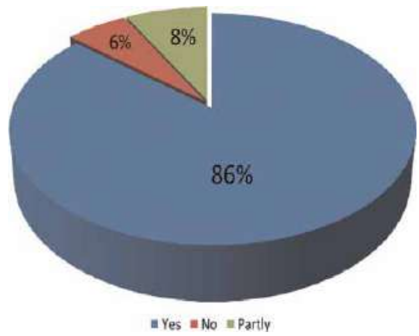

Figure 11.
Working with another person helped me complete the exercise effectively (was it helpful working with a peer).

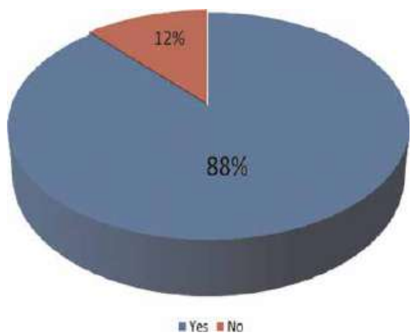

Figure 12.
Do you think more studio sessions should be organised like this (activity based learning).

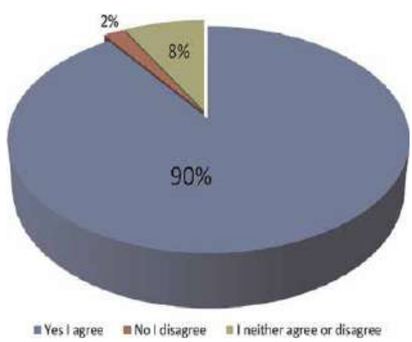

Figure 13.
I found the activity interesting and relevent to the module and course.

Figure 13 indicates that 90% of learners regarded the technical content as interesting and relevant to their course. 2% disagreed and 8% were neutral. These results can be explained in that leaners often have misconceptions as to what is relevant to their chosen field of study as they are unable to see the wider picture.

The fact that 90% had responded entirely positive is testimony to the engagement by the majority of students who took part in the game.

14. Differences in assessment results

At the end of year students submit an individual project report as part of the Mechanical Design module. A similar report is also submitted for assessment by students on the equivalent module in Automotive Design. This submission consists of a report and a set of technical drawings.

A marking scheme was devised so that half of the available marks for this assignment are allocated to elements of detailed design such as applying tolerances, correct dimensioning, surface finish considerations and manufacturing and materials considerations.

It was noted that there was a difference in performance in this assignment for current student cohort and the previous year's cohort, but this was considered to be inconclusive. The average score between the two cohorts was almost identical to within 0.1%. In Mavromihales and Holmes [4], changes in performance were gauged by comparing the profiles, in terms of tariff points at the entry point to the course, between two groups of consecutive years of entry to undergraduate study. In this case, this was not viable due to changes in the currency of the tariff points. It was therefore not possible to adjust for discrepancy in the levels of qualifications between the control group and the experimental group.

As a separate measure, we also compared the performance of individuals who were in groups that had ranked amongst the top ten finishers in the activity. The overall average of individuals who had ranked amongst the top ten finishing groups was significantly higher with overall individual scores of nearly 8 percentage points higher (69.7% as compared to 62%). Results were also compared with another cohort of students who participated in the same activity but as part of a similar 'sister' module, in Automotive Design. Results in performance were unsurprisingly similar in that the top-scoring half of groups accounted for a 10% improvement in students' individual scores for the end of year individual detailed design project. This was accomplished despite the fact that groups were made up of mixed ability students in the ABL activity. This raises a question as to whether the students who ranked amongst the top 10 in the activity were more motivated and would have scored better individually in any case, or whether participation in the gamification activity had assisted them to achieve better results, individually. However, it is evident that students who had performed outside the top 10 ranking groups had an absent member during one activity session which clearly hindered the group performance. Other possible underlying issues of weaker performing groups in the activity will be explored and discussed later and addressed as part of future work.

15. Summary of addressing research questions and conclusions

In this paper we reported on a studio based GBL/ABL activity and presented the results of our findings in the form of qualitative feedback received from learners as well as quantitative results obtained from levels of attainment and performance in the modules where GBL/ABL activity was used. GBL/ABL learning enabled the observation of the effects on students' performance in a simple in-class game.

It was established that the students performed better in the subjects which build on the knowledge, skills and understanding acquired in GBL/ABL, such as an end of year detailed design project. There was a clear benefit of engaging the students in a collaborative learning activity which was evident from individual assessment scores.

Through individual and instructor questions and answers, they 'filled' knowledge gaps, leading to successful completion of design tasks.

Mostly, the students were not hindered by participating in a group activity and benefited from a competitive environment gauging their performance against their peers, and competing for the top-scoring place in the ranking.

In addition, it was clear that students who ranked within the top half of collaborating groups in the GBL/ABL activity had also performed better on an individual basis at the end of year assessment. Groups consisting of either two or three participants were of mixed ability and level of background knowledge but still performed individually better if they were part of a top-scoring group.

As a result of GBL/ABL, it has emerged that learners acquired knowledge, skills and abilities according to the learning outcomes for the module, whilst also experiencing an enjoyable learning activity and hence requested further collaborative learning sessions.

Based on the evidence acquired it can be concluded that a blended learning approach to teaching and learning can produce a powerful set of tools for Mechanical Engineering education that improves motivation, engagement and attainment of students in undergraduate engineering courses.

We have addressed the challenge of providing a robust education to engineering undergraduates students and equipping them with the skills and knowledge for a real-world environment through motivating and engaging them as learners. Our approach was one of GBL and ABL which require collaborative learning and access to the web and a VLE.

This approach has led to the University's recognition of this innovative approach to teaching and learning by awarding 'The Teaching Excellence Prize'—best course team for student outcomes (student cohort exceeding 100 students).

16. Future work

The results of this research in GBL/ABL and the positive feedback from students taking part in the research activities have provided a foundation for furthering the approach to other modules in Engineering undergraduate courses.

Although not entirely devoted to online GBL, it demonstrates through ABL and utilisation of the Web along with a VLE, that the learning experience is enhanced.

The development of this model can be used as a template in designing future activity work of this nature for other fundamental mechanical engineering discipline subjects.

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References

[1] Hamari J, Koivisto J, Sarsa H. Does gamification work? A literature review of empirical studies on gamification. In: IEEE 47th Hawaii International Conference on Systems (HICSS). Waikoloa, HI, USA: IEEE; 2014. pp. 3025-3034

[2] Seaborn K, Fels DI. Gamification in theory and action: A survey. International Journal of Human-Computer Studies. 2015;**74**:14-31

[3] Markopoulos AP, Fragkou A, Kasidiaris PD, Davim JP. Gamification in engineering education and professional training. International Journal of Mechanical Engineering Education. 2015;**43**(2):118-131

[4] Mavromihales M, Holmes V, Racasan R. Game-based learning in mechanical engineering education: Case study of games-based learning application in computer aided design assembly. International Journal of Mechanical Engineering Education. 2018;**0**(0):1-24

[5] Krathwohl David R. A revision of Bloom's taxonomy: An overview. Theory in to Practice. 2002;**41**(4):212-218. DOI: 10.1207/s15430421tip4104_2

[6] Ross JA, Cousins JB. Intentions to seek and give help and behavior in cooperative learning groups. Alberta Journal of Educational Research. 1994; **89**:109-117

[7] Johnson DW, Johnson R. Cooperative learning methods: A meta-analysis. Journal of Research in Education. 2002b; **12**(1):5-14

[8] Veenman S, Denesen E, van den Akker A, van der Rijt F. Effects of a cooperative learning program on the elaborations of students during help seeking and help giving. American Educational Research Journal. 2005;**42**: 115-152

[9] Webb N, Mastergeorge A. Promoting effective helping in peer-directed groups. International Journal of Educational Research. 2003;**39**:73-97

[10] Gillies R. The effects of communication training on teachers' and students' verbal behaviours during cooperative learning. International Journal of Educational Research. 2004; **41**:257-279

[11] Webb NM. Peer interaction and learning in small groups. International Journal of Educational Research. 1989;**13**: 21-40

[12] King A. Autonomy and question a asking: The role of personal control in guided student-generated questioning, invited article of special issue of learning and individual differences: Question asking and strategic listening processes: Individual differences and their consequences. Learning and Individual Differences. 1993;**6**:162-185

[13] Karau S, Williams K. Social loafing: A mata-analytic review and theoretical integration. Journal of Personality and Social Psychology. 1993;**65**:681-706

[14] Johnson DW, Johnson R. Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning. Englewood Cliffs, NJ: Prentice-Hall; 1987

[15] Abrami P, Chambers B, Poulsen C, Kouros C. Positive social interdependence and classroom climate. Genetic, Social, and General Psychology Monographs. 1994;**120**:327-346

[16] Kegan S, Kegan M. The structural approach: Six keys to cooperative learning. In: Sharan S, editor. Handbook of Cooperative Learning Methods. Westport, CN: Greenwood Press; 1994. pp. 115-133

[17] King A, Rosenshine B. Effects of guided cooperative questioning on childrens knowledge construction. Journal of Experimental Education. 1993; **61**:127-148

[18] King A. Ask to think-tel why: A model of transactive peer tutoring for scaffolding higher level complex learning. Educational Psychologist. 1997; **32**:221-235

[19] Gagne RM, Briggs LJ, Wagner WW. Principles of Instructional Design. 4th ed. Fort Worth, Texas: Harcourt Brace Jovanovich College Publishers; 1992

[20] Becker K. How are games educational? Learning theories embodied in games. In: Paper Presented at the DiGRA 2005 2nd International Conference, "Changing Views: Worlds in Play". Vancouver, British Columbia, Canada: DiGRA; 2005

[21] Becker K. Video game pedagogy: Good games=good pedagogy. In: Miller CT, editor. Games: Purpose and Potential in Education. NY: Springer; 2010. pp. 73-125 ISBN: 978-1-4419-3533-5

[22] Gillies RM, Ashman AF, Terwel J. The teacher's Role in Implementing Cooperative Learning in the Classroom. New York: Springer; 2010

[23] Vygotsky LS, Hanfmann E, Vakar G, Kozulin A. 'Thought and Language' Rev and expanded ed. Cambridge: MIT Press; 2012

[24] Webb NM, Palincsar AS. Group processes in the classroom. In: Berliner DC, Calfee RC, editors. Handbook of Educational Psychology. New York: Macmillan; 1996. pp. 841-873

[25] Cohen E. Restructuring the classroom: Conditions for productive small groups. Review of Educational Research. 1994;**64**:1-35

[26] Graesser AC, Singer M, Trabasso T. Constructing inferences during narrative text comprehension. Psychological Review. 1994;**101**:371-395

[27] Kintsch W. The role of knowledge in discourse comprehension: A constructive-integration model. Psychological Reviews. 1988;**95**:163-182

[28] Johnson D, Johnson R. Learning together and alone: Overview and meta-analysis. Asia Pacific Journal of Education. 2002a;**22**:95-105

Chapter 6

Making Education More Brain-Friendly through Gamified Instruction

Daniel Rueckert and Robert Griffin

Abstract

Just because you can does not mean you should. Although gamified instruction is being widely adopted, there needs to be compelling research that supports gamification as an effective educational modality. Without this support, gamification is just a novelty. This chapter explores research that provides evidence to support the appropriacy of gamified learning as a modality that more closely adheres to how the human brain functions. It explores suggestions from Mind, Brain, and Education Sciences and NeuroELT to set a standard for what is good education. Using these suggestions as a basis to evaluate gamified instruction, it looks at recent studies to determine if gamified instruction is a brain-friendlier mode of instruction than traditional models.

Keywords: gamified instruction, NeuroELT, MBE, brain-friendly learning, learning modalities

1. Introduction

Over that last decade, gamification has gained traction as an option for modality of instruction. Prominent learning management systems have developed features to support the gamification of instruction using badges. While these options have been available, there is still slow progress towards adopting the modality as a central approach to providing education. As adopting a gamified approach takes an investment of time and creativity, this chapter seeks to explore the question of why educators should consider the shift in instructional modality. At the heart of this question of why is the issue of improving teaching and learning experiences.

What is the optimal learning modality for learning? There have been many efforts to define what is good teaching and learning. As there are many different approaches for teaching and learning, this question merits evaluation of the different modalities. In this chapter, we will draw from the research provided by Mind, Brain, and Education Sciences (MBE) and NeuroELT. Principles of "good learning" will be evaluated in the context of findings provided by research into gamified learning in regard to language education.

2. Claims made by advocates for gamified learning

In 2011, Extra Credits, a Youtube channel geared towards the gaming community, published two videos about gamification and its potential impact on education [1, 2]. The claims they made mirrored those promoted by Lee Sheldon in his book, The Multiplayer Classroom [3] and Kapps books [4, 5]. They claimed that the use of game design features, such as accumulative grading, levels, badges, do-overs, and path choices could convert the mundane process of traditional learning into a rewarding experience where students would be more motivated to engage in tasks and learning while feeling a greater sense of agency over their own education. There have been several studies since this time to investigate the correlation between gamified learning and student motivation to learn the subject through this modality. Motivation is key component of language learning which has been found to have significant correlation to proficiency attainment [6]. Most focus on extrinsic motivation provided by badges, levels, etc. [7–9] while others like Bovermann and Bastiaens looked at gamification and its ability to be an intrinsic motivator [10]. Homer, Raffaele, and Henderson [11] go further in stating that intrinsic motivators such as challenge and self-actualization are essential to gamified instruction. Worthy of note is the fact that motivation is a difficult thing to measure. It is a dynamic feature and very few studies have investigated the use of gamification in a longitudinal study. An area of concern is if all education were to be gamified, it would lose its novelty. In the vast majority of studies, the use of gamified learning and its effects on motivation are not distinguished from the boost in motivation scores that occur when encountering novel activities.

While motivation is a valuable piece to be evaluated, the other claim made by Extra Credits also merits further investigation. The claim that using a gamified modality has the ability to improve the sense of agency by the student participants is bold and valuable to explore. Bradbury et al. [12] investigated the amount of agency felt by participants and their actual achievement. They determined that subjects who had partial agency, having to complete all steps in a navigation path, had higher outcomes on their game than those that had full agency. Too often students feel that they have no control, or very limited control, over the courses they take. Hence, students talk about grades as the grade that this teacher has given instead of the grade that the student has earned. Fabrizio Poltronieri [13] presents agency as an integral part of game design. This game feature may give students various paths to choose or can be hard set for the navigation path the participant will "choose". Regardless of how hard set the navigation path is, the participant will have a final sense of agency over the decisions made to follow their chosen path.

Research has shown that modifying the modality used in education has correlational impacts on factors such as motivation and a sense of agency. The research presented here represents positive findings on the potential impact of gamifying education to improve these two factors. These findings create the additional question of what other valuable educational factors can be impacted, for better or worse, by adopting a gamified modality? To explore this question, this chapter will explore principles of good teaching and learning as they are presented by Mind, Brain, and Education Sciences and NeuroELT research. These fields have established principles and maxims of good education, and thus, provide research driven factors to consider when determining what is "good education".

3. Good educational principles from mind, brain, and education sciences

The first way to evaluate teaching and learning quality is by considering principles presented by Mind, Brain, and Education (MBE) researchers. In her book, Mind, Brain and Education Science, Tracey Tokuhama-Espinosa [14] presents 21 principles that great teachers follow. These principles are grounded in research conducted in neuroscience, psychology, and pedagogy. Using a transdisciplinary approach, Tokuhama-Espinosa established these 21 principles that are supported by these three fields and give greater insight into what is brain-friendly learning. These principles are adapted from Tokuhama-Espinosa (pg. 206) and presented in **Table 1**. They are adapted to simplify each principle and frame them as components of good, brain-friendly education.

Each principle presented represents an element of what MBE research promotes as good education. As Tokuhama-Espinosa proclaims in her book, these principles should serve as an agent of change to how education is offered. As research advances the understanding of how the brain works with education, it should be expected to see changes in the educational system to better adhere to those findings. This merits an exploration gamified instruction to determine its congruence with these important

1	**All people are unique and organized information uniquely**
2	People aren't equally good at everything
3	The brain is complex, dynamic, and changes daily
4	Learning is a constructivist process and continues through all developmental stages
5	The search for meaning is innate to humans
6	The brain maintains plasticity throughout the lifespan
7	MBE science principles apply to all ages
8	Learning is based on the ability to self-correct
9	Meaning occurs through pattern recognition
10	Brains seek novelty
11	Emotions are needed to detect patterns, make decisions, and learn
12	Challenge improves learning while threat inhibits learning
13	Focused attention and peripheral perception are involved in learning
14	Students process parts and wholes simultaneously
15	Interactions are important to process social situations
16	Feedback is essential for learning
17	Memories and attention are essential for learning
18	Memories differ in input and recall
19	Learning should be integrated with natural contexts
20	Learning is both conscious and unconscious
21	Physiology affects learning

Table 1.
Tokuhama-Espinosa's [14] 21 principles adapted to simplify each concept as presented in Rueckert et al. [15].

findings. If the gamified modality is more closely congruent with MBE principles than other options, this would strongly advocate for the mass adoption of the modality to improve instruction for all learners.

As gamification has become increasingly prominent as an educational mode of delivery, there has been a growing call for transdisciplinary research investigating the underlying brain-friendliness of the gamified classroom [16]. Rueckert et al. [15] began to address the lack of substantive inquiry into how gamification may align with underpinning claims of brain-based education by conducting a survey study on student perceptions of a gamified classroom and its congruence with 21 principles suggested by MBE research [14]. Their study looked at two university level English language classes in Ecuador. Each class was a different section of the same course and taught by the same instructor. One was gamified and one was taught as it had been traditionally. Students were given pre and post surveys to measure the extent with which they agreed that their classroom adhered to the 21 MBE principles. They were further asked open ended questions about their experience and the instructor submitted a journal of the experience. Their preliminary investigation found a significant correlation with 14 of the 21 principles for the gamified group. Further, the ratings improved for all 21 principles. This data showed promising results for improving adherence to all 21 MBE principles through gamifying instruction with 14 of those principles being significantly improved. Their study presented 14 correlations between the use of gamified instruction and adherence to the MBE principles presented. Their 14 correlations are as follows.

1. Gamified instruction tailors foreign language learning to the unique thinking of each student better than traditional instruction

2. Gamified instruction builds upon the previous knowledge of foreign language learners more than traditional instruction

3. Gamified instruction is more conducive to foreign language learners having meaningful experiences with language than traditional instruction

4. Gamified instruction more logically designs learning from easiest to hardest at a reasonable pace than traditional instruction

5. Gamified instruction makes greater use of errors as learning experiences than traditional instruction

6. Gamified instruction provided a more interesting class due to its novelty than traditional instruction

7. Gamified instruction created a better effective class for foreign language learning than traditional instruction

8. Gamified instruction provided greater connection of content to learn a foreign language than traditional instruction

9. Gamified instruction provided foreign language learners with more feedback than traditional instruction

10. Gamified instruction used greater interaction with others than traditional instruction

11. Gamified instruction made better uses of the five senses to learn foreign language than traditional instruction

12. Gamified instruction provided learning that was more natural to everyday life than traditional instruction

13. Gamified instruction made better use of indirect/unconscious learning than traditional instruction

14. Gamified instruction allowed students greater autonomy of their learning than traditional instruction

4. Good educational principles from NeuroELT

To provide further substantiation to Rueckert et. al's study as expressed in the 14 claims above, NeuroELT, an interdisciplinary field combining Applied Linguistics and Educational Neuroscience, presents 50 maxims to consider when teaching for a brain-friendly setting. Similar to the key principles for good education as espoused by MBE research, investigations into NeuroELT provide another conceptual framework for brain-friendly learning that supports the 14 MBE tenets considered to be key features of gamified instruction by Rueckert et al [15].

4.1 What is NeuroELT?

NeuroELT is an interdisciplinary field encompassing the domains of Applied Linguistics and Educational Neuroscience that focuses on individual humans and their evolution in extracting useful information from the natural and social worlds around them [17]. This approach was extended to the classroom by describing the ability of the brain to learn by providing new measures for effective learning and teaching which Robert Murphy presented via 50 maxims, established during his FAB conference series educating instructors about the role of neuroscience in education [18].

4.2 Eight maxims for brain-friendly teaching via gamified instruction

Murphy's 50 maxims supporting NeuroELT encompass the primary features for a brain-friendly classroom with regard to English language teaching. For the purposes of this chapter, 8 key dicta as shown in **Table 2** below have been selected which underpin strong educational principles that support brain-friendly learning and are consistent with claims made by proponents of gamification.

The NeuroELT maxims provide underlying features of a classroom that is brain-based given research conducted at Robert Murphy's 's NeuroELT lab at the University of Kitakyushu. The presentation of the select NeuroELT maxims and corresponding MBE claims reflect the benefits of gamified instruction as a modality of delivery from the perspective of Educational Neuroscience and lend

NeuroELT maxim	Explanation of the maxim	Corresponding MBE claim (Rueckert et al.)
13. "Choices" fuel learner motivation	Autonomous choice making commonly activates neural networks that provide feelings of satisfaction. Thus, acting with autonomy is typically a naturally pleasurable experience.	14. Gamified instruction allowed students greater autonomy of their learning than traditional instruction
14. "Prediction" is a tremendously powerful tool	Humans derive pleasure from making a prediction and experiencing a corresponding outcome (as is abundantly clear when people are gambling in casinos, etc.). Thus, similarly, if learners are encouraged to make predictions of learning outcomes, the motivation to "see it through" is often quite compelling, as can be observed in the phenomenon of gambling addiction. This maxim works hand-in-hand with several of the other maxims on this list.	3. Gamified instruction is more conducive to foreign language learners having meaningful experiences with language than traditional instruction
15. "Real-time feedback" is at the core of cognitive development	The human love of the prediction-outcome dichotomy stems from the rewarding rush of dopamine received when we perceive our solutions to be correct. Thus, real time feedback satisfies and even nurtures our craving for the dopamine rushes. This	9. Gamified instruction provided foreign language learners with more feedback than traditional instruction
16. "Aha moments" enhance neural networks	Pleasurable dopamine rushes also result from successful problem solving. The neural networks involved become more efficient through myelination; the most often used networks therefore become super-enhanced for superior processing (speed and quality actually become enhanced).	3. Gamified instruction is more conducive to foreign language learners having meaningful experiences with language than traditional instruction 12. Gamified instruction provided learning that was more natural to everyday life than traditional instruction
19. "Happy students" learn better	Studies show that happier individuals perform better academically, with enduring motivation. Positive Psychology has found that engagement in perceived meaningful activities may sustain happiness more effectively than the simplistic pursuit of pleasure.	3. Gamified instruction is more conducive to foreign language learners having meaningful experiences with language than traditional instruction 11. Gamified instruction made better uses of the five senses to learn foreign language than traditional instruction
24."Performances of Understanding" are essential for good assessment	PoU activities provide learners with the opportunity to make their learning and understanding visible by having them demonstrate their Understanding (real world mastery) of the concepts. PoU-based pedagogies are aimed at synthesizing student learning and advancing it all to the next level in the form of a real world applicable performance. This is often lacking in traditional top-down, rote-memorization only teaching.	1. Gamified instruction tailors foreign language learning to the unique thinking of each student better than traditional instruction 2. Gamified instruction builds upon the previous knowledge of foreign language learners more than traditional instruction 4. Gamified instruction more logically designs learning from easiest to hardest at a reasonable pace than traditional instruction

25. "Assess" in three ways	There are 3 synergistic ways to assess performance (referred to as the Trinity of Assessment): 1. Self-assessment 2. Peer to peer assessment 3. Teacher-student assessment. It is the culmination and synergy of all three that is ideal for nurturing students' metacognitive prowess, problem solving skills, and overall academic growth.	1. Gamified instruction tailors foreign language learning to the unique thinking of each student better than traditional instruction 5. Gamified instruction makes greater use of errors as learning experiences than traditional instruction
41. "Encourage" mistakes; celebrate mistakes	People can and do learn from mistakes. However, in contexts where people are afraid of making mistakes—they are in an extreme disadvantage. The negative context may be detrimental to natural learning processes. An environment where mistakes are treated as special teaching/learning moments that are essential to learning may lead to more neuro-efficient cognitive development.	5. Gamified instruction makes greater use of errors as learning experiences than traditional instruction

Table 2.
Murphy's eight NeuroELT maxims and MBE equivalents (Murphy [18]; Rueckert et al., [15]).

support to the call for a transdisciplinary investigation of gamification and brain friendliness.

4.3 NeuroELT maxims and the gamified classroom

4.3.1 Maxim 13 choices

The perception of choice as an option while learning is a pleasurable event in which the brain releases dopamine and other endorphins generating feelings of comfort and safety [19]. Brain-based learning requires that the learner survive in the classroom jungle where students can feel threatened, and the fight-flight reaction is easily reproduced. Giving the learner the ability to choose during learning creates a safety net in the classroom, making it easier to acquire information without feeling threatened as is the case in top-down traditional classrooms. The perception of choice by the learning brain establishes a sense of ownership and personal investment in the mind of the learner who will defend his/her choice without question [20].

Given that the gamified classroom has also been claimed to promote a sense of choice in keeping with MBE research, it can be suggested that gamified education is a strong alternative to the traditional classroom in which teaching through lecture, rote memorization, text-based techniques, or other top-down methods is not conducive to brain-based learning. Within gamification, features such as different alternate task paths and the ability to resubmit a homework do over provide students greater choice than traditional education.

4.3.2 Maxim 14 prediction

The maxim of prediction posits that humans take satisfaction in making predictions and experiencing the outcomes. We can see repeated patterns of human behavior related to this such as scientific research that sets a hypothesis and then gathers data to prove/disprove it. In a less scientific context, this behavior is exhibited in gambling and investment. Individuals are wired to look at a situation, look at the surrounding data, and then make predictions. Once those predictions are set, the individual lets the situations play out and monitors the outcomes.

In MBE, the focus is on meaningful experiences, which involve interactions with the material being learned. If a student can take an idea or concept and then test it out using prediction or hypothesis testing, then they have created a meaningful interaction with that concept. Their active participation in this experimentation has allowed them to more meaningfully interact with what is being learned.

Elements from gamified instruction that lead themselves to more fully provide prediction and meaningful interaction is the element of submitting an assignment with the expectation that all objectives are met. The student is predicting the positive outcome of task achievement. Of course, the objective is not always met. In these instances, the assignment is returned with feedback that helps the student to make another attempt. This is equal in process to the game feature of losing a life and making a new attempt to pass a level in a game. The player receives the negative outcome, reassesses their strategy and tries again with the prediction that the desired outcome will be reached. As the personal choices made to alter the strategy plays out, the task is more personal because the player's choice changes the outcome while action is taken. The resultant outcome supports the prediction process, reinforces a choice and creates a meaningful experience with the content.

4.3.3 Maxim 15 real-time feedback

Feedback is vital in education. Feedback should be given in real time, or as quickly as possible. In language education, feedback can be real-time as students use the language to communicate. The communication between interlocutors gives simultaneous feedback to each language user. MBE suggests that feedback should be ample and of high quality.

Automated feedback, like test scores, are usually not of high quality as they tend to be impersonal. This means that to qualify as quality feedback, it should be directly meaningful to the learner. Feedback like this can take more time. However, in gamified learning, tasks are usually evaluated using benchmarks. Students have either met an objective or not. Many tasks will have multiple objectives. This will result in a list of benchmarks that must be met to have satisfactorily completed the task. Having clearly defined benchmarks makes the task of evaluation much easier and feedback can be given for each benchmark that is not met. This allows a quicker turnaround time for marking tasks as complete or sending them back for modification. This also provides a much more objective focused assessment, improving the quality of feedback which when correctly attended to by the student results in a rise in dopamine levels in the brain and a corresponding sense of pleasure and motivation.

4.3.4 Maxim 16 "Aha moments"

The heuristic educational approach of the "aha moment" has been around for centuries. This is shown in cartoons as the moment the light bulb turns on in someone's head. The brain releases dopamine when people figure things out. Education should be a series of tasks that enable students to figure things out. This is in contrast to memorization without application. A more meaningful experience is created when students experiment with tasks and then discover knowledge as it relates to their creation. MBE supports this notion with the emphasis on meaningful and more natural learning.

Gamified learning supports this with its task-based approach towards learning. Students are tasked with figuring out how to successfully complete each assignment. They then submit each assignment with the hope that they have met each benchmark. However, benchmark completion is only part of the learning. A good gamified task will be one that does not explicitly give students the answers, but lets them discover the knowledge. The gamified classroom provides students a repetitive platform for 'trial and error" as benchmarks are reached. This occurs as students attempt to solve an objective by increasing the efficiency of the neural pathway to quickly process a problem. Pujol et al. [21], note that such regular use of particular neural paths become more myelinated, leading to neuro-efficient connections within the brain. Learning a sport or playing an online game are examples of this and prove to be brain friendly.

4.3.5 Maxim 19 happy students

Learning is an emotional process. It does not just rely on logic, but instead involves the whole self. A happy learner does better. MBE says the brain responds better to joy than to fear. It also emphasizes the use of the five senses in learning. As students are meaningfully engaged in learning that has fewer negative motivators, students will be happier and freer to take risks.

There are three elements of gamification that specifically relate to this maxim. The first is accumulative grading. The traditional grading system is punitive. A student enters the class with 100% of the grade but loses points across each assignment. This gives a sense of losing. It uses a negative motivation component of fear. Students fear they will lose too many points for their desired grade, so they work hard not to lose points. Accumulative grading has students begin the class with 0 points. Each task earns points, so grading is no longer subtractive. This reverses the psychological element with positive motivation. It is more pleasant to see a grade grow than shrink. Levels help to support this feeling of growth and progression. This gives a positive psychological boost to learners. Also, the ability to resubmit assignments to earn full points eliminates the fear of subtractive grading because students have a second chance of getting their full points.

4.3.6 Maxim 24 performances of understanding

The brain desires recognition of understanding. This happens through creation of products that are visible and demonstrative of students' knowledge. As students learn, they should produce products that represent their level of mastery of what is being taught. In MBE, it is understood that each student is unique with their own way of thinking and processing information. So, tasks that students produce should be adaptable so that individuals and/or groups can produce work that is unique to those learners. MBE also advocates for building upon learners' previous knowledge. As tasks are flexible for students and adaptable to build upon unique life experiences and diverse cultural differences, the tasks become more meaningful and conducive to how the brain processes information. Finally, these tasks should be organized in a way that allows students to progress logically from easier concepts and ideas to more complex ones. Good instruction is adaptable to student differences while building upon their unique prior knowledge and organized in a way that will build from easier to harder. All this should be done while providing demonstrable products that can be recognized visibly.

One very common way to implement gamification is through badging. Badges are visual representations of learning, or as NeuroELT states, visible "performances of understanding". Badges visually recognize objective completion and achievement. The tasks created to earn each badge should be adaptable to accommodate the uniqueness of learners. They should allow for personalization of tasks to build upon each learner's previous knowledge. The organization of badges should provide a clear progression of difficulty. The nature of most badging systems have smaller badges that are earned, often for microskills. When the set of these badges are earned, this can qualify learners for a more complex task to earn a more advanced badge. Hence, there is a visual representation of understanding and clear progression from easy to hard provided by this style of gamification.

4.3.7 Maxim 25 assess in three ways

Assessment from the teacher should be the culminating assessment. Prior to that experience, students should self-assess and engage in peer assessment. Utilizing the three types of assessment creates a culture of metacognition and learning from errors. MBE posits that the brain learns from errors. Errors happen and in the process of fixing those errors, learning occurs. Further, this use of self and peer assessment provides a personal environment where people have a voice for why they believe tasks should be done the way they are. This can also inspire changes and further steps to be taken, which is in sync with tailoring education to the uniqueness of each learner.

There are a few features within gamification that can be utilized to increase the metacognitive aspect of assessment and error correction. The do-over options on assignments are very helpful to provide additional and personalized feedback to students at the moment that they are most receptive. Ideally, students use the benchmarks for each assignment to evaluate if the assignment meets the objectives set. In group tasks, students give peer feedback as they prepare tasks for successful submission. If the submission is not successful, the student or group of students receive timely feedback and then self-assess and strategize to better meet the set objectives.

4.3.8 Maxim 41 encourage mistakes: Celebrate mistakes

Errors should not be viewed negatively. The natural process of learning involves unsuccessful attempts. If a student does not make mistakes, they are not taking risks, and thus are not maximizing their learning. Embracing errors and using them as learning opportunities is at the heart of both NeuroELT and MBE.

A central tenet of gamification is learning from doing, making mistakes, learning from mistakes, and fixing the problem. The use of accumulative grading deemphasizes the grade by focusing on the increase in points versus highlighting their subtraction. The allowance for do-overs contributes to a culture that does not penalize errors, but instead uses them as an educational tool.

4.3.9 Brain-friendliness and potential challenges of gamification?

While gamified learning shows the potential to promote a brain-friendly classroom, questions nevertheless remain about the implementation of such an approach particularly given the overall impact of technology on the classroom setting. Anderson and Rainie [22] noted that today's networked lifestyle leads many learners to seek instant gratification and quick choices, resulting in a lack of patience. Such need for immediate satisfaction diminishes the desire for long-term engagement as with traditional modes of education (i.e., top-down, teacher-fronted methods), making it increasingly difficult to maintain learner interest without the compulsion to engage in constant internet activity.

Although a premise for inattentive learning is possible with any form of novel educational approach, gamified learning, when carefully incorporated into course objectives, can serve to provide the type of intense, goal-focused activities that embrace higher dopamine levels driving the brain-friendly classroom. As further developments such as AI and the evolution of the VR world create new ways to implement gamification in the classroom, teachers will be continually called to reflect on gamified approaches to teaching and learning in light of the neurobiology of learning. In this respect, this chapter serves as a call for further discussion on additional brain-based maxims that underpin the use of gamification technology in the classroom.

5. Conclusion

As research in the fields of neuroscience, pedagogy, psychology, and linguistics advance, there are exciting findings that help to better understand the nature of teaching and learning. The culmination of this research and effect of the increased understanding of how the brain functions and learns best should result in modifications being made to how education is structured and provided. Without the proper application of this emergent knowledge, education does not improve. Using this transdisciplinary approach towards informing best educational practices is essential.

Recent research from Rueckert et al. [15] and other gamification scholars provide strong evidence that gamified instruction is not just a novelty to pique the interest of students, but a modality that is more congruent with how the brain learns. Changes in how instruction is delivered and organized are hard to implement [23]. However, a change towards a more brain-friendly learning system, such as gamification, should be embraced.

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References

[1] Extra Credits. Gamifying Education—How to Make Your Classroom Truly Engaging [Internet]. 2011. Available from: https://www.youtube.com/watch?v=MuDLw1zIc94. [Accessed: May 5, 2022]

[2] Extra Credits. Gamification—How the Principles of Play Apply to Real Life [Internet]. 2011. Available from: https://www.youtube.com/watch?v=1dLK9MW-9sY. [Accessed: May 5, 2022]

[3] Sheldon L. The Multiplayer Classroom: Designing Coursework as a Game. 2nd ed. Boston, Massachusetts: CRC Press; 2020

[4] Kapp K, Blair L, Mesch R. The Gamification of Learning and Instruction Fieldbook. San Francisco, California: Wiley; 2014. pp. 23-26

[5] Kapp K. The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education. San Francisco, California: Pfeiffer; 2012. pp. 93-98

[6] Utkir M, Nilufar K, Ra'no I, Kuchkeldiyeva U. The role of motivation in learning foreign language. The American Journal of Social Science and Education Innovations. 2020;**2**(12):14-21. DOI: 10.37547/tajssei/volume02issue12-04

[7] Jayalath J, Esichaikul V. Gamification to enhance motivation and engagement in blended elearning for technical and vocational education and training. Technology, Knowledge, & Learning. 2022;**27**(1):91-118. DOI: 10.1007/s10758-020-09466-2

[8] Azzouz Boudadi N, Gutierrez-Colon M. Effect of gamification on students' motivation and learning achievement in second language acquisition within higher education: A literature review 2011-2019. The EuroCALL Review. 2020;**28**(1):57-69. DOI: 10.4995/eurocall.2020.12974

[9] Delello J, Hawley H, McWhorter R, Gipson C, Deal B. Gamifying education: Motivation and the implementation of digital badges for use in higher education. International Journal of Web-Based Learning and Teaching Technologies. 2018;**13**(4):17-33. DOI: 10.4018/IJWLTT.2018100102

[10] Bovermann K, Bastiaens T. Towards a motivational design: Connecting gamification user types and online learning activities. Research and Practice in Technology Enhanced Learning. 2020;**15**:1. DOI: 10.1186/s41039-019-0121-4

[11] Homer B, Raffaele C, Henderson H. Games as playful learning: Implications of developmental theory for game-based learning. In: Plass J, Mayer R, Homer B, editors. Handbook of Game-Based Learning. The Massachusetts Institute of Technology; 2019. pp. 25-52

[12] Bradbury A, Taub M, Azevedo R. The effects of autonomy on emotions and learning in game-based learning environments. In: 39th Annual Meeting of the Cognitive Science Society. Austin, Texas: Cognitive Science Society; 2017. pp. 1666-1671

[13] Poltronieri F. Communicology, apparatus, and post-history: Vilem Flusser's concepts applied to videogames and gamification. In: Fuchs M, Fizek S, Ruffino P, Schrape N, editors. Rethinking Gamification. Luneberg, Germany: Meson Press; 2014. p. 165

[14] Tokuhama-Espinosa T. Mind, Brain, and Education Science. New York, NY: W.W. Norton & Company, Inc; 2011. p. 206

[15] Rueckert D, Pico K, Kim D, Calero SX. Gamifying the foreign language classroom for brain-friendly learning. Foreign Language Annals. 2020;**53**(4):686-703. DOI: 10.1111/flan.12490

[16] Copaert J, Spruyt E. Toward a task design model for mental acceptance and motivation: A transdisciplinary approach. In: Simons M, Smits TFH, editors. Language Education and Emotions: Proceedings of the Third International Conference on Language Education and Testing. Antwerp: University of Antwerp; 2018. pp. 148-155

[17] Frith C. Making up the Mind: How the Brain Creates our Mental World. Oxford: Blackwell; 2007

[18] Murphy R. The 50 Proposed Maxims for ELT [Internet]. 2016. Available from: http://fab-efl.com/page15/index.html

[19] Schultz W. Neuronal reward and decision signals: From theories to data. Physiological Reviews. 2015;**95**(3):853-951. DOI: 10.1152/physrev.00023.2014

[20] Murphy R, Stubbings C, Uemura T. NeuroELT perspectives: Directed motivational currents – theoretical, experimental, and pedagogical research. University of Kitakyushu Kiban Center Journal. 2017;**29**:19-135

[21] Pujol J, Soriano-Mas C, Sebastian Galles N, Losilla J, Deus J. Myelination of language-related areas in the developing brain. Neurology. 2006;**66**(3):339-343. DOI: 10.1212/01.wnl0000201049.66073.8d

[22] Anderson J, Rainie L. Millennials will benefit and suffer due to their hyperconnected lives. The Pew Research Center's Internet and American Life Project. 2012. Available from: http://www.pewinternet.org/reports/2012/hyperconnected-lives/overview.aspx

[23] Sarmiento B, Hernandez-Prados M, Carbonell Bernal N, Aguaded GM. Alfabetizacion del profesorado en gamificacion mediada por las TIC. Estado del arte. Media. Education. 2021;**12**(1):53-65. DOI: 10.36253/me-10262

Chapter 7

Creating Effective Management Simulations: Rapidly, Responsibly, Relevantly

Gordon Fletcher

Abstract

This chapter presents a critical discussion of the current state of management simulations and considers this specific genre of software against the backdrop of wholesale gamification of activities within organizations and the widespread popularity of games that are available for a variety of computing devices. These two contemporary phenomena are presented as a tension to current management simulations that require synthesis. The chapter then progresses to an exploration of the possibility of a systematic approach to consistently define management simulations that encourage academic involvement through the authorship of games as well as building an aspiration to make simulations more "game-like" in their interface. The purpose of this approach is multiple. It provides a consistent framework that helps to democratize the creation of simulations, provides an input language around which developers can then develop multifunctional simulation platforms and engines, and, more speculatively, provides a solid platform on to which additional layers of visual "game" play can be developed. Being able to package the essence of a simulation into a distributable file that can be used interchangeably at other institutions also encourages wider use of simulations as the key kinesthetic form of learning within management education.

Keywords: gamification, management games, management simulations

1. Introduction

The many opportunities for incorporating gamification within everyday life and the advantages that it brings are an important rationale for the increasing digitalization and digital transformation in all aspects of work and play. Gamification encourages purposeful engagement with a product or service for longer periods of time than might otherwise happen. Through apps such as Strava, our personal leisure time has been gamified, and Microsoft Viva tries to create the same emotional and even competitive responses with our work Outlook calendar.

Gamification is possible as part of everyday activities because of two closely interrelated phenomena. The first phenomenon is the widespread process that has driven the digitalization of "serious" products and services, enabling a systematic unpicking of processes, the sequences of actions and activities that can be isolated and manipulated. By viewing work and play as a sequence of smaller and more granular activities, it is possible to then attach numeric values and weightings to each undertaking and completing each activity in ways that create scores. Individual scores and relative rankings can then be shared through social media. A score or ranking is a more self-contained unit of comparison than the explanation required for all the actions that brought you to that outcome. Searching for "Strava rankings" through Google will even directly embed the top three cyclists in "Distance Leadership" on its results page. Achievements of this type can also become badges to permanently share through social media. Within the world of work and through the Open Badges system, LinkedIn enables professional success to be displayed in this way too.

An exemplar of the process of digitalization and the opportunities that this process brings is found in the move away from using physical media in the distribution of films and music. Shifting music consumption patterns onto a streaming service enables new music to be recommended based on listening preferences and enables everyone to have their own entirely personalized radio station. A user experience that effectively describes the product that is Spotify. Popular music is one example of gamification that existed prior to widespread digitalization. Because sales, downloads, or listens can be measured so readily that the use of the weekly music charts has existed for over 70 years. And Spotify has a range of charts to introduce a form of light competition across multiple dimensions of artists and songs that now includes a "daily viral song" chart. As such an integral aspect of popular music, it is sometimes difficult to recognize the long-term presence of gamification. But music industry also introduces an important lesson about the benefits of gamification. Gamification can reflect back positively on the core business by driving new sales and introducing greater awareness of new artists. Gamification does not necessarily work well if it is "tacked on" without thought and cannot clearly offer additional value for the end user.

The digitalization of core products and services benefits from being supplemented with additional digital assets, including badges, scores, and unlockable extras. But, briefly, moving away from consumer gamification there are similar benefits for the application of gamification within the internal operations of an organization. As consumer technology shows, turning an activity into a score enables comparison and inevitably, competition. Introducing a scoring mechanism can be a way to motivate people to retry actions to improve which can, in turn, improve overall efficiency and productivity. This is particularly useful in situations where repetition is necessary to bring mastery. It should be stressed that solely repetitive roles are those most likely to be automated. However, mastery within a role that includes variability and change is building the capacity to deal with the one-in-a-hundred, one-in-a-thousand, and one-in-a-million situations when they arise and being able to recognize these situations in the future. Within a work environment introducing a form of scored competition can encourage teams to compete in ways that improve overall performance and encourages knowledge sharing between team members to improve personally and collectively. The Leagues.ai system does exactly this. By providing a mechanism for competition at granular levels of the organization, it is possible to reward strong individual performance on a weekly basis. Over longer periods of time the Leagues.ai system can provide a rank order of success that imitates the team ranking table in a football or a cricket league.

Working alongside the new opportunities offered by the digitalization of "serious" goods is the second phenomenon that makes gamification possible; a proliferation and wide-ranging continuum of games. There is a vast array of "idle games" or "clicker games" that are downloadable from the various platform app stores for playing on mobile devices or directly accessible for play through a browser window.

This specific genre of the game relies on the primary mechanic of clicking on items to use them in some way. Clicking generates an in-game income that can be increased by spending some of this income on upgrades. This is why the games are sometimes described as "incremental games". This category of games employs three significant mechanics that are also highly relevant for gamification within other domains. In these games, there is a reward for returning, there is a push to leave (in order to return), and the dynamics of the game will shift as a player improves their experience and knowledge of the game [1]. These three elements can also be found in the application gamification tactics either singly or in combination across many examples. The creator of one of the best-known incremental game, AdVenture Capitalist, has documented the maths behind these games. In describing the variants around the exponential growth found in the games there are also indications of how the three key mechanics of clickers are embedded within this code [2]. In order to keep players coming back despite the relatively simple mechanics. These are games that have had the principles of gamification reflected onto themselves. Clicker games can also make good business. The *Idle Heroes* game was reported to have achieved US$70 m in net revenue in its first two years of availability [3].

However, these numbers pale in comparison to the "serious" games that require the advanced computing power of a dedicated games console or PC. The headline numbers show the scale of these activities with a global industry worth US$300 billion and 2.9 billion active users [4]. A more startling finding is that gamers, on average, spend 16 hours a week playing games and another 8 hours watching gaming streams [4]. The speculation from the industry is that these numbers will also continue to grow. With a third of the global population engaged in gaming and with an inevitable distortion in favor of the 70% of the world population living within developed economies, games are everywhere. All these figures indicate that games are a key aspect of popular culture and everyday life.

While the prevalence of gaming is impressive there are also strong indications that engagement with games is clustered more heavily among younger people. The uptake of a relatively simple word game, such as Wordle, offers a somewhat surprising indication of this bias and challenges the assumption that this simple word puzzle game might be more popular with older people. With 300,000 daily players in the US, the generational differences are noticeable. "In total, 26% of respondents in the [millennial] generation said they play "Wordle," compared to 18% of Gen Zers and 9% of Gen Xers. Just 5% of baby boomers are playing the game." [5]. Perhaps indicating different preferences for consuming and accessing games, the private British Broadcaster ITV reintroduce its gameshow "Lingo" in 2021 based on the success of Wordle and a full 33 years after the original 10-episode run, which was a licensed format taken from the US television. With a free-to-air broadcast time in the UK of 3 pm, the show is presented for primarily an older audience or those with home caring responsibilities.

The value of gamification rests on these twin pillars that see the digitalization of "everything" and the dominant role of games in popular culture. The benefits of successful gamification are significant as any product or service will benefit from increased engagement and long-term connections with its target audience.

2. The challenge creating by management simulations

A key area of activity where there is a continuous need to create effective and meaningful engagement is higher education. Within higher education, the various disciplines have developed a heritage of ensuring engagement with students that works at an immediate level, when the student enters education and still has relevance within their future careers. The pedagogic engagement is aligned with professional outcomes [6] and tends to sit within kinesthetic modes of learning rather than the more commonly used straight reading/writing or auditory modes. Put more simply, it is the Bunsen burner effect enjoyed by chemistry. A student walking into a chemistry lab on their first day is excited by a subject that lets them burn things. While the Bunsen burner may not figure a part of every lesson, it is symbolic of the discipline and may continue to be used by a graduate if they continue to work in chemistry. Similar examples can be found in other areas of higher education. At one point, there was a tradition in some universities offering aeronautical engineering courses that graduating students would build a wind tunnel as almost a form of a rite of passage. New students benefitted, as they had wind tunnels to place their new models into. It may be apocryphal, but there are claims that this graduating practice fell out of favor because the cumulative result was too many wind tunnels in the department.

The Bunsen burner effect can also be seen beyond the sciences. Theater and drama students have studios and theaters to practice and perform. In some universities, because these facilities were developed as part of recent new builds, the quality and capability of the spaces exceed in quality anything else available in the local area. In the area of health education, the use of patient simulators has extended beyond CPR dummies and covers areas including midwifery and the correct placement of monitoring devices. The concept of clinical simulation is an important tenet of nursing education where the reduction of risk and the avoidance of errors in real situations is essential. One curious indication of how embedded the use of patient simulators has become is the thriving second-hand market on sites, such as eBay, for antique and unusual examples.

Creating the Bunsen burner effect for business education brings several challenges. Although sometimes presented as a single discipline there are multiple bodies of knowledge to understand. To matters worse, these bodies of knowledge also span from the most qualitative to the most quantitative. While economics is regarded as a major intellectual contributor to the wider realm of business there is no one aspect of the body of knowledge that necessarily dominates. The learner is often guided to choose their —own specific priorities and preferences all without a Bunsen burner effect in sight. The UK makes use of subject benchmark statements, in an effort to create light touch uniformity across all degree awarding institutions. For business and management, the 2019 statement summarizes a three-point purpose for degrees in this area, as given below:

- Increasing understanding of organizations, their management, the economy, and business environment.

- Preparation for and developing a career in business and management.

- Enhancement of a wide range of skills and attributes, which equip graduates to become effective global citizens [7]

While there is a constant revision to the statements it is unlikely newer versions will shift noticeably from this intentionally vague, career-orientated but nonetheless worthwhile statement of purpose.

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Further into the statement, however, the topics of knowledge and understanding that a business and management graduate should be able to exhibit are made more explicit. These is an extensive list: markets, marketing and sales, customers, finance, people, organizational behavior, operations, information systems and business intelligence, communications, digital business, business policy and strategy, business innovation and enterprise development, and social responsibility [7]. There is no expectation that graduates have equal knowledge of these thirteen or seventeen categories as many are interrelated. But despite this interlinkage, the list also emphasizes the breadth of knowledge expected of a graduate in this field. The list of expert skills that are expected to manifest within a business graduate is also impressive. The list covers seven or ten quite divergent capabilities: people management, problem-solving and critical analysis, research, commercial acumen, innovation, creativity and enterprise, numeracy, and networking. Graduating with the knowledge and skills expected by the benchmark statement does help to explain why business degrees are sometimes regarded as being general-purpose or even generic degrees but perhaps they are better seen as multipurpose.

The challenge that comes with such a broad range of topics and skills is that few Bunsen burner effects emerge with topics that can largely be taught in a traditional or online classroom. Students new to business studies can also bring many misconceptions to this classroom, driven by their own consumption of mainstream media representations. The HBO series Succession or the Netflix series Ozark may shape their understanding of how business works, it may even have been viewed by the prospective student as a type of documentary. A distorted and exaggerated representation of businesses permeates media consumption from an early age, for example, with the Krusty Krab, through to media requiring viewer discretion, such as Los Pollos Hermanos. There are most certainly lessons to be learned in all these examples that align neatly with the subject benchmark statement, but no business degree exclusively uses the deconstruction of popular media representations of business to deliver their intended learning outcomes. Teachers and academics will tend to focus on issues, examples, and concerns that are currently pivotal or were perhaps contemporary during the period of their own studentship. If the academic has actively engaged in research of the topic, they will tend to use this material in the classroom too. In 2018, the UK communications regulator Ofcom conducted research to identify news consumption patterns. Of the 12–15 age group, 40% indicated little or no interest in the news, but 53% said it was "important to know what is going on." However, the most interesting news topics for this age group were sports (19%) and music (18%). Although this age group cited Facebook (34%) and YouTube (27%) as popular new sources only 34% thought that social media sources reported content truthfully [8]. This milieu of perspectives can create a frustrating session for an academic trying to bring some contemporary issues into a first-year business studies classroom.

These gaps in perspective need to be bridged to deliver effective teaching that will translate into contemporary learning. But a classroom environment does not reflect any graduate's day-to-day reality. At this point business educators often turn to management simulations for a solution but the prevalence of games in everyday life and the potential misnomer of "business games" then opens up a chasm. Students are offered what appears to be a Bunsen burner moment with the tantalizing use of "games" only to be disappointed by—depending on the simulation being used—a clunky, nonintuitive interface that they must first be trained to use before they even begin playing a "game."

Business simulations have a long history of merging the need for understanding key concepts within the framework of current and future issues. Although it may seem outdated now, MIT's Beer Game from 1960 sets the tone for most subsequent simulations being used today. This heritage brings challenges. Reflecting this sixty-year heritage most business simulations present a user interface that will invariably feel dated to an audience who are daily immersed in the rendered game worlds, slick apps, streaming videos, and dynamic content. Almost all existing simulations are designed with pre-set values and built for a single disciplinary standpoint among the 13 or 17 options found in the subject benchmark statement. These simulations generally used fixed calculations and present a pre-configured scenario with set decision points. More recently introduced products have brought greater ability to "tweak" some values but generally only modestly in order to not overly disrupt the core scenario. Most management simulations can be characterized as standalone opaque-box software with variable capabilities to integrate with institutional Learning Management Systems (LMS).

Although somewhat of a tangent to the main thrust of discussion, the relatively slow evolution of management simulations in contrast to the development of entertainment game genres, does also reflect the absence of critical software studies within academic discourse. Examination of software as an artifact of the organization and the cultural conditions that built it is a fruitful but under-recognized line of inquiry. The tendency is to examine individual pieces of software as separate phenomena characterized by the descriptions of sales volumes or active monthly users. Reporting of this type reflects the assumed neutrality of software that pervades mainstream thinking. However, the software does shape opinions and perspectives. This can be evidenced by a variety of examples from social media where the anonymity of the 4chan system enabled the origins of the QAnon conspiracy theory [9], the use of the 3½" floppy icon to indicate the save function on even the most recent user interfaces despite not being in common use for 20 years [10] and then consider how during the COVID-19 pandemic people would always complain when asked to use a video-conferencing software that was the not *first* one they used [11]. The general basis of resistance was that it was not simple or intuitive enough in comparison to their favorite–first–video conferencing software they experienced. For the student of business taking a critical view of software is beneficial [11]. Many management simulations exist and these cover the full range of knowledge areas they must cover. As different products are offered by different companies there is no consistency of user experience between titles in this genre of software and there is often a need to "train" the learners on every new simulation they encounter.

The productization of management simulations means that few institutions now have the capacity or infrastructure to create their own simulations. Instead, they must identify the best possible fit from among available titles and either work with that existing configuration options or possibly pay additional fees to enjoy customizations that make the simulation closer fit the curriculum requirements. In a period when work to decolonize the curriculum [12] is receiving renewed and reinvigorated attention this lack of flexibility will eventually force more rapid evolution among simulation software vendors.

As it currently stands and much to the disappointment of many first-year learners, a business "game" is not what they expect.

3. The anatomy of a management simulation

Software tends to be judged by its user interface. This is an important part of all software and is why software engineers undertake user experience and user interface testing. But beneath the interface exists the code that manages the other aspects of all software. For management simulations, this code performs a relatively limited number of actions. The decisions being made in each turn are received from user input–usually a straightforward Web form-like interface—and formulaic calculations are applied. Some calculations will be informed by previous decisions made at earlier turns; some calculations will have random influences introduced to the calculation. These random influences can be as simple as a random number generator function between a specified range being applied in each turn. Some vendors also claim real-world influences can be incorporated into their simulation such as historical Nasdaq data.

At the core of a simulation are the calculations that it performs on the user's decisions and subsequent input. The calculations are represented through a variety of algorithms that have been documented in a significant body of literature [13] that particularly covers supply, demand, marketing, and finance. However, the body of literature also reveals that for some calculations there is no definitive scholarly agreement about which algorithm correctly models the observed experience. Beyond this level of scholarly debate, experiments have been conducted with business students that purposefully inserted faulty algorithms into a simulation. The conclusion of this research was that players were unable to detect the error and the error's presence had no impact on the quality of their economic performance [14]. In many ways, this conclusion confirms the opaque-box nature of simulations as students—or instructors—cannot see which algorithms are being utilized or when. It is a real consideration as to whether algorithmic validity is simply assumed when institutional purchasing decisions are being made, or whether algorithmic validity is only one aspect of the many considerations within the experience of the overall game world irrespective of the user interface [14]. Since the mid-2000s the number of academic papers discussing algorithms for management simulations have declined significantly. Two potential speculations regarding this decline are possible: the algorithms are now business sensitive to those companies productizing management simulations, and more generously, the algorithms that are being used are well-documented through conventional literature within the specific area of knowledge. This later speculation could be regarded as true for many common functions that are applied in everyday business, such as the power function and the price elasticity of demand. But as an opaque-box what specific algorithms are being used are obscured from the academic and their learners. The original Beer Game is perhaps a rare example of a largely transparent simulation, but this is partly a result of its longevity and relative simplicity. It is primarily based on the Bullwhip effect and the goal is to try and manage available resources on the wholesale side to minimize the amplifying effect of small changes applied on the retail side.

A common linkage between the Beer Game and many of the more recent developments is their connection to system dynamics thinking. That is a systems-based view of organizational activity that examines long-term change to recognize the functions of a system in order to abstract regular models of observed behavior. A system dynamics approach lends itself to algorithmic validity precisely because of this abstracted nature. While the algorithms will not model precise day-to-day behaviors, the tendency will be to provide an accurate outcome based on the received inputs. Many of the algorithms are relatively "simple"—with the benchmark for "simple" being the ability to recreate the algorithm as a formula within a single cell in Excel. But no commercial management simulation enables an individual installation to "tweak" existing underlying formulas or to completely replace the preferred option with an alternative perspective. The 30,000 papers regarding the bullwhip effect on

Google Scholar offer the clear suggestion that there have been some refinements to the concept and its representation since the Beer Game was first introduced. Although some of these papers are also admittedly and effectively formal academic documentation of how to win the Beer Game. This specific body of work could be seen as a marker of how effective, debated, and engaged with that this particular simulation has been across its lifetime.

While software-based management simulation provides the kinesthetic learning and Bunsen burner effect for business students, there is one further example of a more practical experiment from the 1970s that goes beyond being the computer interface of a simulation to becoming the reality. It is notable that the project, directed by Stafford Beer and a cybernetician, came from a different intellectual tradition than that of system dynamics. This is a sufficiently different enough community of practice to have already seen Beer create an analog computer in the 1950s out of a pond with scientist, author, and artist, Gordon Pask [15]. Beer's published work in cybernetic theory as well as related topics and practical work with United Steel, SIGMA, and the International Publishing Company all brought Beer to the attention of the new Allende government in Chile [15]. By 1971, Beer was in Chile working with the government building project Cybersyn to coordinate the many newly nationalized industries [16]. Project Cybersyn was closely modeled on Beer's theorization of the viable system model, which present a specific model of how the parts of an organization relate to one another and to the external world. Beer applied these principles to create a centralized control room—echoing the title of his book that had first attracted the Allende's government's interest, "the Brain of the Firm." [17] The control room received daily reports from individual industries, including farms and mines, that reported on outputs and other key metrics. Within the control room decisions were then made through a strategic lens considering the current prevailing international and domestic political and economic conditions. Most importantly individual production decisions were made with fuller knowledge of national conditions, including upcoming peaks in demands or changes to government policy. The resultant decisions were then conveyed back out to the different elements of the economy controlled by the government. In some cases, this may have been an instruction to reduce production or even to call for a temporary cessation of certain activities. Cybersyn used the latest technology of the period with custom-designed chairs for the control room—that oddly echoed those of the Star Trek television series a decade earlier—and Teletext machines to enable immediate nationwide communications [16]. In fact, Cybersyn was itself four sub-projects; Cybernet, the national network of telex machines, Cyberstride, the software system that created alerts when a variable fell outside an acceptable limit, CHECO, an attempt to model the entire Chilean economy, and the OpsRoom, the control room at the center of the system and based on the concept of the war-room with seven chairs facing each other representing separate elements of the economy that were being reported [18]. Ultimately, Cybersyn is an unfinished and unproven experiment as the Allende government was soon overthrown in a military coup, and Beer was forced to flee Chile.

The Cybersyn approach is instructive for a rethinking of management simulations in the way that it (necessarily) separates inputs, decisions, actions, and outcomes. The management simulation puts the student into the control room where they can see their decisions produce consequences in terms of resultant short-term and longer-term outcomes. The unfinished and inaccurate CHECO sub-project [18] also reinforces how difficult it can be to accurately define multiple models of different aspects of an economic situation that must also necessarily interact with each other.

Sometimes, any decision is better than no decision, particularly in an environment that is permeated with incomplete data. The Cybersyn experience also raises a more mundane question for management simulations. This is a question of the default settings offered for each decision at each turn. Many simulations may force a student to make a decision each turn with a blank input box or a slider set to zero. Some simulations will use the student's previous inputs as the default for their next turn—even if other circumstances have subsequently changed. Far fewer simulations will offer a "median" default option that would provide a "steady state" outcome for the turn being played. This approach would mean that the most neutral response would neither disadvantage nor advantage a student unexpectedly, something that is possible in the other scenarios for setting default values. This perverse situation can be occasionally spotted in practice too, when a simulation that uses the input of other students to calculate the current environmental situation accepts extreme inputs from disengaged students (such as "0") and unwittingly rewards them as inaction was ultimately, and unexpectedly, the most suitable decision for that particular turn.

These examples all highlight different ways in which simple algorithmic validity is not the sole or even primary basis for a successful simulation. The way the game world is created and enables students to interact and compete with one another are equally crucial factors for a successful simulation. These are the gamification elements found inside a simulation. But even these considerations still ignore the way a simulation might actually be played as a game in the way that it might be popularly understood outside a university environment. The majority of simulations are text-based affairs with inputs based on variants of HTML based forms, for example, radio buttons, checkboxes, dropdown menus and free-text boxes. There is a general absence of a rendered, flowing or interactive game world.

These are the multiple areas in which all management simulations need to progress. But also important is the need to re-introduce the capability for academics to create simulations for their own specific needs rather than needing to resort to a productized and generalist simulation that best matches their requirements.

4. Rapid, responsive, relevant simulations

Confronted by the many challenges facing a business academic to bring a relevant simulation rapidly into the classroom, it is possible to see why some give up, some accept the nearest match to what they need, and some will accept whatever was offered on the syllabus last time around. It is by no means laziness on the part of the academic but a diminished capacity to deal with technologies that they are unfamiliar with, navigating internal approval systems to purchase something new, or having the time to understand the different forces being modeled in each new simulation. Change, in this respect at least, in terms of pedagogic practice is incredibly difficult. These are the many factors that are already at play before any consideration is given as to how new students may receive any form of changes being made to their learning experiences. While a new management simulation may bring quantifiable improvement on the previous syllabus there will still be a need to accommodate and adjust student expectations to decouple the association of simulation in management education from their perceptions of game-based simulators or games in general. The reality is that, in terms of the student experience, the clock can only be reset to zero with every new delivery not many have deep and sweeping change may be in contrast to the previous delivery.

The solution to the many issues raised by this current situation is not a simple, neat, or pretty one as it necessarily exposes the workings of a simulation beyond the attention of the developer alone. It could be argued to also be an idealistic one that expresses a preference for open access and open-source forms of working in preference to a closed proprietary system. The solution also requires more organizations to work together and interact then it is currently the case within the productised world of packaged software genre of management simulations. However, this level of transparency and collaboration is itself an appropriate way to transact contemporary business and focuses on the adage that you concentrate on what you do best. That is, academics are good at knowledge exchange and software developers develop systems that can enable this knowledge exchange. The solution is represented by four separate layers of activity and development. Each layer is independent of the other and can certainly function independently without knowledge of one another. Separating these four layers of activities enables existing organizations and individuals involved with management education to potentially contribute their own specialism without having to become specialists in any one of the other layers. Importantly, academics can (once again) become engaged with the creative process of building simulations by contributing their own existing knowledge without having to become technicians or developers. The additional benefits of this layered ecosystem are clear in contrast to the existing packaged software approach.

The four layers described in this proposed solution for a simulation ecosystem are the story layer, the simulation description layer, the decision-making layer, and the visualization layer. Each of these layers is presented as part of a dynamic simulation ecosystem.

4.1 The story layer

The story layer is the ideation layer of a simulation. It exists within completed research, case studies, and within the experiences of those creating the simulation. The story layer already exists through a range of resources, including the UK's Case Center (thecasecentre.org), where thousands of different business case studies are curated and made available (for a fee) to students and academics. The value of cases as the core story for a new simulation is that they are relatively brief and, in the written form, they then follow a consistent structure. Importantly, business cases are not complete stories. "The case must quickly pull the reader in and force them to think about what they would do and why" [19] and "the most common mistake that new case writers make is that they think a case should be a story from the start to finish. In fact, it should be half a story. Students should be left asking, what am I going to do now." [19] One of the reasons for the success of business cases in the classroom is the similar kinesthetic responses it provokes in students to that of a simulation—it asks them to do something rather than wait for the teacher's next statement or observation.

The story layer sets out the environment, the constraints, and the general context in which the activities are occurring and then makes the student decide on the subsequent course of action. Most case studies ask for one set of decisions from students, possibly from a range of different variables. Working through a case study in a classroom equates to playing one turn of a simulation. The experience without the burden of software is a test of the story and its viability as a full-blown simulation. A simulation would continue the decision-making across multiple rounds and often pit the consequences of the students' decisions against one another, presuming that they comprise the entire universe of external factors. In this way, running through a story is the starting point for constructing a game world reality rather than becoming enmeshed in a cycle of algorithm modeling and testing.

Stories can also be generated through other techniques too. In the classroom, a story can take shape through techniques, such as science fiction prototyping [20] or the Lego Serious Play methodology.

Simulations can find inspiration from within any story and become the narrative basis for the subsequent actions. Having a human frame of understanding and incorporating the flourishes of individuality helps to flesh out a game world and make it more real to those who will participate inside it. Being able to introduce local landmarks, local personalities, or names into the story can help to contextualize the learning and make the impact of their own decision-making within the game world seem more real and significant.

4.2 The simulation description layer

The description layer of existing simulations is locked away within proprietary software. This is the primary layer of existing simulations as it shaped the way that decisions made by students will be transformed through algorithmic manipulation based on a specific formula.

The proposed open-source description layer utilizes the advantages of creating an XML document that could be verified against a consistent XML Schema (XSD). The initial structure for an appropriate XSD has been shared on GitHub [21] by the author as a starting point for further development and discussion. The principle in play is one of simplicity, transparency, and a gradual handoff to the more technical elements of a more sophisticated management simulation engine. An XML document describing the simulation is a text-based document and can be edited by any text editor by multiple authors. The XML contain tags, similar to the way that HTML can be read by a browser to render web pages. In this case, the tags are specifically relevant to defining management simulations. A "storyteller" could easily recognize many of the elements of the XML document and assist to document their simulation in more structured way.

The core set of three tags <steps>, <variables>, and < formulas> are the key building blocks for the simulation. These tags contain further tags. Inside <steps> are <step> tags. Each <step> or turn of the game is defined in this way. Within each step, there is a < narrative> tag that explains the story so far and provides students with a contextualized understanding of what is happening within the game. Each <step> can contain multiple < decision /> tags. Each <decision/> is based on some student input, some static values stored by the simulation, some calculated outputs from previous decisions made by the student or other students, and/or some generated value that has been generated by the progress of the game including values taken from one of the simulation's defined <influence /> variables. For the student, they would see the <narrative> tag's contents at the start of their turn, and based on the decisions being made in the round the interface would also display the user inputs needed to get the expected student decisions for this turn. The inputs being asked from the student would relate to the variables that the game could not itself complete or calculate. The most likely reason would be the need for an input value required from the student based on the formula being used in each decision and what values were already available. Once the suitable inputs were received the simulation could progress to the next <step> depending on the conditions set by the <dimensions> tag and specifically whether this game was being run in "interactive" mode or not.

The <variables> and < formulas> tags are important to move some of the complexity away from the <step> tag itself. <formulas> contain many <formula> tags and < variables> contain many <variable> tags. Any <formula> will be composed of a combination of <variable>s being brought together to represent specific formulaic transitions that occur at <decision/> within each <step>. The XML Schema does not define where the values are stored or how they might be stored but the implication is that this would be done with some form of persistent storage such as an SQL database available locally or through a cloud-based service. This service would also maintain the logged-in state of the participants (against some form of institutional authentication) and their progress within the simulation itself.

The simulation description layer does exactly what it saysit describes the simulation completely in a single text document. For a simple simulation that runs for a small number of turns, this may be a relatively small document but the structure is flexible and a complex simulation running over many turns may require thousands of lines of description (and represent substantial academic output in its own right).

The description of the simulation sets out the individual steps of the simulation in a structured and consistent manner and in a format that remains largely readable by anyone involved in the design of the simulation. By separating out the <variable>s and < formula>s from each of the potentially many <step>s there is an opportunity to consistently reuse these components throughout the simulation without having to continuously redefine and repeat the same statements many times over.

4.3 The decision-making layer

In combination with variants of the description layer, this layer is found in all existing management simulations. The simulation takes in the decisions from participants through various types of form-like inputs, such as checkboxes and text boxes. The input is then applied to the internal algorithmic model and a response is prepared for displaying before the next round of decision-making. In effect, existing management simulations are this layer alone. In the proposed ecosystem, the decision-making layer does not change in purpose or in the way that it responds. The difference is found in the transparency between the <step>s of the description layer and the actions that are conducted at the decision-making layer. By using a consistent and structured description layer it becomes possible to create a decision-making simulation engine that can read in any similarly consistently formed XML document and then enable the simulation to be played through by an individual, a single group, or as part of global competition.

Decoupling the description of simulation from the engine that can deliver the interaction with a simulation enables a greater level of experimentation, customization, and the refinement of existing simulations (or formula) to reflect changing conditions or to update new academic knowledge in the area.

Using the description layer means that a small "tweak" can be tested in a simulation at steps nine and ten and then the <step>s can be returned to a simple repetition of the original definition used for the first eight <step>s. Defining simulations step by step also consciously encourages creativity by suggesting that influences change and shift over time and do not simply remain static for the convenience of a simulation developer.

Being able to separate the description of the simulation from the decision-making playing of the simulation also creates the prospect that more than one decision-making system might become available, and would be licensed by different institutions but that the descriptions of different simulations could freely be shared between academics and institutions to be used on their own institution's decision-making systems in the same way that a JPEG can be shared fairly between different image "viewing" and "editing" software. This more open environment may also encourage some authors of papers and case studies to define a simulation based on the insight and learning expressed in their research to come out in a more practical and kinesthetic way. Taking this further it may even be possible for an organization to express their own operations in the same manner and encourage students to "play out" different scenarios to find the best possible solution. Students could even be rewarded to find the most effective solution to a particular challenge or blocker that the organization regularly encounters.

4.4 The visualization layer

Those with experience with existing management simulations may argue that the current crop of software also offers this final layer. However, the separation of the visualization layer is consciously done to reflect on the relatively poor gaming experience found within existing management simulations. It is a convenient that students are asked to fill in a form-like interface to record their decisions. This is a convenience that reflects the golden age of the "Beer Game" and the relative lack of progress in this aspect of management simulation development since then. While other forms of casual gaming have mastered the idea of the procedurally generated game world, this is an innovation yet to reach the world of simulations. The act of entering a two-digit number into a text box on a flat screen is one solution to data input. However, procedurally generated game worlds have also discovered many others. Within VR space dialing a floating knob to the correct position, drawing the number in the air with a finger, tapping an in-game device, or covering the chosen number with a suitable virtual object have all been explored in different environments.

Removing visualization from the decision layer also separated the more complex task of generating procedural worlds so that a student could provide input at the appropriate decision points through the keyboard but then move to a VR visualization of the same simulation and provide decisions through other forms of input. While this option appears challenging, projects that are entirely separate from the concerns of management simulations have been working to make this relatively straightforward. A ten-year-old project called CityGen3D developed a plugin for the Unity game creation engine that used 2D map data, such as OpenStreetMap to create 3D cityscapes [22]. The potential is that a simulation expressed through an XML description could be pulled through the decision-making layer and be represented within a local neighborhood render by extrapolation from OpenStreetMap. Given that the types of decisions that are required and the user inputs are already known through the definition layer, the challenge for the designer tasked with creating the visualization layer is to produce suitable input systems that can be triggered within the procedural game world. It could be that students have to go and record their decisions at any of the procedurally generated corner stores, or they have to locate a shared office space where they can record their decisions into the generated PC. Because ensuring the player's ability to generate their input is the only requirement for the visualization layer, a designer can then focus on taking more cues from the feedback of the game's progress to populate the virtual game world with elements that are representative. Perhaps, poor overall progress by all the teams would be reflected by streets more littered, creating higher chances of street violence (making it harder to go and make a decision) or a general decline in the urban environment. Similarly, teams enjoying generally good progress might see improvements in their local environment and even more convenient ways to make their next set of decisions.

As these scenarios indicate, better visualization may also provide players with clearer visual expressions of how good management decisions can have wider social value and benefits (and vice versa) in a way that current management simulations can often struggle to portray. This further expands the value of management simulations—as well as, for example, generally improving the awareness of sustainable development goals—beyond their current capacity.

5. Conclusions

Management simulation is an important aspect of the kinesthetic offering of business education. Management simulations, however, are not currently games in a way that new students would recognize and this mismatch between expectations and reality can be a difficult disappointment to reset once the realization has been made. However, this gap also represents an opportunity (and challenge) for management simulations to become more engaging and relevant for learners. By separating the storytelling, the description, the decision-making, and visualization of the management simulation, it is possible to chart a future for these games that encourages more engagement from faculty to design new opportunities, as well as for students to undertake a wider range of relevant and more contextualized simulations. The major challenge being described here is the urgent need to move management simulations onward from being an outdated genre of packaged software to a transparent and shared practical object of research that can have use impact and application long after the publication of the associated journal paper.

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References

[1] Telfer A. Why you should care about Idle Games, Mobilefreetoplay. n.d. Available from: https://mobilefreetoplay.com/why-you-should-care-about-idle-games/

[2] Pecorella A. The Math of Idle Games, Game Analytics. 2017. Available from: https://gameanalytics.com/blog/idle-game-mathematics/

[3] Kim J. How Idle Heroes made $100M in a Year, Deconstructor of Fun. Available from: https://www.deconstructoroffun.com/blog/2018/2/27/u6ap146ff5rkmm7fj1qzuhggp395l4

[4] Wise J. How much is the gaming industry worth in 2022, EarthWeb. 2022. Available from: https://earthweb.com/how-much-is-the-gaming-industry-worth

[5] Shevenock S. The 'Wordle' Craze Is Largely Driven by Millennials, Morning Consult. 2022. Available from: https://morningconsult.com/2022/01/20/wordle-millennials

[6] Ryan A, Tilbury D. Flexible Pedagogies: New Pedagogical Ideas. The Higher Education Academy; 2013. Available from: https://flexlearnstrategies.net/wp-content/uploads/2013/11/npi_report.pdf

[7] Quality Assurance Agency. Subject Benchmark Statement: Business and Management. 2019. Available from: https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/subject-benchmark-statement-business-and-management.pdf?sfvrsn=db39c881_5

[8] OfCom. News Consumption in the UK. 2018. Available from: https://www.ofcom.org.uk/__data/assets/pdf_file/0024/116529/news-consumption-2018.pdf

[9] Zadrozny B, Collins B. How three conspiracy theorists took 'Q' and sparked Qanon, ABC News. 2018. Available from: https://www.nbcnews.com/tech/tech-news/how-three-conspiracy-theorists-took-q-sparked-qanon-n900531

[10] Oliveri S. The Floppy Disk Save Icon: Visual Language of An Era Long-gone. 2020. Available from: https://uxdesign.cc/the-floppy-disk-save-icon-visual-language-of-an-era-long-gone-93f74efc9f9

[11] Fletcher G. Software. In: Connock A, editor. You're on Mute!: Optimal Online Video Conferencing - in Business, Education & Media. Goring, UK: Bite-Sized Public Affairs Book; 2020

[12] Shay S. Decolonising the Curriculum: It's Time for a Strategy, The Conversation. 2016. Available from: https://worldpece.org/sites/default/files/artifacts/media/pdf/decolonising_the_curriculum-_its_time_for_a_strategy.pdf

[13] Gold S. System-dynamics-based modeling of business simulation algorithms. Simulation and Gaming. 2005. DOI: 10.1177/1046878104272433

[14] Wolfe J, Jackson R. An investigation of the need for valid business game algorithms. In: Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL Conference. 1989. Available from: https://absel-ojs-ttu.tdl.org/absel/index.php/absel/article/view/1857

[15] Gross J. Stafford Beer: Eudemony, Viability and Autonomy, Red Wedge. 2020. Available from: http://www.redwedgemagazine.com/online-issue/stafford-beer-eudemony

[16] Medina E. The Cybersyn Revolution. Jacobin. Available from: https://www.jacobinmag.com/2015/04/allende-chile-beer-medina-cybersyn/

[17] Beer S. Brain of the Firm. Chichester: John Wiley and Sons; 1995

[18] P2P Foundation. Cybersyn. Available from: http://wiki.p2pfoundation.net/Cybersyn

[19] The Case Centre. Case Writing Guide. Available from: https://www.thecasecentre.org/caseWriting/guide

[20] Fletcher G, Greenhill A, Griffiths M, Holmes K, McLean R. Creatively prototyping the future high street. Production, Planning and Control. 2016

[21] Fletcher G. Management Simulation GitHub. Available from: https://github.com/gordonfletcher/managementsim

[22] City Gen3D. Procedural City Generation from Map Data. 2012. Available from: https://forum.unity.com/threads/released-citygen3d-procedural-city-generation-from-map-data.514677/

Chapter 8

Improving the Brain-Computer Interface Learning Process with Gamification in Motor Imagery: A Review

Chongli Gao, Mingyue Xia, Zhehao Zhang, Yongpeng Han and Yaxin Gu

Abstract

Brain-computer-interface-based motor imagery (MI-BCI), a control method for transferring the imagination of motor behavior to computer-based commands, could positively impact neural functions. With the safety guaranteed by non-invasive BCI devices, this method has the potential to enhance rehabilitation and physical outcomes. Therefore, this MI-BCI control strategy has been highly researched. However, applying a non-invasive MI-BCI to real life is still not ideal. One of the main reasons is the monotonous training procedure. Although researchers have reviewed optimized signal processing methods, no suggestion is found in training feedback design. The authors believe that enhancing the engagement interface via gamification presents a potential method that could increase the MI-BCI outcome. After analyzing 2524 articles (from 2001 to 2020), 28 pieces of research are finally used to evaluate the feasibility of using gamified MI-BCI system for training. This paper claims that gamification is feasible for MI-BCI training with an average accuracy of 74.35% among 111 individuals and positive reports from 26 out of 28 studies. Furthermore, this literature review suggests more emphasis should be on immersive and humanoid design for a gaming system, which could support relieving distraction, stimulate correct MI and improve learning outcomes. Interruptive training issues such as disturbing graphical interface design and potential solutions have also been presented for further research.

Keywords: motor imagery, brain-computer interface, gamification, video game, training

1. Introduction

World Health Organization (WHO) claims that over 1 billion people suffer types of disability worldwide [1]. Neurological disease is accepted as one of the reasons causing disability. For instance, stroke attacks more than 20 million people each year and causes 45% of the total to become permanent upper-body disabled [2], without mentioning a significant number suffer from lower limb disability or temporary limited mobility. Although there have been several advanced therapies for neurological rehabilitation, the range of compatible users and the rehabilitation efficiency are still limited. For example, in 2017, Langhorne et al. [3] applied a very early rehabilitation trial (AREAT) among patients who suffered a stroke after 24 hours. However, in the inclusion criteria, patients must have at least a capacity to react with verbal commands. Patients with lock-in syndrome [4] would discover it tough to gain such interventions since injury risks might occur if patients could not timely express whether their bodies are suitable for the training intensity or not.

Brain-computer interface based motor imagery (MI-BCI) has the potential to unlock the potential interaction between these patients with their environment. Motor imagery (MI), imagining kinaesthetic movements of parts of the body [5], is widely suggested to utilize as a training method to improve physical capacities and rehabilitation outcomes. Articles claim that MI training could enhance physical performances in tennis [6], basketball [7], and Water polo [8]. Furthermore, this therapy could also positively affect functional network efficiency [9] and motor learning of locomotion [10]. Brain-computer interface (BCI), also called Brain-Machine Interface (BMI), is an advanced technology that plays an intermediary role in sharing information between a human's brain and external devices. With a non-invasive BCI device (wearable head cap with sensors attached for signal monitoring, rather than invasively inserting sensors into the skull), users could safely modulate their brain activity to interact with external devices, such as a robotic arm [11]. The interaction actively navigated by a human is called active BCI mode. This novel control strategy, combined with motor imagery [2, 12, 13], would widen the range of potential beneficiaries of assistive or rehabilitative robotics, such as diagnosed lock-in patients. For example, using MI-BCI for exoskeleton navigation would help lock-in patients to have accessibility for walking assistance by mere imagination [14]. Combining with this principle of robotic therapy, such as residual cortical and subcortical neuronal group facilitation [15], a more significant number of patients can gain positive outcomes.

Dating back to one classical piece of research in 1993, one of the earliest MI-based BCI applications, called motor planning at that moment, was developed and reported at the University Technology of Graz [16]. Afterward, an increasing number of research groups began to focus on potential MI-BCI applications.

1.1 Challenges

Although MI-BCI has been given great attention compared to other BCI applications [17], the gradual reduction in research interest hints at the bottleneck that academia is encountering in MI development. One of the main reasons, claimed by Hwang et al. [17], is that other BCI paradigms could have a shorter training duration and higher information transfer rates (ITR) than MI-BCI. The performance issue mentioned above is not an exceptional case. Several errors are repeatedly diagnosed when applying non-invasive MI-BCI for further research with humans. For instance, one BCI group [18] identifies that distraction around the environment might cause insufficient attention failing to output accurate results and promoting frustration. Therefore, the MI-BCI control system in users learning outcomes seems less competitive than its counterparts.

The most commonly used MI-BCI training modes [19] might not help overcome those challenges above since participants would hardly engage with the graphical interface design [20]. Thus, a new solution for improving the learning outcome of MI-BCI users is demanded.

1.2 Potential solution

Gameplay-based learning, gamification, is a potential method to level up the non-invasive MI-BCI learning outcome. The advantages of gamification in training are the upgraded level of users' engagement and happiness, thanks to its real-world simulation and exciting game content [21]. These might prolong the users' time of willingness to engage in the therapeutic MI-BCI activity. Using gamification for training is also supported by a consensus [22] that playing a PC game has motivations and benefits for users to learn skills. These pieces of evidence increase the possibility of using gamification in MI-BCI.

In 2003, the Graz group designed one of the initial motors imagery-controlled BCI games. Users could imagine their left or right-hand movement to navigate the falling ball inside the screen to the same side basket to finish this gamified task [23]. The interaction between users and the game could teach the participants to adjust to performing MI correctly. Almost at the same time, a 3D first-person shooting game (3D ShT) is created to declare the feasibility of binary gaming MI-BCI control [24]. These findings support the technical feasibility of gaming solutions in MI-BCI.

1.3 Aim of the study

Although pieces of gamified MI-BCI research have published, no literature has mainly and specifically analyzed the existing gamified MI-BCI training methods. This research gap reveals the essence of accomplishing one literature review for the above purpose. Thus, this paper will review the current non-invasive MI-BCI game in academia. We expect the result could help identify the feasibility of existing MI-BCI game development. This finding probably helps optimize the future research-based game design in testing whether gamified MI-BCI training mode would have a better outcome than the traditional mode.

1.4 Research question

This paper designs research questions (RQ) and a search plan using a topic-relevant review for the template [25]. One main RQ is: whether gamification of MI-BCI is feasible as a training method. Specifically, this review answers 2 RQs presented below (see **Table 1**).

Research question	Note
RQ1: What games have been used in MI based BCI? • What is the genre that each game belongs to? • What type of subject (healthy or disabled) has participated in each game testing? • What are the learning outcomes of each game study?	Hybrid BCI would not be included
RQ2: What are the factors that researchers should be focusing on when designing a gamified experiment. • What are the main metrics that have been used • What are the training issues that have been reported	This research presents main quantitative and qualitative metrics.

Table 1.
Two RQs with their detailed aspects of questions.

1.5 Outline

The organization of this review is as follows: The research technique used for reviewing and analyzing literature is presented in Section 2. The findings will be arranged in Section 3, followed by a discussion that focuses on a recommendation of MI-BCI game preferences in Section 4, ended with a conclusion.

2. Method

An MI-BCI review could provide instructions for better game design in the future. We finished a pre-literature review to ensure the scheduled literature review method is achievable. After pre-reviewing, this paper believes that although existing MI-BCI games are various, the research fields regarding what MI-BCI games have been used and what game genres are more preferred for MI-BCI training than others are still virgin land. Thus, a systematic review (SR) based selection strategy could be used in this review to present data objectively. However, a meta-analysis is challenging because of the limited number of published articles and reported trials. Thus, the following part will introduce how this review attempts to utilize PRISMA [26] for scientific analysis.

2.1 Eligibility criteria

Out of variables controlling, this review merely focuses on studies asking subjects to use MI to control a BCI game. In detail, we select experiments with all healthy and disabled human participants using MI solely to control a BCI device to play a game (actively non-invasive MI-BCI). The BCI device must be non-invasive. Additionally, metrics cover both quantitative and qualitative learning outcomes. A Hybrid MI-BCI control system, BCI for assessing MI function, or no human experiment would exclude. Summarization of all the critical aspects of the eligibility criteria is presented in **Table 2**.

2.2 Information sources and searching plan

We apply three searching databases: IEEE Xplore, Scopus, and PubMed/MEDLINE. This review includes three strategies (see **Table 3**) with two additional plans for finding articles. The pre-searching plan is designed relatively broad so that a brief idea of the current gaming MI-BCI systems could help revise the main-researching plan. In contrast, the main-searching plan is designed relatively specifically after referring to

Aspect in the criteria	Eligibility
Control method	Using only motor imagery to control a BCI game
BCI device type (invasive?)	Non-invasive BCI
BCI device type (passive, reactive, active?)	Active
BCI learning outcome	Quantitative and qualitative outcome
BCI experiment type	Human experiments only
Participant type	All healthy and disabled cohort

Table 2.
Summarization of eligibility criteria.

Plan	Group1	Group2	Group3
Pre-search	Brain-Computer Interface	Video game	
Main-search	BCI	Game	Motor imagery
	Brain-Computer Interface	Entertainment	
	Brain Machine Interface	Videogame	
	Neurofeedback	Gaming	
	EEG	Gamification	
	Electroencephalogram	Gamified	
	Mind controlled	Competition	
	Brain Controlled		
	Biofeedback		
compensatory	Motor imagery	game	
		gamification	

Table 3.
Three searching plans with separate groups.

one current published topic-relevant SR [25] and the pre-searching result. We design a compensatory plan so that targeted articles with a slightly expressive difference are unlikely missed. One additional search plan utilizes Google scholar, and another technique is to dig topic-related articles presented as references in the articles already reviewed. The key searching terms are separated into three groups based on the MESH library in Pubmed, template SR [25], and another relevant SR discussing BCI games [27]. All search plans are based on title, abstract, and keywords (TAK), and duplicative articles would be identified and removed via EndNote X9 and a relatively deep read.

2.3 Study selection

Three main types of criteria have been used in this review: Selection Criteria (SC), Exclusion Criteria (EC), and Inclusion and Quality Criteria (IQC). SC is for broadly filtering articles. After determining the scope of literature via SC, EC will determine this scope more precisely. IQC is adopted to decide whether the articles could be suitable after deep reading. The specific SC, EC, and IQC can be seen below:

2.3.1 Selection criteria

For objectiveness, the chosen articles must be written in English. Furthermore, these articles must be peer-reviewed, covering a designed MI-BCI game. There is no restriction for the published years as some early MI-BCI game systems, such as the first-person shooting game [24], are still highly valued in the academic area.

- Written in English
- Peer-reviewed
- No searching duration is limited
- TAK is discussing about a non-invasive MI-BCI game.

2.3.2 Exclusion criteria

The remains still need to be under consideration before being used as a definitive reference. For example, some titles or abstracts, including the typed terms but different prior research aims, should be excluded. We would not recommend any literature review without one own experiment. Additionally, reports aiming at pure MI therapy without BCI, or invasive MI-BCI research, would be withdrawn. Other factors such as a hybrid control method, which might positively influence the feasibility of an MI-controlled BCI game, should be excluded. The lists below are the detailed EC.

- The outcome of the articles does not cover gaming MI-BCI
- If the paper is a review, there is no MI-BCI research or outcome but just the result of literature analysis.
- Motor imagery is not for BCI.

Criteria type	No.	Score	Criteria requirement	Level of result
Compulsory	CQ1	Y1	Are the goals of the paper clearly stated and include gamified MI-BCI system?	If No, the article should be ignored
		P0.5		
		N0		
	CQ2	Y1	Is there any clear outcome related to gamified MI-BCI system presented?	
		P0.5		
		N0		
Non-Compulsory	QQ1	I5	Is this article mainly talking about game (2) training (3) improvement (5)	Satisfactory >= 4
		T3		
		G2		
	QQ2	N1	Is there any main focus on one of the steps in the whole loop of MI-BCI (recording brain activity, preprocessing, feature extraction, classification, translation, and receiving feedback) [29]	
		P0.5		
		Y0		Good >= 7
	QQ3	Y1	Is this paper presenting the gamification metrics of the research?	
		P0.5		
		N0		
	QQ4	Y1	Is there a clear explanation of the result?	
		P0.5		Important >= 9
		N0		
	QQ5	Y1	Is there a scientific evaluation for the outcome?	
		P0.5		
		N0		Excellent >= 11
	QQ6	Y1	Is there a useful discussion for recommending further research?	
		P0.5		
		N0		

Table 4.
ICQ form. Yes (Y) for 1, Partially (P) for 0.5, and No (N) for 0.

- Gamified MI-BCI system with other control or feedback methods as a factor that could influence the result, such as a hybrid BCI control system with MI and P300 together [28].

2.3.3 Inclusion and quality criteria

Rather than distinguishing between inclusion criteria and quality criteria, this paper combines these two as IQC (see **Table 4**). This combination is because the inclusion criteria could also be qualified (totally fulfilled or partially fulfilled) and become one part of the article evaluation. We will withdraw the study if it cannot match any one of the two compulsory questions (CQs). Six main quality questions (QQs) are subsequently presented to assess the level of the selected article. If the article failed to be higher than the four scores, this work would also be rejected because of the low report quality.

QQ1 is estimated with different scores because different research aims reveal different study repeatability. For example, 5-scores are rewarding for the studies' attempt to improve the gamification outcome. These studies are probably continuous studies with a developed system under a reproducible experience. These articles might therefore be convincing for result reviewing. In contrast, if the research aims to design and test an MI-BCI game, it would be scored two since this game system might need more evidence for reproducible testing. MI-BCI applied for subjects training research will gain 3-scores. That is because a training environment is more challenging for MI-BCI robustness than just a game test. However, the lower level of challenge and number of supportive studies than the 'improvement' study positions them in 3 scores. We then divide the quality of articles into four levels: satisfactory, good, important, and excellent.

3. Results

3.1 Study selection

This review finds 2524 articles after using the TAK searching strategy above. The exact numbers of each database and term can be seen in **Table 5**. After removing the duplication and first reviewing with SC, 549 articles are saved in three plans, and seven more articles are included with two additional searching methods. Sixty-one articles remained after a second review with EC. Three main reasons for high elimination (approximately 90% of the articles) are no gamification, hybrid BCI, and BCI for assessment but not control. After detailed reading with IQC, we finally marked 28 articles. This reduction is due to insufficient reporting data. The whole search process is presented in **Figure 1**

	Plan1	Plan2	Plan3
Scopus	192	719	357
IEEE	67	344	21
Pubmed	82	172	563

Table 5.
The number of the articles found in 3 plans of stage 1.

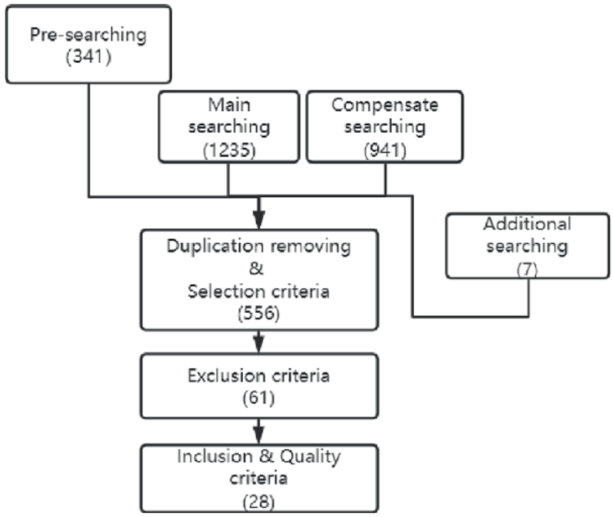

Figure 1.
The whole process of searching strategy using PRISMA.

The means of ICQ of 28 articles are 9.3, while the standard deviation is 2.1. These parameters show that the quality of the chosen articles is relatively high, with an average level of 'important' with slight fluctuation.

3.2 What games have been used in MI-based BCI?

In this study, we refer to the book written by Ernest [30] to classify different games. The seven main genres are action, strategy, role-playing, real-world simulation, construction and management, adventure, and puzzle games. Additionally, we use subgenres for a better description. This subgenres classification strategy is also agreed by Ernest, who claims the classification change constantly with different circumstances.

Thus, this review develops a subgenre classification for the chosen 28 MI-BCI games depending on three aspects of the graphical interface: ① whether it is the first-person view, ② which visual type (2D, 3D, VR) it is, and ③ what the game content type is. For content-type differentiation, this paper pays strong attention to task-orientate separation, i.e., what targets the gamers are asked to achieve, or what functions they are expected to present. Games with these similar contents would be linked. For instance, one study [31] describes itself as a cue movement game. Nevertheless, the game aims to pick a falling parachutist via a controllable platform. These contents, such as control method, feedback, and mission, are similar to the game [23], whose participants attempt to control a failing ball to land on a fixed basket. Thus, we identify the saving parachutist game as a ball-to-basket (B2B) game but not a cue movement-based searching coins game [32] (**Table 6**).

After game classification, four genres with 11 subgenres of MI-BCI games have been identified (see Appendix 1). We present each research group with its summarized game content type in this detailed form. In Appendix 1, the game vision type is shown. For easy understanding, we match both the content and vision of the games with the abbreviation (Ab.).

Game subgenre		Category		
First-person	Dimension	Content	Classic Genre	Abbreviation
No	2D	Ball to basket	Action	2D B2B

Table 6.
An example of game differentiation.

Genre	Total score	Total study	Average
Action	264	19	9.428571
Puzzle	173.5	7	9.131579
Adventure	16.5	2	8.25
Simulation	16	2	8

Table 7.
Four genres total score, number of studies and average score.

The four main genres of MI-BCI games are action, puzzle, adventure, and simulation. **Table 7** presents the quality of each genre. The following paragraphs explain each genre with its typical subgenre games in order.

3.3 Action game genre

Most games (18/28) belong to action games whose players try to control the gaming character to present physical activity, such as jumping or moving to one side, to overcome the challenges and gain rewards. The following paragraphs introduce four main subgenres of action games (2D avoiding obstacles, 2D ball to basket, 3D Cybathlon brain-running, VR first-person action) and other games.

2D avoiding obstacles (2D AO) games (5/18) are a series of games where players use different imaginations to control the character's direction to avoid obstacles and collect rewards. In 2007, one study [33] presented a “Jump and Run” game whose ten healthy players used their adept imagination (right hand, left hand, or feet) to send jump commands to avoid the intermittent obstacles. Two out of five subjects presented a high accuracy of more than 90%. An ‘arcade game’ with similar up and down movement was present with an accuracy of 70% among ten subjects [34]. In 2011, a spaceship control game was provided [35]. Gamers used two out of four motor imageries (left hand, right hand, both feet, or tongue) to control the spaceship to move left or right to avoid falling asteroids. The synchronized game score also rises when the character passes asteroids successfully. Two out of three subjects reported increasing classification accuracy during this gameplay. A similar game is a design where a spaceship is replaced by a car, adding a coin reward [36]. Feet MI was linked with left movement, and right-hand MI could control the car to the right. An average multiple event accuracy (ME_Acc) could reach 78.3% among four participants. One game [37] provided an environment where three classes of MI could be presented. Gamers could move to the left or right by ipsilateral hand imagery to collect coins. A jump command is sent by feet of imagination when the subject has to avoid the snake on the lane. After three gameplay sessions, an increasing average classification rate (53% to 63%) and game score (1600 to 1900) are presented among 14 BCI naïve healthy participants.

2D ball to basket (2D B2B) games (3/18) are games where players use one side of their body image to control a falling ball landing on the ipsilateral side of the basket. In 2003, one article indicated the feasibility of applying this game to 4 paraplegic patients [23]. 3 out of 4 participants succeeded in controlling the falling ball to an exact color basket by using two optimized MI from left hand MI, right hand MI and feet MI. One study in 2010 revealed the feasibility of using this type of game for stroke patients with a moderate classification accuracy of 60%-75% among five novices BCI subjects [2]. This result is similar to a previous study [38] with six healthy users (average classification accuracy of 69.2%). In 2016, nine healthy users were trained to use left or right-hand MI to control a platform (basket demo) to save a falling parachutist (ball demo) [31]. All the accuracy performances are higher than 70%.

3D Cybathlon brain-running (3D CyR) is a game (3/18) designed for the first Cybathlon competition held for a disabled cohort in 2016 in Switzerland [39]. Cybathlon competitors, called pilots, in BCI Race, present four different MIs depending on the areas the role needs to pass through. The result is ranked from the shortest runtime in order. In the MIRAGE team, whose pilot is a post-stroke patient, the average runtime could reduce from 178s to 143s during training and 196s (rank 11/11) in competition [40]. The optimized 2 MI classes are right hand MI, both feet MI, with other two mental subtraction, and auditory imagery. In the same competition, two tetraplegic pilots in the Brain Tweakers team [41] present 90s (rank 1/11) and 123s (rank 2/11) runtimes in the first race. In the final round, these two pilots present 125s (1/8) and 190 (4/8). Their control strategy is a 3-class MI (right hand, left hand, and both feet) combined with resting. Those two groups of pilots are training regularly for months before participating Cybathlon competition. In contrast, one research [42] shows that a healthy cohort trained with only two sessions could reach an accuracy of 68.62% with 2-classes of MI (right hand MI and stomach MI).

VR first-person games (VRFP, 4/18) is a group of action games with visual reality (VR) devices to present a first-person vision gamified feedback. From the players' view, no realistic but misleading interruption such as a passing-by researcher would occur so that players could fully be engaged in the game. In 2013 [43], 12 healthy subjects with one post-stroke patient accomplished a VR B2B game. Participants tried to use the ipsilateral hand MI to control the virtual hands to the right side for picking the falling basketball. Results show that although the disabled users only trained for one session, the final accuracy could reach 77%, whereas the highest accuracy among two-session healthy users is 70.67%. A similar VR B2B game designed in 2019 with 4-class MI (left hand MI, right hand MI, both feet MI, and resting) presents a mean accuracy of 70% with 10 participants [44]. One game with not only visual but also auditory and haptic feedback, called "NeuRow," was present in 2016 [45]. 13 healthy users use their left- or right-hand MI to navigate the boat towards the same side. Two high-fidelity arms enhance the MI of users by linking the imagery environment with the real world. The classification score (70.7%) in NeuRow compared with the other six studies with the same classification method indicates that the NeuRow has scored the best. Another VR MI-BCI game designed in 2019 is a simplified shooting game [46]. Nineteen users try to destroy the asteroid (VR DA) with the same side hand MI. After receiving the MI commend, the embodied visual hand would move to switch on the trigger of the weapon to shoot the asteroid. The average peak accuracy among these users could reach 75.84%.

In 2003, one 3D first-person shooting game (3DShT, 1/18) was tested among four healthy participants [24]. Since it is the earliest MI-BCI game, researchers did not limit the users to control the game in a certain fixed MI way. Instead, participants are allowed to discover how to adjust mu rhythm, which is related to sensorimotor control by themselves. Result reveals that mu activity could be actively adjusted to control the scenery to the left or right. Researchers subsequently indicated the potential that mu rhythm becomes a binary signal for MI-BCI control. In 2013, researchers developed BrainArena, a simplified football game (2D FB, 1/18), where two users could play in a collaborative or competitive mode [47]. Eight healthy subjects in 4 pairs show an average classification accuracy of 75.4% (collaborative manner) and 74.6% (competitive manner). In 2018, a 3D ball balance game (3D BL, 1/18) was designed. Ten healthy subjects use left or right-hand MI to control the platform to slightly rotate clockwise or anti-clockwise so that the planet on the platform would not move to the low end and fall off [48]. Final accuracy could reach 70% with the concentration improvement.

3.3.1 Adventure game genre

Adventure games (2/28) are a series of a game whose target is mainly task-orientated exploration. For example, adventure gamers usually need to explore the map with specific targets, such as finding a particular non-player character (NPC) or finishing a specific mission.

We only found one type of adventure game for the MI-BCI system. Scherer et al. [49] designed a 3D first-person searching coins game (3D SC) called “freeSpace” in which two out of three healthy players succeeded in collecting all three coins in three minutes. Three out of four MI classes (right hand MI, left hand MI, tongue MI, foot MI) are used for left, right, and forward navigation to find three hidden coins on the whole map. After a few trials, two participants could see improvement in covered distance and searched coin numbers. In another report of this game experiment with a different angle, research indicates that the whole runtime would be 110s with 100% classification accuracy [27].

3.3.2 Puzzle game genre

Puzzle games (7/28) usually offer enjoyable logic or cognitive training tasks. Gamers need to identify the link among the provided items, answer specific questions or find a way out of a maze in a limited duration.

2D fix route maze games (2D FxM, 2/7) are a group of games whose characters should walk following a pre-designed line. In 2007, a research group redesigned the 2D “Pacman” game to be compatible with MI-BCI users [50]. Users could navigate the Pacman with left hand MI or right-hand MI to finish the instructed route in the maze with the highest score. Additional credit will be rewarded if the user could pick the apple on the lane, and the game score will decline if the Pacman hits the wall. A similar maze game was designed in 2017 [51] where users could use 4-class MI (left hand, right hand, both feet, and tongue MI) to finish the instructed route. The highest gaming accuracy is 48.7% among the four subjects, while the average classification accuracy is 68.5%.

2D Voluntary route maze games (2D VM,3/7) are maze games without a fixed path but only a start point and an endpoint. In 2009, 2 healthy players performed well in a maze-like cursor control game [52]. Gamers are asked to move to the target area and avoid one fixed trap with left- and right-hand MI. One gamer could reach an offline classification accuracy of 73%. This game is then used among one amyotrophic lateral sclerosis (ALS) patient and one primary lateral sclerosis (PLS) [53]. ALS user presents a receiver operating characteristics (ROC) rate of 81.8%, and the ROC rate for PLS user is 86.7% in two visits. A similar game was developed in 2012, and 4-classes MI (left hand MI, right hand MI, both hand rise MI and both hand fist MI) are used for navigation in four directions [54]. Healthy gamers present an accuracy of 60%-70% in this study.

2D Jigsaw puzzle (2D JP) games (2/7) are a group of games where players try to finish collecting the jigsaw by specific tasks. One case study reports that Arm MIs could help play a jigsaw puzzle game [55]. The cerebral palsy (CP) participant uses left or right-arm MI to accomplish tasks and collect puzzles. The result shows that the acquired MI skill could help the participant gain additional MI-BCI skills such as choosing, playing, and pausing videos. Furthermore, the skill could last for more than six weeks, as proven by the subject's successful control of the MI-BCI virtual cube. An afterward study in 2017 with the same game but a larger number of subjects (eight patients with CP) showed the potential for CP patients to interact with this MI-BCI puzzle game [20]. However, the quantitative result in performance score for all users is relatively negative with several training issues such as head cap discomfort.

3.3.3 Simulation

Simulation (1/28), or real-world simulation, is a group of games, including vehicle driving or particular physical challenges. However, unlike action games, simulation is often more focused on navigation experience and related tasks. In 2019, one VR drone racing game called "Brain eRacing" (VR DR) was reported with 30 healthy participants [56]. However, unlike other games using MI for navigation control, MI is only used to accelerate the drone's speed. The final average game time is 54.88s, while the group with the last average time is 69.6s.

3.4 What are the metrics of MI-BCI game?

3.4.1 Performance metrics

24 out of 28 articles use quantitative measurement to test the learning outcomes, whereas four use qualitative metrics to report the participants' performance (see Appendix 2). One article has not tested their result [50]. One study [54] only presents a description indicating that a user who was not an expected volunteer could control the mental task easily in a short duration. We will not consider these two articles in metrics recommendations. Therefore, the following paragraph will indicate the commonly used performance metrics in the qualitative and quantitative groups.

Appendix 2 lists several performance metrics used for learning outcomes measurement (see Appendix 2). Twenty-four articles used quantitative metrics for MI-BCI gaming mode measurement. The two most frequently used metric is accuracy (16/24) and performance score, or game score/rate (5/24). In four articles using qualitative evaluation, the commonly used metric is the game experience questionnaire (GEQ) (2/4). In the discussion part, we will present a detailed introduction and analysis.

3.4.2 Training issue

The existing issues identified in the experiment are reported from the first designed MI-BCI game till now (see Appendix 2). We found six main issues: ① environmental background and distraction (3/28), ② trial length relevant fatigue (4/28), ③

Training issue	Factors/potential solutions need to consider
Environmental distraction	Balance between distraction and engagement
Fatigue	Shorten trial length and test in the morning
Performance variation	Real-world experimental environment but consider the difficulty
Increasing False Positive rate	Method eliminates the expectation of next MI, and find optimal threshold for better classification
Performance decrease	Reducing physical demand
Toughness	Reforming environment and consider classification

Table 8.
Summarization of training issue and its considerations.

performance variation (4/28), ④ increasing false positive rate (2/28), ⑤ performance decrease (2/28), ⑥ toughness to complete game (2/28). **Table 8** below shows the summarization of each issue with its consideration. We gave a detailed explanation in the discussion part.

4. Discussion

4.1 What are the factors that researchers should be focusing on when designing a gamified experiment

4.1.1 Metrics for MI-BCI game mode

Quantitative metrics: Researchers usually identify the learning outcome by comparing the accuracy of each experiment in sequence [43]. The testable and quantitative characteristics keep accuracy as the top used metric. Performance score, or game score/rate, is another commonly used quantitative metric equally ranked with consuming time. The game score could reflect real-time performance intra-trials and quantitative improvement cross trials objectively. One study [37] uses online game scores to motivate BCI users to improve their next performance. Moreover, line graphs for describing performance score fluctuation could be more visible for presenting learning outcomes [55]. The same Auckland group used the score-line curve one year later in another research with ADHD patients [20].

Based on the writers' experience in the rehabilitation equipment market, the scoring method is more intuitive for patients and therapists to identify the rehabilitation outcome. In contrast, accuracy is more reliable for the technical measurement of outcomes from both users and the system. Therefore, we suggest using accuracy for research aims, such as identifying whether gamification could enhance the learning outcome more than non-game MI-BCI. Synchronized gaming score, in contrast, could be applied to potentially enhance the performance of users or check the rehabilitation stage.

Qualitative metrics: The commonly used qualitative metric is the game experience questionnaire (GEQ) (2/4). GEQ is the response from MI-BCI gamers. Researchers use GEQ for measuring several experiences, such as flow experience. A guideline is recommended to quantify all the qualitative answers and group them into a specific experience [57]. For example, Tezza et al. [26] use a 1–5 Likert scale to evaluate the experience.

4.1.2 Existing issues

Environmental Background and Distraction: Distraction is an environmental or feedback issue that would disturb the users from performing a correct MI. In one of the earliest MI-BCI gaming experiments [24], researchers assumed distraction caused the no-growth low mu rhythm used for game control. In a simplified football game [47], 7 out of 20 subjects argue similar disturbing feedback. One article reports the same disturbing issue [35], but they claim this issue offers more engagement in the game, in contrast. Serious consideration to balance the augmented engagement and distraction, thus, is required when applying the idea of multi-player MI-BCI games.

Trial Length, Experimental Time and Fatigue: Fatigue is another issue that generally happens during MI-BCI training. The length of trials and the time for experiments are linked to fatigue. Significant variability in performance is found in different lengths of trials [23], which might be due to fatigue. In one 2D B2B game [2], researchers discover similar performance variability due to evident fatigue and depression cross-subjects. In detail, two participants complain that the sessions are too long to keep them performing well. Researchers report similar fatigue issues and lack of concentration in one subject whose performance is not ideal after four sessions [36].

Authors from the 2D B2B game research [2] also believe that the chosen time (afternoon) for an experiment is one factor that increases the tiredness providing low performance. One puzzle game case study [55] supports this argument, in which authors suggest a morning experiment to avoid fatigue.

Performance Variation: Performance variation is when outcomes of distinct trials are different. It often happens when different individuals use the same MI-BCI device with all other factors being the same. For example, in one gamified training mode [27], two participants showed improvement in the game performance while one subject showed a decrease in performance.

However, variation would not only be found in cross-subjects but also found in the same subject when they failed to provide reproducible MI effort in each trial. This variation is called intra-subject performance variation. Psychological states, such as nervousness and motivation, correspond with intra-subject performance variation [40]. Another study [31] reports the same issue and claims that it is possible to solve this problem by using adaptive assistance in changing the trial length. Consistency and personalization are two issues causing cross-subject and intra-subject performance variability [42]. Researchers predict that a competitive training environment might help maintain users' excitement [35]. However, this reviewer would consider whether this environment could have side effects, such as distraction, on learning outcomes in a short time.

The Increasing False Positive Rate: The false-positive rate is the proportion when the classified command is against the imagination of participants. Scherer et al. [27] reveal that the increasing false positive rate might be related to premature brain activation. Researchers also believe this non-stationary brain wave links with the unsatisfactory robustness of the system.

An optimal threshold is also a factor that impacts the false positive rate. The threshold of MI-BCI is the digital criteria to identify whether the amplitude of Electroencephalogram (EEG, one type of brain signal) could be a task-relevant mental task. One study shows the rate declined when adjusting the decision boundary from 0.6 to 0.8 [44].

Performance decrease: Performance decrease is the declining quality of quantitative performance metrics, such as decreased accuracy, ITR, and increased time. One study indicates its link with increasing workload [45]. To solve this, reducing the physical demand is recommended [53]. Furthermore, to keep a good performance, minimum eyes and body movement are required [44].

Toughness in playing games: Toughness is the difficulty for participants to finish a goal in the game. One study [42] argues that though the gaming concentration is satisfied, the controlling difficulty is still visibly raised when the number of MI classes grows. This evidence informs that the number of MI control types impacts toughness, which could then cause performance variability.

4.2 What games have been used in MI based BCI?

4.2.1 Feasibility of MI-BCI gaminification

Appendix 3 indicates the evidence of the feasibility analysis. For research reporting with performance accuracy, the criterion of feasibility is that the average accuracy (accuracy/no. person) could finally reach 70% of accuracy, based on the criteria of BCI application [58, 59]. Although the articles concluded that 233 subjects successfully went through the MI-BCI experiments, only 111 individuals have examined the feasibility of the MI-BCI game with its gaming accuracy.

This review chooses the maximum average accuracy (MAA) for quantified feasibility as one metric. For example, Djamal et al. [34] presented two groups of average accuracy (a non-FFT group with 50% versus an FFT group with 70%). This review picked the 70% FFT group as an MAA since this accuracy is reachable with existing system upgrade technologies, such as FFT. After analysis, 28 chosen articles present an average accuracy of 74.35%, higher than the threshold. Additionally, 26 out of 28 articles (92.86%) possess positive responses to the feasibility of the MI-BCI game. These two results illustrate that it could be feasible to apply gamified MI-BCI training mode for further experiment.

4.2.2 Game recommendation

From the analysis above, it is explicit that 2D AO is the commonly used game type (5/28, 17.86%). The evidence to support this argument is generally high (46.5 total scores in AQ with a mean of 9 and a standard deviation of 2.17). These statistic results advise 2D AO to become a high-priority recommended game. The advantage of the 2D AO game is the high level of motivation. The coming obstacles would increase the tension and stimulate the users to accomplish the correct MI to rescue the character intuitively.

However, except one study uses 3 MI classes (left- and right- hand MI and feet MI), others do not use more than two MI types for gaming navigation. This circumstance is a limitation of current 2D AO games. Future 2D AO game design should cater to real-world complexity by providing more MI class on the one hand and a reliable user experience with guaranteed accuracy on the other hand.

A potential solution is to add more controllable gaming factors in the 2D AO game. For example, forward and backward, acceleration and deceleration, and even shooting a bullet against the obstacle could become controllable by additional MI types more than just left and right hands' imagination. Furthermore, different MI classes could depend on environmental color changes. 3D CyR games apply this idea to reality [40–42], where competitors produce four MI classes based on the above mission colors.

2D B2B game is ranked equally with 3D CyR in report number (3/28, 10.71%) and similar quality (30.5 total scores in 3D CyR vs. 29.5 in 2D B2B). Like a 2D AO game, game designers should notice the limited MI control classes since all three studies using 2D B2B games only present the learning outcome of two classes of MI (Left and Right hand). The failure in recommending a 2D B2B game is because of its lower level of motivation than a 2D AO game [35].

We advise the 3D CyR game since this game could be not only for training but also for the Cybathlon competition. These applications encourage researchers to further the development of rehabilitation and patients to open out to build relationships and share their life with their competitors from other nations or territories. Nonetheless, an advanced challenge for the CyR game requires an excellent feature selection method to afford the upgraded complex data calibration and classification due to the increasing number of MI classes and highly competitive interruptions.

One limitation in all three games above is the lack of immersion, i.e., players feel difficulty linking their MI with their motor execution (ME) when playing a game. This condition raises challenges for presenting correct MI since no environment could work as humanoid neurofeedback to motivate the gamer to produce the related MI. Therefore, humanoid factors should be a focus when utilizing these three types of games.

First-person VR action games (VR FP) do not need to consider humanoid environment issues. Advantages of VR application are imaginative immersion and a high level of sensation. [56] Karácsony et al. [44] share the comments from participants who played VR B2B games: gamers feel they are using their own hands to catch the falling balls via VR-based MI-BCI game. Therefore, these humanoid advantages could improve the participants' performance [44]. Furthermore, one study reports a high gaming accuracy in the VR B2B game. However, the VR DR game does not reproduce a similar extent of learning outcome. This review believes a lower level of immersion, such as a non-first-person humanoid control environment and no visible link between MI and navigation, causes the game to become relatively distracting. This phenomenon prevents the VR DR game from recommendation.

The interest and the difficulty of the game design are required to consider [27]. Although VR games could reach a high level of learning outcome, the complexity of designing the platform and synchronized interaction with numerous MI-BCI data is not as easy as a 2D PC game. The immersion provided by a VR game might be lower than a 2D AO game if designers sacrifice the quality of a game system to reduce complexity. That is because potential high delay, game bugs, and illogical graphical switches might occur as distractions reducing the MI-BCI experience. A 2D MI-BCI game with good design could also present well in tactical, strategy, or narrative immersion, which are not specific to VR [30]. These facts prevent VR FP action games from becoming the only recommended game.

In summary, if there are temporal and spatial limitations, we advise researchers to choose game content close to 2D avoiding obstacles. The insufficient degree of immersion and the number of MI classes are two main issues that need to consider. 3D Cybathlon running game is another choice for researchers due to its futuristic maturity in competition, stakeholders, and technique. In contrast, we recommend a VR first-person action game with first-person vision when there is no limitation in designing and experimenting with an upgraded gamified MI training system. In particular, the VR ball to the basket game and destroying asteroids game are suggested as two existing first-person VR examples.

Another game genre, puzzle game, is not recommended in this review because motor imagery is still easily disturbed by other factors, as mentioned in both current issues and Appendix 2. A hybrid game with an action factor to motivate correct MI and a puzzle factor to enhance the strategy immersion is still potential for improving learning outcomes of MI-BCI. However, we suggest designing the game navigated by action-dominated factors. For example, the game story could cover puzzle game questions. However, for choosing an answer and continuing the story, the graphical interface of the MI-BCI game could use a humanoid hand for assistance.

4.3 Limitation

No article has discussed the comparison between gaming MI-BCI with a control group. The main reason is that majority of the studies are still focusing on the feasibility of using different feature selection methods in the MI-BCI game, aiming to improve the performance outcome with more advanced techniques. Even though three existing articles [32, 43, 47] claimed the improved learning outcome with comparison tests, their research process is not sufficiently scientific as randomized control trial (RCT). This limitation shows a research gap that could be filled shortly: a randomized control experiment for evaluating whether gamification could improve the learning outcome of MI-BCI is required.

Another limitation is the objectiveness of this review. Since gamification in MI-BCI is an interdisciplinary study covering tremendous academic fields, this review cannot present an in-depth analyzed review and recommendation. This research group hopes to complete a systematic review with video game experts when enough RCTs have tested an optimal training mode.

Furthermore, we advocate more significant attention to users' cohorts. Only 7 out of 28 articles test the feasibility of games in a disabled cohort. One study in this group using a commercial wireless BCI device reports a highly negative result: all participants failed to complete the initially designed trial. None of them shows a learning outcome increase after the full training [55]. This situation absorbs attention on an appropriate task for different users. A relatively short training duration with a more comfortable experiment setting is probably more friendly to patient-participants. Additionally, one study reports the possibility that subjects with video game experience would have a better MI-BCI performance [60]. Gender is also a probable factor related to performance [46]. Therefore, when separating the participants and analyzing the results, these participants-relevant factors should consider.

Real-World Study (RWS) [61] is a research type covering the data collected widely and randomly. Researchers pick the evidence (Real World Evidence) without strictly classifying one controlled particular pattern. For MI-BCI, existing data is often gained from healthy cohorts or individuals with specific neurological impairments. These data are not sufficient for testing the robustness and reliability of MI-BCI for real-world users and applications. More influential factors would occur than subjects whose patterns are controlled in an RCT. For applying MI-BCI to these real-world users with a reliable outcome, this review recommends having an additional RWS after a sufficient number of RCT studies show positive results.

4.4 Insisting pure MI-BCI control strategy in game

This review studied gaming BCI systems controlled by only MI. Plenty of research has tested the feasibility of hybrid BCI control [62] with games. One article successfully used a hybrid technique with MI to control a well-known but highly complex game, World of Warcraft, surprisingly seven years before [63]. Although these combination control methods might accomplish more remarkable improvement than mere MI control, this review still insists on the importance of exploring the maximum outcome of pure MI.

The reason for insisting on single MI control is that the source of performance issues still needs to be researched. On the one hand, well-direct optimization of the pure MI control could efficiently improve the hybrid control system. This review is not denying the better performance that hybrid MI devices could achieve. In contrast, after digging out and solving the problem caused by MI-related factors, a combination of other methods might have higher performance growth in another dimension.

On the other hand, even if a hybrid MI system has been designed, the outcome would still not be ideal if we have not sufficiently explored and solved the potential performing issue. Like a disease, low MI performance is a symptom of MI-BCI, and unsuitable MI design is one of the root causes. Using merely hybrid MI control seems like treating the low-performance symptom, but not the root causes. This assumption could be supported by one study [62] that participants still need to be trained for a long duration with a hybrid control system that has been applied in their Tetris game. In contrast, discovering suitable MI-BCI gamification to help users is a metaphor for treatment for the root cause.

As a product manager in Fourier Intelligence, our regular marketing survey shows that patients requiring long training duration would still get bored of the game provided by our rehabilitation equipment. However, a number of games have been included in our game library for different rehabilitation equipment. Therefore, providing MI-BCI games to patients requiring several weeks or even months of training would still challenge keeping patients engaged. Designing other MI-BCI games for satisfying patients might not be a long-term solution (**Figure 2**).

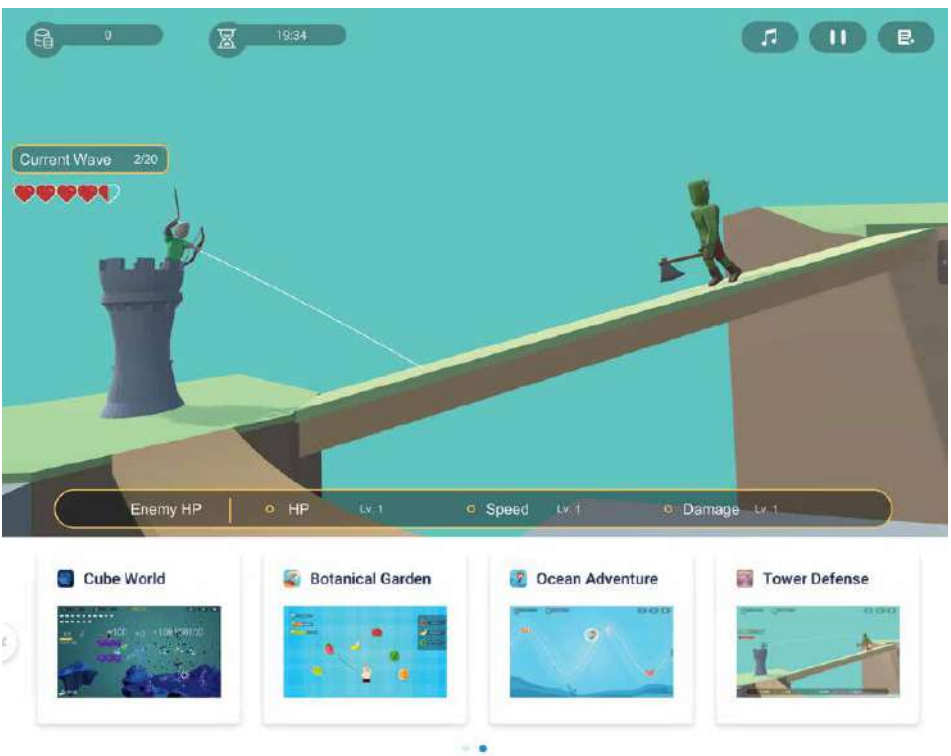

Figure 2.
An example of training game in game library.

4.5 Future work

This literature review presents several research gaps. For achieving the target of using an RCT and an existing game to test the improvement of MI-BCI gamification in a short time, we advise designing a 2D AO game first. A simulation could be done first to test the feasibility of this theoretical recommendation via OpenVibe software. Suppose the classification accuracy is higher than 70%. In that case, the participant-based study will try the designed game training model, the non-game control group model, and the third-party outcome testing mode. Also, if no significant variation can be observed between the game and control groups, the game type will be optimized. For example, a 2D first-person humanoid game might replace the 2D AO game to identify whether the negative result is due to the lack of a humanoid environment. The argument claiming gamification would not improve learning outcomes would be reported if even a VR first-person humanoid game could not present a significant difference from its control group.

5. Conclusion

Presently, researchers and clinicians expect to apply the combination of MI and BCI to a great range of users for rehabilitation purposes. Thus, existing challenges in current MI-BCI works must be solved, such as training issues. This review has utilized the majority of SR to present a scientific and objective review of one potential solution, gamification, to optimize MI-BCI training outcomes. Our finding through evidence (28 articles, 111 individuals with accuracy test, 74.35% average accuracy, 26 out of 28 positive responses) shows that using the MI-BCI game for training could be feasible.

The result also recommends 2D avoiding obstacles game, 3D Cybathlon game, and VR humanoid first-person action game as prior MI-BCI games for further research. Moreover, this review maps the cautions of the current issues of gamified MI-BCI training mode and the potential methods to overcome them. The literature review is predicted to provide a new vision of the appropriate gamified MI-BCI training modes and what elements, such as metrics and issues, are suggested to consider for scientific research.

A. Game information

Study			Game		Category		
ICQ	Author	Year	First-person	Dimension	Content	Classic Genre	Abbreviation
11	Pineda et al. [24]	2003	Yes	3D	Shooting game	Action	3D ShT
9.5	Graz(Krausz et al.) [23]	2003	N/A	2D	Ball to basket	Action	2D B2B
7.5	Graz(Müller-Putz et al.) [33]	2007	N/A	2D	Jump obstacles	Action	2D AO
6	Berlin(Krepki et al.) [50]	2007	N/A	2D	Pac-man	Puzzle	2D FxM

Study		Game			Category		
ICQ	Author	Year	First-person	Dimension	Content	Classic Genre	Abbreviation
6.5	Graz(Scherer et al.) [49]	2007	Yes	3D	Searching coins	Adventure	3D SC
10	Graz(Scherer et al.) [27]	2008	Yes	3D	Searching coins	Adventure	3D SC
6.5	USA(Huang et al.) [52]	2009	N/A	2D	Sokoban	Puzzle	2D VM
7.5	USA(Ou Bai et al.) [53]	2010	N/A	2D	Sokoban	Puzzle	2D VM
8.5	Prasad et al. [2]	2010	N/A	2D	Ball to basket	Action	2D B2B
11	Coyle et al. [35]	2011	N/A	2D	Avoiding obstacles	Action	2D AO
9	Bordoloi et al. [54]	2012	N/A	2D	Maze game	Puzzle	2D VM
10	Anopas et al. [43]	2013	Yes	VR	Ball picking game	Action	VR FP
12	Bonnet et al. [47]	2013	N/A	2D	Football game	Action	2D FB
11	Asensio-Cubero et al. [37]	2016	N/A	2D	Running game	Action	2D AO
11.5	Kreilinger et al. [36]	2016	N/A	2D	Car game	Action	2D AO
11.5	Switzerland (Saeedi et al.) [26]	2016	N/A	2D	Ball picking	Action	2D B2B
11	Auckland (Taherian et al.) [55]	2016	N/A	2D+ audio	Puzzle	Puzzle	2D JP
8	Vourvopoulos et al. [45]	2016	Yes	VR+ vibration	Rowing game (NeuRow)	Action	VR FP
5.5	Djamal et al. [34]	2017	N/A	2D	Arcade avoides obstacles	Action	2D AO
8	Graz (Statthaler et al.) [40]	2017	N/A	3D	Brain running (Cybathlon)	Action	3D CyR
9	Auckland (Taherian et al.) [23]	2017	N/A	2D	Puzzle game	Puzzle	2D JP
11	Zhou et al. [42]	2017	N/A	2D	Maze game	Puzzle	2D FxM
12	Switzerland (Perdikis et al.) [41]	2018	N/A	3D	Brain running (Cybathlon)	Action	3D CyR
10.5	Ponferrada et al. [42]	2018	N/A	3D	Brain running (Cybathlon)	Action	3D CyR
7	Yang et al. [48]	2018	N/A	3D	Balance game	Action	3D BL
11	Karácsony et al. [44]	2019	Yes	VR	Catching&kicking falling items	Action	VR FP
12	Škola et al. [46]	2019	Yes	VR	Destroying asteroids	Action	VR FP
6.5	Tezza et al. [56]	2019	N/A	VR	Drone competition	Simulation	VR DR

B. Game output information

Author	Year	Performance metric	Performance Issue
Pineda et al. [24]	2003	Low / high mu power changes learning curve (10H in total)	Non-increase of low mu might be due to feedback distraction.
Krausz et al. [23]	2003	Information transfer rate(ITR)	Significant variability in ITR with different trial lengths might be because MI and attention effort cannot be kept at the same level over the session.
Müller-Putz et al. [33]	2007	Accuracy	—
Krepki et al. [50]	2007	Not test yet	
Scherer et al. [49]	2007	Time for finish mission(maximum time 3 mins)	
Scherer et al.[27]	2008	Time for finish mission(maximum time 4 mins), Accuracy	Training: the expectation of the next cue to come might change the brain activity and produce False-positive command; although a higher detection threshold could reduce the false positive rate, motivation would also be decreased
Huang et al. [52]	2009	Accuracy	—
Ou Bai et al. [53]	2010	Accuracy	Vividness: participants reported difficulty imagining wrist extension; it might be improved by VMIQ (vividness of movement imagery questionnaire) or by teaching efficient motor imagery.
Prasad et al. [2]	2010	Qualitative1+Accuracy	Fatigue and Depression: a higher level of fatigue can contribute to more considerable variability in the BCI performance among subjects; two find treatment sessions are excessively lengthy and tiring (mainly in the afternoon); subjects want the game to be more exciting and challenging.
Coyle et al. [35]	2011	Accuracy	Challenging is due to background distraction, but this is also engaging
Bordoloi et al. [54]	2012	Only a description	—
Anopas et al. [43]	2013	Accuracy	—
Bonnet et al.[47]	2013	Accuracy	Feedback disturbing 7/20; purely informative 8/20; positive feeling 5/20; 4/8 users find multiuser feedback helpful, 3/8 find they were disturbed. None prefers single-user conditions among the best players.
Asensio-Cubero et al. [37]	2016	Accuracy, Kappa, and game score	High accuracy and less amount of analyzing data could be achieved by the best basis selection method; The difference between features in the calibration stage and game stage could be identified (this difference could be due to the mental state such as frustration or stress)

Author	Year	Performance metric	Performance Issue
Kreilinger et al. [36]	2016	Success rate, error rate	Fatigue and lack of concentration is found after 4 runs in one user (S04)
Saeedi et al. [31]	2016	Accuracy, success rate	Performance variation in different trials for the same subject (intra-subject performance variation). Solved by adaptive assistance (that is, a user-dependent time out in a single trial)
Taherian et al. [55]	2016	Game score learning curve	Motivation, fatigue, and concentration influence performance. Subjects bored with a puzzle game loss are interesting. Performance decrease might be due to fatigue, increased concentration, and curiosity to identify new videos. The workload might need to be decreased by some methods such as meditation practice. Recommendation: BCI training needs to show users application of their learned skills from early on to increase a sense of self-efficacy and confidence; experiment should be done in the morning due to fatigue; also, a small office for less distraction.
Vourvopoulos et al.[45]	2016	Qualitative2	Low physical demand increases effort and good classification performance. Increasing workload causes worse performance.
Djamal et al. [34]	2017	Accuracy, time for finish mission	—
Statthaler et al.[40]	2017	Running time	Feature distribution had changed considerably between training and the game. This distribution might be due to a long time of rest (45min gap between sessions) and nervousness in competition (different heart rates). There are limited BCI systems in new environments; the pilot's performance fluctuations might be due to intra-subject performance variation, and intra-subject performance variation is related to psychological states such as motivation. Races with human competitors and a sizeable audience in training help the pilot himself to better prepare.
Taherian et al. [20]	2017	Game score	The unique head shape prevents subject three from using BCI; linear reduction could be seen in subject one since he has interval illness during the training and visual impairment, making him unable to focus on the screen. Subject2 feels discomfort when researchers touch his head; subject 5 is interested in doing it but is upset about it at home. Subject 7 feels frustrating in playing puzzles with sometimes no reaction; all 6 participants found EPOC uncomfortable wearing for more than 15 mins; EPOC cannot be used among patients with head support. Hearing the auditory feedback could improve their performances (comment from a special educator).
Zhou et al. [51]	2017	Accuracy	—

Author	Year	Performance metric	Performance Issue
Perdikis et al.[41]	2018	Accuracy	Unsatisfactory robustness might be related to non-stationary brain signals; longitudinal mutual learning could help increase robustness.
Ponferrada et al. [42]	2018	Accuracy	Three commends control is significantly more complicated than two commends. Although enough concentration could be provided, high variability could be seen across different trial subjects: consistency and personalization are significant challenges. An ideal solution is to run multiple sessions to identify which motor imageries each subject can best control.
Yang et al. [48]	2018	Concentration(TBR,SMR)	Portability is required
Karácsony et al.[44]	2019	Accuracy, game score	The 0.6 decision boundary (low activation threshold) causes high false positives (after increasing to 0.8, the false positive is reduced). For good performance, subjects are asked to minimise their eye and head movements; immersiveness in the game could increase the deep engagement.
Škola et al. [46]	2019	Accuracy + Qualitative3	Females perform better than males on average (in only the first run). Fatigue is higher in BCI-naïve subjects in the first run than inexperienced but not replicated in any remaining runs. People are alert and motivated sufficiently to improve their results by fast but not long MI. No evident fatigue influencing the performance has been confirmed.
Tezza et al. [56]	2019	Qualitative4	—

C. Appendix

Author	Year	No.Participants	Final Accuracy	Final recommendation
Pineda et al. [24]	2003	4	—	positive
Graz (Krausz et al.) [23]	2003	4	—	positive
Graz (Müller-Putz et al.) [33]	2007	10	65%,72%,51%,70%,70% (5 subjects finally tested)	possible
Berlin (Krepki et al.) [50]	2007	1	—	positive
Graz (Scherer et al.) [49]	2007	3	—	positive
Graz (Scherer et al.) [27]	2008	3	83%, 88%, 80%	positive
USA (Huang et al.) [52]	2009	5	73%, 59.2%(2 subjects finally tested)	positive

Author	Year	No.Participants	Final Accuracy	Final recommendation
USA (Ou Bai et al.) [53]	2010	6	81.1%, 86.7%(2 subjects finally tested)	positive
Prasad et al. [2]	2010	5	70%(average acc for 5 subjects)	positive
Coyle et al. [35]	2011	3	92.6%, 75.3%, 79.8%	positive
Bordoloi et al. [54]	2012	14	—	positive
Anopas et al. [43]	2013	12	70%,72%,70% (3 subjects finally tested)	positive
Bonnet et al. [47]	2013	20	73.94%(average acc for 20 subjects)	positive
Asensio-Cubero et al. [37]	2016	14	63%(average acc for 14 subjects)	positive
Kreilinger et al. [36]	2016	10	—	positive
Switzerland (Saeedi et al.) [31]	2016	9	85%,88%,91%,92%,89%, 75%,82%,75%,96%	positive
Auckland (Taherian et al.) [55]	2016	1	—	positive
Vourvopoulos et al. [45]	2016	13	—	positive
Djamal et al. [34]	2017	10	70%(average acc for 10 subjects)	positive
Graz (Statthaler et al.) [40]	2017	1	—	positive
Auckland (Taherian et al.) [20]	2017	6	—	negative
Zhou et al. [51]	2017	4	45%(average acc for 4 subjects)	negative
Switzerland (Perdikis et al.) [41]	2018	2	93.8%,96.8%	positive
Ponferrada et al. [42]	2018	2	68.62%(one subject finally tested)	positive
Yang et al. [48]	2018	10	—	positive
Karácsony et al. [44]	2019	10	100%(average acc for 10 subjects)	positive
Škola et al. [46]	2019	19	75.84%(average acc for 18 subjects)	positive
Tezza et al. [56]	2019	30	—	positive

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References

[1] "Disability and health," Who.int, 2021. [Online]. Available from: https://www.who.int/news-room/fact-sheets/detail/disability-and-health [Accessed: 10 July, 2020]

[2] Hettiarachch I, Nguyen T, Nahavandi S. Motor Imagery Data Classification for BCI Application Using Wavelet Packet Feature Extraction. Cham: Springer International Publishing; 2014. pp. 519-526

[3] Langhorne P, Wu O, Rodgers H, Ashburn A, Bernhardt J. A Very Early Rehabilitation Trial after stroke (AVERT): A Phase III, multicentre, randomised controlled trial. Health Technology Assessment. 2017;**21**(54):1-120

[4] Smith E. Locked-in syndrome. BMJ. 2005;**330**:7488

[5] Malouin F, Jackson P, Richards C. Towards the integration of mental practice in rehabilitation programs. A critical review. Frontiers in Human Neuroscience. 2013;**7**(536):1-20

[6] Guillot A, Genevois C, Desliens S, Saieb S, Rogowski I. Motor imagery and placebo-racket effects in tennis serve performance. Psychology of Sport and Exercise. 2012;**13**(5):533-540

[7] Zhang L, Pi Y, Zhu H, Shen C, Zhang J, Wu Y. Motor experience with a sport-specific implement affects motor imagery. PeerJ. 2018;**6**:e4687

[8] Napolitano S, Rosa R, Cusano P. The analysis of technical movement of the shooting in water polo. Sport Science. 2019;**12**:93-98

[9] Lee D, Jang C, Park H. Neurofeedback learning for mental practice rather than repetitive practice improves neural pattern consistency and functional network efficiency in the subsequent mental motor execution. NeuroImage. 2019;**188**:680-693

[10] Nicholson V, Keogh J, Low Choy N. Can a single session of motor imagery promote motor learning of locomotion in older adults? A randomized controlled trial. Clinical Interventions in Aging. 2018;**13**:713-722

[11] Bhattacharyya S, Konar A, Tibarewala D. Motor imagery and error related potential induced position control of a robotic arm. IEEE/CAA Journal of Automatica Sinica. 2017;**4**(4):639-650

[12] Prasad G, Herman P, Coyle D, McDonough S, Crosbie J. Applying a brain-computer interface to support motor imagery practice in people with stroke for upper limb recovery: A feasibility study. Journal of NeuroEngineering and Rehabilitation. 2010;**7**(1):1-17

[13] Aggarwal S, Chugh N. Signal processing techniques for motor imagery brain computer interface: A review. Array. 2019;**1-2**:100003

[14] Choi J, Kim K, Jeong J, Kim L, Lee S, Kim H. Developing a motor imagery-based real-time asynchronous hybrid BCI controller for a lower-limb exoskeleton. Sensors. 2020;**20**(24):7309

[15] Dobkin B et al. Methods for a randomized trial of weight-supported treadmill training versus conventional training for walking during inpatient rehabilitation after incomplete traumatic spinal cord injury. Neurorehabilitation and Neural Repair. 2003;**17**(3):153-167

[16] Pfurtscheller G, Flotzinger D, Kalcher J. Brain-Computer Interface—A new communication device for handicapped persons. Journal of Microcomputer Applications. 1993;**16**(3):293-299

[17] Hwang H, Kim S, Choi S, Im C. EEG-based brain-computer interfaces: A thorough literature survey. International Journal of Human Computer Interaction. 2013;**29**(12):814-826

[18] Vourvopoulos A, Liarokapis F, Chen M. The effect of prior gaming experience in motor imagery training for brain-computer interfaces: A Pilot Study. In: VS-Games 2015 –7th International Conference on Games and Virtual Worlds for Serious Applications. Skovde, Sweden: IEEE; 2015

[19] Pfurtscheller G, Neuper C. Motor imagery and direct brain-computer communication. Proceedings of the IEEE. 2001;**89**(7):1123-1134

[20] Taherian S, Selitskiy D, Pau J, Claire Davies T. Are we there yet? Evaluating commercial grade brain–computer interface for control of computer applications by individuals with cerebral palsy. Disability and Rehabilitation: Assistive Technology. 2017;**12**(2):165-174

[21] Kapp K, Blair L, Mesch R. The Gamification of Learning and Instruction Fieldbook: Ideas into Practice. 1st ed. Pfeiffer; 2013. pp. 13-67

[22] Peterson M. Computer Games and Language Learning. Basingstoke: Palgrave Macmillan; 2016

[23] Krausz G, Scherer R, Korisek G, Pfurtscheller G. Critical decision-speed and information transfer in the Graz Brain-Computer Interface. Applied Psychophysiology and Biofeedback. 2003;**28**:233-240

[24] Pineda J, Silverman D, Vankov A, Hestenes J. Learning to control brain rhythms: Making a brain-computer interface possible. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 2003;**11**(2):181-184

[25] Vasiljevic G, de Miranda L. Brain–computer interface games based on consumer-grade EEG devices: A systematic literature review. International Journal of Human Computer Interaction. 2020;**36**(2):105-142

[26] Moher D, Liberati A, Tetzlaff J, Altman D. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ. 2009;**339**(211):b2535-b2535

[27] Ahn M, Lee M, Choi J, Jun S. A review of brain-computer interface games and an opinion survey from researchers, developers and users. Sensors. 2014;**14**(8):14601-14633

[28] Ahn M, Lee M, Choi J, Jun S. Brain-computer interface speller using hybrid P300 and motor imagery signals. Sensors. 2014;**14**:14601

[29] Clerc M, Bougrain L, Lotte F. Brain-computer interfaces 1. In: Foundations and Methods. Hoboken, New Jersey: ISTE Ltd/John Wiley and Sons Inc; 2016. pp. xvi-xvii

[30] Adams E. Fundamentals of Game Design. Second ed. New Riders. 2010. pp. 26-80

[31] Saeedi S, Chavarriaga R, Leeb R, Millan J. Adaptive assistance for brain-computer interfaces by online prediction of command reliability. IEEE Computational Intelligence Magazine. 2016;**11**(1):32-39

[32] Scherer R, Lee F, Schlogl A, Leeb R, Bischof H, Pfurtscheller G. Toward self-paced brain–computer communication: Navigation through virtual worlds. IEEE Transactions on Biomedical Engineering. 2008;**55**(2):675-682

[33] Müller-Putz G, Scherer R, Pfurtscheller G. Game-like Training to Learn Single Switch Operated

Neuroprosthetic Control. Graz University of Technology; 2007. Available from: elsevier.com

[34] Djamal EC, Abdullah MY, Renaldi F. Brain computer interface game controlling using fast fourier transform and learning vector quantization. JTEC. 2017;**9**(2-5):71-74

[35] Coyle D, Garcia J, Satti AR, McGinnity TM. EEG-based continuous control of a game using a 3 channel motor imagery BCI: BCI game. In: 2011 IEEE Symposium on Computational Intelligence, Cognitive Algorithms, Mind, and Brain (CCMB). 2011. pp. 1-7

[36] Kreilinger A, Hiebel H, Muller-Putz G. Single versus multiple events error potential detection in a BCI-controlled car game with continuous and discrete feedback. IEEE Transactions on Biomedical Engineering. 2016;**63**(3):519-529

[37] Asensio-Cubero J, Gan J, Palaniappan R. Multiresolution analysis over graphs for a motor imagery based online BCI game. Computers in Biology and Medicine. 2016;**68**:21-26

[38] Herman P, Prasad G, Mcginnity TM. Design and on-line evaluation of type-2 fuzzy logic system-based framework for handling uncertainties in BCI classification. In: Conference proceedings:. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. 2008. pp. 4242-4245

[39] Zurich E. CYBATHLON—bewegt Mensch und Technik. 2021. [Online]. Available from: http://www.cybathlon.ethz.ch/ [Accessed: July 10, 2020]

[40] Statthaler K et al. Cybathlon Cybathlon experiences of the Graz BCI racing team discipline. Journal of NeuroEngineering and Rehabilitation. 2017;**14**(1):129, 1-16

[41] Perdikis S, Tonin L, Saeedi S, Schneider C, Millán J. The Cybathlon BCI race: Successful longitudinal mutual learning with two tetraplegic users. PLOS Biology. 2018;**16**(5):e2003787

[42] Ponferrada E, Sylaidi A, Aldo Faisal A. Data-efficient motor imagery decoding in real-time for the cybathlon brain-computer interface race. In: NEUROTECHNIX 2018—Proceedings of the 6th International Congress on Neurotechnology, Electronics and Informatics. 2018. pp. 21-32

[43] Anopas D, Horapong M, Wongsawat Y. BCI-based neurorehabilitation and prediction system for stroke patients. In: i-CREATe 2013—International Convention on Rehabilitation Engineering and Assistive Technology Conjunction with SENDEX 2013. 2013

[44] Karácsony T, Hansen J, Iversen H, Puthusserypady S. Brain computer interface for neuro-rehabilitation with deep learning classification and virtual reality feedback. In: ACM International Conference Proceeding Series. 2019

[45] Vourvopoulos A, Ferreira A, Badia S. NeuRow: An immersive VR environment for motor-imagery training with the use of Brain-Computer Interfaces and vibrotactile feedback. In: Proceedings of the 3rd International Conference on Physiological Computing Systems. 2016. pp. 43-54

[46] Škola F, Tinková S, Liarokapis F. Progressive training for motor imagery brain-computer interfaces using gamification and virtual reality embodiment. Frontiers in Human Neuroscience. 2019;**13**(329):1-16

[47] Bonnet L, Lotte F, Lecuyer A. Two brains, one game: Design and evaluation

of a multiuser BCI video game based on motor imagery. IEEE Transactions on Computational Intelligence and AI in Games. 2013;**5**(2):185-198

[48] Yang C, Ye Y, Li X, Wang R. Development of a neuro-feedback game based on motor imagery EEG. Multimedia Tools and Applications. 2018;**77**(12):15929-15949

[49] Scherer R, Schloegl A, Lee F, Bischof H, Janša J, Pfurtscheller G. The self-paced Graz brain-computer interface: Methods and applications. Computational Intelligence and Neuroscience. 2007;**79826**:1-9

[50] Krepki R, Blankertz B, Curio G, Müller K. The Berlin Brain-Computer Interface (BBCI)—Towards a new communication channel for online control in gaming applications. Multimedia Tools and Applications. 2007;**33**(1):73-90

[51] Zhou T, Chen A, Chen K. A brain computer interface based on motor imagery for maze game. In: 2017 10th International Symposium on Computational Intelligence and Design (ISCID). 2017. pp. 398-401

[52] Huang D, Lin P, Fei D, Chen X, Bai O. EEG-based online two-dimensional cursor control. In: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 2009. pp. 4547-4550

[53] Bai O, Lin P, Huang D, Fei D, Floeter M. Towards a user-friendly brain–computer interface: Initial tests in ALS and PLS patients. Clinical Neurophysiology. 2010;**121**(8):1293-1303

[54] Bordoloi S, Sharmah U, Hazarika SM. Motor imagery based BCI for a maze game. In: 2012 4th International Conference on Intelligent Human Computer Interaction (IHCI). 2012. pp. 1-6

[55] Taherian S, Selitskiy D, Pau J, Davies T, Owens R. Training to use a commercial brain-computer interface as access technology: A case study. Disability and Rehabilitation: Assistive Technology. 2016;**11**(4):345-350

[56] Tezza D, Garcia S, Hossain T, Andujar M. Brain eRacing: An Exploratory Study on Virtual Brain-Controlled Drones. In: Chen J, Fragomeni G, editors. Virtual, Augmented and Mixed Reality. Applications and Case Studies. HCII 2019. Lecture Notes in Computer Science(). Vol. 11575. Cham: Springer; 2019. DOI: 10.1007/978-3-030-21565-1_10

[57] Norman KL. GEQ (Game Engagement/Experience Questionnaire): A review of two papers. Compute. 2013;**25**(4):278-283

[58] Kübler A, Neumann N, Kaiser J, Kotchoubey B, Hinterberger T, Birbaumer N. Brain-computer communication: Self-regulation of slow cortical potentials for verbal communication. Archives of Physical Medicine and Rehabilitation. 2001;**82**(11):1533-1539

[59] Pfurtscheller G, Neuper C, Birbaumer N. Human brain-computer interface. In: International Conference of the IEEE Engineering in Medicine & Biology Society. 2005

[60] Vourvopoulos A, Bermudez S, Badia I, Liarokapis F. EEG correlates of video game experience and user profile in motor-imagery-based brain–computer interaction. The Visual Computer. 2017;**33**(4):533-546

[61] FDA. Real-World Evidence to Support Regulatory Decision-Making for Devices. U.S. Food and Drug Administration. 2021. [Online]. Available from: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/

use-real-world-evidence-support-regulatory-decision-making-medical-devices [Accessed: 15 January 2021]

[62] Wang Z, Yu Y, Xu M, Liu Y, Yin E, Zhou Z. Towards a hybrid BCI gaming paradigm based on motor imagery and SSVEP. International Journal of Human Computer Interaction. 2019;**35**(3):197-205

[63] Scherer R et al. Brain–computer interfacing: more than the sum of its parts. Soft Computing. 2013;**17**(2):317-331

Chapter 9

Dynamic and Adaptive Playout of Competency-Based Learning Games Based on Data in Learners' Competency Profile Considering Didactical Structural Templates

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Abstract

In this chapter, a competency-based approach, based on the qualifications-based learning model (QBLM), will be presented, which makes it possible to store the acquired competencies and qualifications (CQ) in a so-called CQ-profile (CQP) while playing an educational game. The game and the course are based on a didactical structural template (DST), making it possible to switch between the course and the game. Before the educational game can be played, it must be checked whether a learner has all the required CQs for the course or learning unit in which the educational game is included. Therefore, this chapter shows an approach to how the CQPs can be implemented, and the data from the CQP can be used to check course prerequisites. Finally, a prototypical implementation with its evaluation and the remaining challenges will be presented in this chapter.

Keywords: competence-based learning, adaptive playout, competence profiles, applied educational games, learning data, qualifications-based learning model, QBLM, didactical structural templates, DST

1. Introduction

A central content focus of the module AF A, "Industrial and Organizational Psychology," in the bachelor's degree program in Psychology at the University of Hagen (FUH) [1] is industrial psychology [2], which deals with the effect of work on the working person. The critical teaching of theoretical basics of psychological work design, which is mainly done by reading and discussing relevant theories and research results, is unfortunately mostly lacking in the experience of actual work design during studies. This can only be achieved by experiencing and trying out different forms of work design. However, confrontation, one's own experience and trying out, as well as intensive reflection on what is experienced is an essential prerequisite for the acquisition of action competencies [3], as they are also demanded within the framework of the recommendations of the German Psychological Society for the design of psychology studies [4, 5]. According to [6], the main tasks of work psychology consist of analysis, evaluation, and design of work activities and systems according to defined human criteria. Accordingly, theories and models are taught in the study of work psychology that explain and predict the effect of specific characteristics of work (characteristics of work content, work processes, or social interactions, [7]) on people, their work performance, their motivation, and their health (e.g., action regulation theory, job demand-control model, JDR model, effort-reward imbalance, cf. Lehrbrief Modul AF A Grundlagen und Arbeitspsychologie: p.66, p.126f, p.132ff.). The topic has gained relevance due to an increased social focus on psychological stress at work, which has also been reflected in the consideration of the subject in the Occupational Health and Safety Act. A growing field of work for (industrial) psychologists has emerged. Psychologically relevant task features (e.g., time pressure, work interruptions, information overload, social support, feedback, and task variability) can be systematically manipulated from the outside. After the processing, the feedback of the results, the own reflection of individual and condition causes for specific results, and the debriefing with a systematic analysis of the work situation and the independent derivation of solution suggestions for a better work design occurs. The planned didactic innovation's primary learning objective is to acquire competencies in occupational psychology to analyze, evaluate, and design work tasks according to defined human criteria [6]. In addition, going through the simulation task and the subsequent reflection should lead to a deeper and better understanding of the differentiation between situational and behavioral prevention, which is central in occupational science and condition-related and person-related interventions [8]. Through minor adjustments, other learning objectives can also be focused on (e.g., employees' leadership, communication organization, and information flow). Methodological competencies are also developed through a systematic work analysis, which the students must carry out following a work task they have experienced themselves. The development of digital technologies in the form of so-called serious/applied gaming (SG/AG) [9] allows the use of computer-based simulations to enable experiences in the completion of work tasks quasi-virtually, which are typically only possible in actual practical activities. These experiences are at least like those in real life and allow the reflection of unexpected or surprising results [10].

According to the results from [10], the learners' follow-up/simulated training success is to be captured with a final quiz and then measured using learning analytics (LA) [10] and map it to training outcomes and corresponding qualifications in terms of factual knowledge (competencies) and action knowledge (skills and proficiency levels) on the topic area of job design. The factual knowledge and action knowledge refer to declarative and procedural knowledge definitions of the adaptive control of thought-rational (ACT-R) theory [11]. Action knowledge refers to the procedural knowledge that indicates how something should be executed. This is the knowledge about the appropriate execution of actions [12]. Factual knowledge refers to the declarative knowledge of the ACT-R theory [13]. To accomplish a task or problem, an interplay of both bits of knowledge is needed [14].

The PAGEL project has the aim to provide an AG within the so-called knowledge management ecosystem portal (KM-EP) [15] in combination with the learning management system (LMS) Moodle [16]. As outlined in a previous paper [10], currently, the qualifications-based learning model (QBLM) [17, 18] supports the assignment of competencies and qualifications (CQ) [18], which are the achievements of the learning objectives and learning successes of the game/simulation sequences within an integrated applied game (AG) or any other learning unit. The learning management system (LMS) used at the FUH is Moodle [16] and offers digital learning content at the FUH. Therefore, the already existing LMS will be used as a basis in this work [19]. A didactical structural template (DST) [20, 21] supporting QBLM can be used as a starting point to describe the underlying process and provide the measurement criteria for the success of achieving learning objectives regarding CQs. This includes the success of training skills on different proficiency levels in a game-based simulation. DSTs represent the didactical structure of a course.

Furthermore, it can support a hybrid environment existing of a "classical" course in combination with applied gaming content, like a pedagogical structure for AG. For example, the AG can be a web-based computer game or a VR/AR-based game; therefore, one DST can have different modalities [20, 21].

Within the framework of the PAGEL project, there is a "classical" course with study books [10] for teaching theoretical content and factual knowledge. After successfully completing the "classical" course, the knowledge of action is to be imparted with the help of an AG [10]. "The DST, with its possibilities, offers the option to provide the learner with different media types for the same learning content. The same contents can be given for different platforms or in different modalities. The DST can provide the information cross-media. Some courses are more useful in a texture-based form, others as a game or video. The most obvious dimension in choosing a media type is the content. For example, it does make sense to provide learners in a driving school with a game or simulator to teach them driving, more than giving them a text with technical instructions. On the other side, a list of traffic symbols would also be meaningful. A mixture seems to be a good solution. However, other dimensions are also conceivable. These additional dimensions depend on the situation and can vary based on some parameters. Learners have different preferences and strategies for learning. Some learners have already acquired knowledge or CQs, making the course partly a repetition. That should lead to an abbreviated form of that content" [22]. Subsequently, the measured results from the AG are to be explained in a final quiz using the previously imparted theory knowledge [10]. These results are to be evaluated accordingly concerning the achievement of a CQ using LA. The results are stored in a competence and qualifications profile (CQP) [23]. Whether parts of the course have to be attended or not has to be checked in advance. Here, it should be checked whether the learners have already stored the corresponding CQs in their CQP or not [24].

The motivation of the book chapter is to enable the dynamic playout of the different course contents of the PAGEL project based on DSTs and to attest to corresponding CQs in a CQP [23] based on the learning outcomes and check in advance whether the learners have to attend this course at all.

Several problem statements (PS) can be derived from the objectives and motivation mentioned above.

Problem statement 1 (PS1) is that from today's perspective, for the PAGEL project, the DST is based on the current course structure [10], and to be added, AG does not exist. PS2 is that it is impossible today to store and read out the acquired CQs in a CQP to play out courses and learning units adaptively. PS3 is that from today's point of view, it is not possible to check, based on the CQs in a CQP, whether learners already have all the prior knowledge to complete a course or whether they first need to acquire further CQs. PS4 is that currently it is impossible to track the progress inside a DST implementation. Progress tracking across DST implementations is required to allow learners to switch the modality inside the learning unit. The possibility of switching the modality while executing an ACT and continuing at the same position in the learning progress inside another DST implementation is desirable for learners. This enables the learners to switch according to their current needs.

The PSs mentioned above result in the following research questions (RQs): RQ1: "What does a DST for the PAGEL project need to look like?", RQ2: "What components and interfaces are needed to adaptively play out a course based on the data in a CQP?", RQ3: "How can the progress tracking in a DST based on the CQs of a learner be tracked and verified?", and RQ4: "How can the progress across DST be tracked?"

Based on the research methodology of [25], the following research objectives (ROs) were derived from the RQs. RO1 is assigned to the observation phase (OP). This phase identifies suitable interoperability standards for interfaces for the CQs exchange. Also, suitable systems and tools are identified. RO2 is assigned to the theory-building phase (TBP). A concept is designed that shows what system components and interfaces are needed. The system development phase (SDP) moves the concept into a prototype and is assigned to RO3. The result of the SDP is evaluated in the evaluation phase (EP) in the context of a cognitive walkthrough (CW) [26]. Finally, the EP is assigned to RO4. In this phase, all RQs are evaluated.

The remainder of this paper is structured according to the ROs. This means that in state-of-the-art section, the OP is described. In conceptual design section, the TBP is described, and the SDP is presented in this paper in proof-of-concept implementation section. In evaluation section, the EP is presented. Finally, the paper concludes with a summary and indications of future developments.

2. State of the art and technology

The previous section has already mentioned some research projects and software systems related to the research goals. In the following, the most important are described in more detail.

2.1 Qualifications-based learning model

To increase the comparability of learning objects based on qualifications, the QBL-approach described by [17, 18] was implemented at the FUH [1]. The QBLM has evolved out of the CQ-based learning approach [18]. The QBLM approach includes a domain model (QDM), an architectural model, and several service distribution models. The QDM introduces the qualifications-relevant learning element (QRLE). A QRLE instance can de facto stand for a personal development plan (e.g., a study program), a unit of learning, a learning activity, or a knowledge resource. In QBL, CQ-based learning goals (LGs) and access requirements (ARs) are represented by CQPs consisting of CQ instances (the actual CQs). CQPs are applied to specify QRLE-related LGs and ARs and describe students' personal LG (target profiles) and the current state of attested CQs (actual profiles). After successfully completing a QRLE, the students' actual profiles are updated. The gap between the actual and the target profile must be bridged by appropriate CQ programs, including suitable QRLEs such as courses, learning activities, and knowledge resources [18]. In addition, KM-EP [15] has been developed within the project Realizing an Applied Gaming Ecosystem (RAGE) [17]. In addition, the portal offers various web-based tools for knowledge management and user-friendly course authoring tools (CATs) to create Moodle courses without much previous knowledge [17].

The KM-EP enables QBLM-based work with CQs. For this purpose, a CQ administration enables creating CQPs and assigning LUs (modules, courses, and teaching resources within courses) to these profiles. Furthermore, courses with assigned CQs can be exported to Moodle and executed [17]. Moodle stands for modular object-oriented dynamic learning environment [16] and is a freely available open-source software under the GNU Public License. It is software with which courses can be conducted and developed via the internet.

With the learning tools interoperability (LTI) standard, further applications such as games can be integrated into an LMS like Moodle [16]. To transfer QBLM-based CQs to Moodle, [18] developed the plugin QBL4Moodle. This plugin is the interface between Moodle and KM-EP. QBL4Moodle is used to work with QBLM in Moodle itself and map CQs created with it to the CQy approach of Moodle itself. The plugin also imports QBLM-based CQs, profiles, and frameworks from other systems. Currently, this is realized for the KM-EP [18] only.

The LMS used at FUH is Moodle. This LMS already offers digital learning content at FUH. Therefore, the already existing LMS will be used in this work. Within the KM-EP, it is possible to define CQs as conditional- and goal profiles (CP and GP) for courses [22]. QBL4Moodle also allows the transfer of CPs and GPs for courses to Moodle and directly connects them with the courses [18]. This feature has been extended to make it possible in the KM-EP to define CPs and GPs on every level or element below the course level [27]. In addition, the QBL4Moodle-Plugin and Moodle have been extended in the same way that it is possible to define CPs and GPs on every course element [28].

To support, for example, adaptive learning or the dynamic playout for courses, [23] extended Moodle in the way that explicit CQPs exist for learners. Until then, learners did not have a specific CQP. When learners wanted to know which CQy profile they had, they had to gather every single CQ spread over different Moodle pages. With the implementation of [23], learners can go to a specific page in Moodle to see which CQs they have. At the same time, the CQPs in Moodle have been designed and implemented; [24] designed and implemented a possibility for Moodle to support a dynamic outplay for courses. Dynamic outplays mean that if course A has qualification A', course B needs qualification B' and course C needs qualification C', and the student has already acquired qualification A' and the student wishes to start course C, then course B must be offered to the student. To realize the dynamic outplay of courses in Moodle, [24] analyzed Moodle's functionalities and how it would be possible to extend Moodle so that CQs can be supported for the dynamic outplay. Due to the fact that [23, 24] have been designed and implemented at the same time, the CQP did not exist in Moodle, so [24] had to assume that a CQP exists to build his design accordingly. Therefore, the remaining challenge is to bring both parts together so that the result of [24] uses the implemented CQPs [29].

2.2 Didactical structural templates

The so-called didactical structural templates (DSTs) have been introduced in [30] and extended in [20]. As described, the DSTs are based on the IMS learning design (IMS-LD) [31] and represent the didactical structure of a course and cannot only be used as a didactical structure for creating courses. The DSTs can also be used as a didactical structure for a hybrid environment existing of a "classical" course with integrated applied gaming content, just like a pedagogical structure for the applied game, which can be a web-based computer game. Therefore, one DST can have different implementations. The advantage of this approach is that learners will be able to switch between different implementations of one DST whenever they want to. They have got the same learning progress as if they had used only one specific implementation of this DST. This means that if learners like gaming, they can use the applied gaming implementation to work on the learning content. For example, suppose it is easier for the learners to answer the self-test or the final test—to stay in the exemplary stated pedagogical structure of a course—for example, multiple-choice quizzes. In that case, they can switch to a course within an LMS to answer the questions. Therefore, the DSTs have the following hierarchical structure:

Method: There are many different ways a person can learn or teach. Each learning method is a sequence of learning processes.

Play: It is a key part of the learning design, representing a teaching-learning process. Like a theatrical play with a sequence of acts, when an act is completed, the next act begins until the completion condition is met.

Act: An act represents a series of simultaneous activities and activity structures.

Activity: It is one of the core elements of learning design, which relates to many learning environments.

Activity structure: Activities can be combined into an activity structure with sequence mechanisms or freely selectable structuring. To access the DSTs, we have provided a RESTful API described in [32]. With the DSTs, we can provide the didactical structure of learning content in a standard, conform way.

2.3 E-learning interoperability standards

To fulfill the RO for the OP, corresponding interoperability standards were consulted and examined regarding their suitability for the given use case. "In general, the purpose of e-learning interoperability standards is to provide standardized data structures and communications protocols for e-learning objects and cross-system workflows. When these standards are incorporated into vendor products, users of e-learning can purchase content and system components from multiple vendors, based on their quality and appropriateness, with confidence that they will work together effectively" [33]. According to [33], the interoperability standards can be divided into the following five categories:

1. Metadata

2. Content Packaging

3. Learner Profile

4. Learner Registration

5. Content Communication

The “metadata” type [33] is used in the e-learning context to ensure that data is stored, indexed, searched, and retrieved appropriately [33]. For this purpose, corresponding standardized exchange formats have been developed for platform-independent exchange by different organizations [33]. The type “Content packaging” [33] is used to exchange course data between different learning systems [33]. Specification examples according to [33] are IMS Content Packaging specification, IMS Simple Sequencing specification [33], Sharable Content Object Reference Model (SCORM) [34] or Aviation Industry CBT Committee (AICC) guidelines [35]. The “Learner profile standards [33] allow different system components to share information about learners across multiple system components. Learner profile information can include personal data, learning plans, learning history, accessibility requirements, certifications and degrees, knowledge assessments (skills/CQs), and the status of participation in current learning” [33]. According to [33], examples of specifications for the Learner profile standards are IMS Learner Information Package (LIP) [36] or the Personal and Private Information (PAPI) [37] specification. The Learner Registration standard is intended to enable learning management components to know what learning content to deliver to each learner [33]. Examples of this are IMS Enterprise and Schools Interoperability Framework [33]. The Content Communication Standard allows information about various activities to be communicated to individual pieces of learning content [33]. Activities can include but are not limited to the start of the learning content or the completion of a learning content [33]. The completion status ranges from test results to course grades or achieved CQs [33]. Currently, two initiatives create standardized communication protocols and data models for content communication [33]. One is the Computer Managed Instruction (CMI) [38] standard of the AICC [35], and the other is the SCORM standard [39]. An even newer standard in the context of content communication is the Experience Application Programming Interface (xAPI) standard [34, 40]. In addition to the standard scope of SCORM functionalities, the xAPI standard also offers further functionalities such as tracking data in serious games or simulations [34].

To export CQs from the personal CQP, currently, only an interoperability standard of the type “Learner Profile” [33] can be considered. This allows information about the learners to be shared, such as personal data and data about degrees or assessments of knowledge [33]. According to [33], the exchange formats LIP [36] and PAPI learners [37] can be considered. IMS LIP was chosen because it also supports the transfer of CQs. One standard published by IMS is the learner information package specification (LIP) [36]. The purpose of the specification is to define a set of packages that can be used to import data into an IMS LIP-compliant system and extract the data from it [41]. In addition to a textual description of the standard, an extensible markup language (XML) [41, 42] schema is also provided. The LIP is based on a data model that describes the characteristics of learners [43]. A LIP consists of 11 main information pieces considered the basis for the learner information data structures [43]. The learner information [43] element acts as the container [43]. Each of the 11 main structures can occur any number of times within the learner information structure [44]. The content information, the so-called content type [43] element, refers to the data described with the LIP [43]. Each content type consists of a referential [43], temporal [43], and privacy [43]. The 11 main structures can contain content information and sub-content in addition to their content. The content information here allows a specific reference to the data described there, for example, for a CQ, an ID with the help of which one can find the CQ in a table [43]. With the sub-content, recursive substructures can be defined [43].

To import CQs into a personal CQP, the interoperability standard of the type "Content Communication" is used since results of, for example, learning games or a quiz can be transmitted with this. As shown above, the CMI guidelines [38] and xAPI are available from the AICC. Since the CMI [38] is a standard that can only communicate with systems that have also implemented the CMI standard, xAPI was chosen. The experience API (xAPI) is a free specification that enables learning technologies to collect data about a person's diverse experiences (online and offline) [40]. The collected data are managed consistently about a person or group [40]. Disparate systems can thus communicate securely by capturing and sharing this stream of activities using xAPI's simple vocabulary [40]. xAPI statements describe an experience (usually a learning experience, but it can be any other activity or state of affairs) that a person has performed [45]. The general structure of a statement is described in English as "I did this" or formalized as "[actor] [verb] [object]" [45]. An xAPI statement is represented as a JavaScript Object Notation (JSON) document [46]. It contains at least three components, namely actor, verb, and object [46]. An actor is an individual or a group whose activity is recorded with the statement [46]. A special feature is that no ID has to be used for internal identification (in the sense of a record within a database table) [46]. Instead, other data or methods can be used for unique identification, such as e-mail addresses. The verb is the action performed by the actor within the activity [46].

Verbs are represented as Internationalized Resource Identifiers (IRI) and can optionally be extended with a short textual description in different languages. IRIs are an evolution of the Uniform Resource Identifier (URI), using Unicode characters instead of American Standard Code for Information Interchange (ASCII) characters [47]. There are no restrictions on the definition of verbs. It only has to be a valid IRI [46]. However, this circumstance makes it possible for a verb to be defined multiple times with different URIs. To prevent this, there is a central registry for normalizing common verbs [48]. An object represents the experience, activity, or other states of affairs that an actor has performed [46]. A type property can be used to specify what type it is. By default, an activity is assumed. Depending on the type, the further structure of the object is determined. As with verbs, there is also a registration point for normalization [49, 50].

3. Concept

This section of the chapter represents the results of the ROs for the TBP. First, the overall system architecture will be represented. Afterward, the concept for the CQPs and the adaptive playout will be described. Finally, in the last subsection, the concept for the usage of DSTs will be described in more detail. Except for subsection 3.2, which is placed in Moodle, all other components described in the other subsections are within the KM-EP.

3.1 DST-based system architecture with established features

This section of the chapter will present the concept for the overall system using the CQP and DSTs.

The KM-EP holds the modules for the following provided features. As a base for the course, the DST is used. The implementation of a DST is named a didactical application (DA). The DA is registered in the KM-EP as the didactical application configuration (DAC). The DAC contains the reference to the DST identifier, a title, a Uniform Resource Identifier (URI)—the implementation is reachable with—and a Universally Unique Identifier (UUID). The UUID is used to link the external system with the DAC. An extension of the KM-EP is implemented to provide the possibility to add and edit DACs, allowing the simultaneous existence of different DAs for one DST.

The system suggests to the user that data rank the registered DAs out of the related DACs. For the recommendation, the system uses several classification parameters to describe learners and the DA. For the DA, the DAC holds the parameters. The parameters are different devices the media type is introduced, which offers a generic categorization. The DAC contains the flags for accessibility ("readout available," "audio required," and "plain language"), information about the possible screen resolutions, an extended reality flag, and a flag to describe the need for user interaction (input device) and the level of interactivity. The concept for the level of interactivity is derived from [51]. It describes six stages of possible levels.

Learners are described by multiple parameters, which describe the learners' preferences, limitations, and devices. The visual aural read kinesthetic (VARK) profile [52] is used to adjust the preferences. Fleming and Mills introduced the model in 1992 [52]. The model categorizes the learners into four types: visual, aural, read, and kinesthetic. Via a test, learners can identify four dimensions points in four dimensions and push them into a radar diagram. The radar shows afterward the preference meaning a higher swing to one of the four dimensions. The limitations of learners are reflected by three flags, which are "visual impairment," "hearing impairment," and "plain language requested." The device and its attributes are automatically derived from the browsers' information and contain the resolution, XR device, and interaction possible (input device) [52].

In the DA recommendation, these two classifications are confronted with each other. This is done via a transposition of the DA classification as a point into a two-dimensional graph. This graph contains the centric point of the VARK profile. The distance between both points defines the rating for a recommendation. If the points are close, the learners' preferences coincide with the DA. The learners' limitations overrule the recommendation process to offer the learners only the DAs they can consume. For example, the DA recommendation offers blind persons ("visual impairment") only DAs with the flag "readout available" true. After rating the different DAs, they are listed in a UI in descending order.

DA recommender and learner adaptive flow enrich this system with additional features for tracking the learners' progress and a CQ-based learning path for every individual learner.

According to the learners' presets according to their VARK profile and their impairments, the registered DAs, and the media type, the so-called didactical application recommender (DAR) calculates the best-fitting DAs. This calculation shows all eligible DAs in descending ranking order in a table so that the learners can choose on their own the DA they want to continue with learning. For more information on how the ranking is calculated, see [22, 53].

As shown in **Figure 1** on the right side, the architecture of Moodle consists of six components [15]. The core, the subsystems, the plugins, the plugin types, the sub-plugins, and the dependencies. In **Figure 1**, the three components, namely core, plugin, and subsystems, are represented [50]. The Moodle concept is explained in more detail in [50]. The PAGEL learning resources are part of the core of Moodle. The core contains all the basic functions of Moodle [15].

The course authoring tool (CAT) on the right side offers a user-friendly CAT to create Moodle courses without much previous knowledge [17].

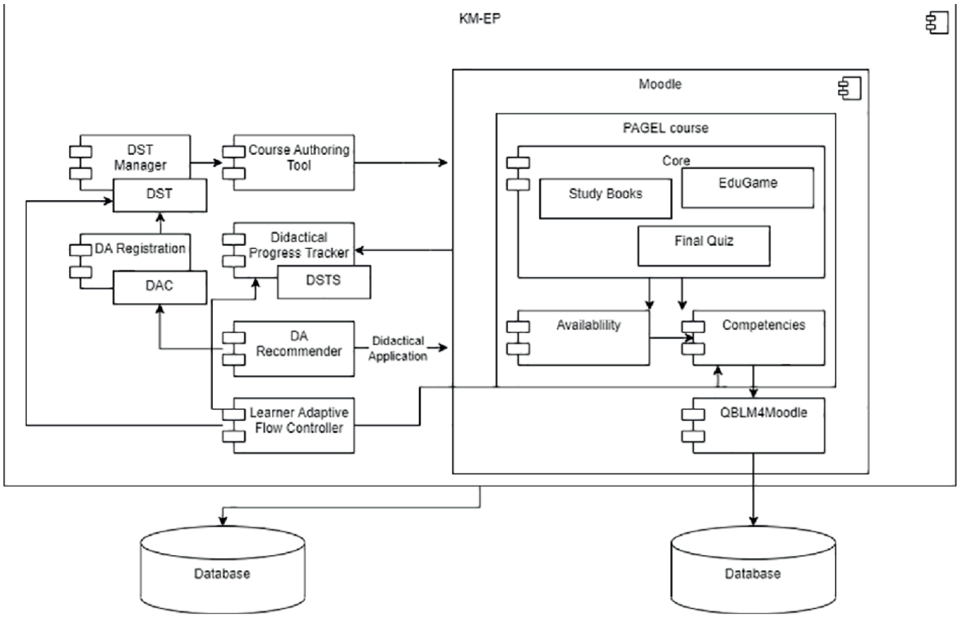

Figure 1.
Overall system architecture.

On the left side in **Figure 1** are placed all components within the KM-EP, which are used in the context of this paper and described in further subsections.

3.2 Concept for the adaptive playout of CQs with CQPs

As shown in the use cases in [50], a CQP is a profile that is assigned to an individual learner. CQPs describe each student's personal learning goals (LG) (target profile) and the current state of attested CQs (actual profile) [50].

As shown in **Figure 2**, the LMS Moodle is required. The architecture of Moodle consists of six components [15], which are the core, the subsystems, the plugins, the

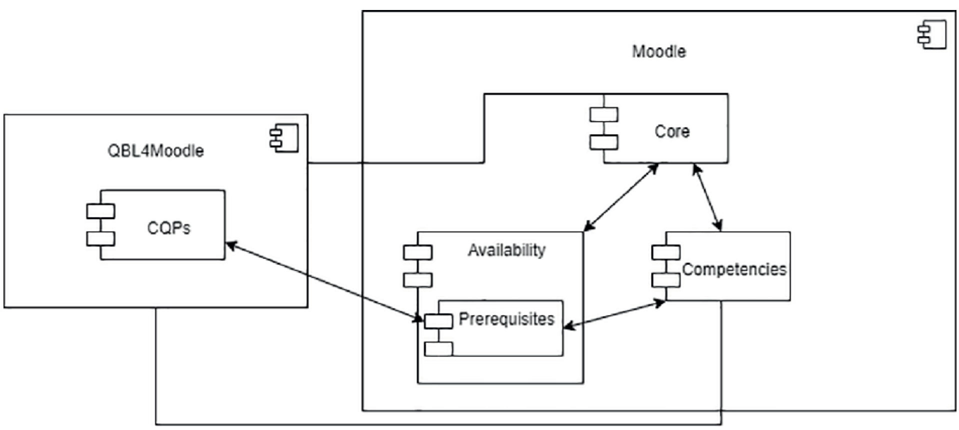

Figure 2.
System concept for the adaptive playout of CQs with CQPs [29].

plugin types, the sub-plugins, and the dependencies. In **Figure 2**, the three components, namely core, plugin, and subsystems, are represented [50]. The Moodle concept is explained in more detail in [50].

The functionality of a subsystem can be partially enabled or disabled by configuration. As an example, it serves the package CQs, which contain the functionality of the CQs. The plugin component [54] contains optional components that extend the basic functionality of Moodle. Plugins such as QBL4Moodle are optional components. The QBL4Moodle plugin contains a bidirectional communication relationship realized via core hacks [50]. To check the course prerequisites, the corresponding interfaces, described in Section 2, query the respective CQs of an individual learner from the CQP [29, 50]. To combine the dynamic outplay of courses in [24] with the learners' CQP [23], the implementation of [23, 55] has to extend the way that the just described interface is called when the CQ-checks are executed. Additionally, it has to be ensured that the checks and the interface work with the same structure of the CQs—either the one Moodle provides or the one QBL4Moodle provides [29, 50].

To export CQs from the CQP, a representational state transfer (REST) [56] interface needs to be provided. A web service called "QBL personal qualification profiles" must be added to the plugin QBL4Moodle. The web service is named "local_qbl_datastructures_personal_ profiles," according to Moodle naming conventions for web services. This provides the functions that a client can call, such as an educational game [23, 50]. To export the CQP, an IMS LIP document containing the CQs is generated from a personal CQP. As a container of all competence/qualifications instances (CQIs) [17, 18] in the CQP, it summarizes them. To import a CQ to a CQP, an xAPI statement must contain all the necessary information to generate a CQI. To identify a single learner, a personal e-mail address is used prerequisite; the address is not used in multiple user accounts. The following structure of the IRI [47] is defined for the object: "qblm://CQI/<CQF Unique identifier>>/<CQS Unique identifier>>/<PL>>." By specifying the unique identifiers for CQF and CQS and a PL, a CQI can be generated and entered in a personal CQP [23, 50].

3.3 Concept for the didactical structural template for the PAGEL project

To be able to use the QBLM and DST software infrastructure inside an actual course at FUH for the PAGEL project, first of all, a DST has to be conceptionally created. Therefore, the course and game flow described in [10] will be used as a basis.

Currently, the course "Industrial and Organizational Psychology" consists of three study books, which give the learners an overview of the theoretical background of industrial and organizational psychology. In addition, an AG should be developed to provide the learners with hands-on experience and action knowledge in the subdomain work task design, as described previously and in [10]. In the AG, the learners should experience the psychological effects of work task design for themselves. To check the learned factual and action CQs afterward, it should be possible that the game results are explained and analyzed using the previously acquired theoretical knowledge. In the end, the learners should receive a detailed overview of their results, including a review [10].

AS described previously, a DST has a hierarchical structure with different hierarchy types. At the top level of the hierarchy for a DST is the DST name. In the given case, this should be the name of the project PAGEL for easier identification. On the level below is the play level. A play element represents a learning process. When one play element is finished, the next one starts. In the PAGEL project, three learning processes could be identified. These would be the preparation, the play, and the course completion. Finally, each play element has the respective act elements on the level below. An act describes activities or activity structures that can run parallel in a play. An activity element is a core element of the learning design. Activity structure elements can be used to combine several activities.

For the PAGEL project and the identified play elements, the structure of the DST results is shown below.

The preparation includes only the theoretical background. This was thought of as an act element because this element and its activities must be completed before the play and evaluation can take place. The activities here are the three study booklets, which the learners can work on in any order.

The play element contains the "work task simulation." In the PLC, it should be possible for the player to carry out various activities in parallel with so-called tools [10]. The tools are each represented as a separate activity.

After the play element preparation and game are completed, the play element course completion can start. The course completion is divided into three ACTs: final quiz, evaluation, and results, each of which has its own activity (**Figure 3**).

3.4 Concept for learner adaptive flow based on didactical structural templates

The learner adaptive flow is introduced to support a learning journey, adapting itself according to the preset of already gained CQs. The learner adaptive flow controller controls the learner adaptive flow. It compares the target CQs of a learning objective (act, activity structure, or activity) with the learners' CQs within the KM-EP. A learning section skip is possible if the learners' CQs contain all target CQs. This skip is offered to the user via a dialog inside the start DA process. The dialog pops up if a learning section skip is possible and lists all possible skips. As the experts for their skills and their need for repetition, the learners select then the desired skips. A learning journey skip is reflected in the system as a completed activity. This is applied in the DSTS and loaded by the started DA afterward [22, 53].

3.5 Concept for didactical progress tracking

As described earlier, the DAs existence is independent of the KM-EP and the DST. That results in the circumstance that the execution of a DA is detached, and the KM-EP or other DAs do not receive any update about the progress of learners. With the didactical progress tracker (DPT), this gap is closed. The DPT holds for every learner's journey a didactical structural template session (DSTS). The DSTS maintains information about the successful completion of activities inside the journey. All activities of the learners' journey DST have an entry inside the DSTS, which is initially "not completed." While executing a DST-based learning journey in a DA, the DSTS gets updates from the DAs after completing an activity. This feature allows tracking in a central place as well as the sharing of the progress through DAs.

This sharing results in the possibility of switching between different DAs. When a DA is started, it requests the DSTS from the KM-EP to get the learner's progress. It then has to define the already completed activities as finished inside itself.

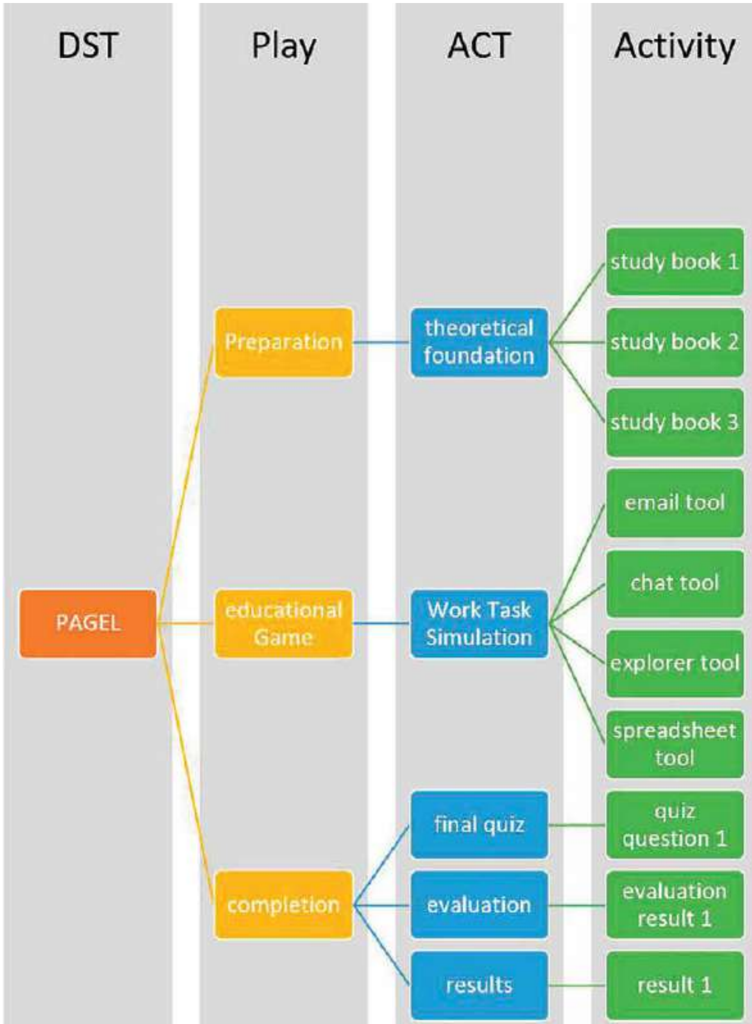

Figure 3.
Concept for the DST for the PAGEL project.

To support the switch of a DA inside a journey, a control panel allows the learners to call a different DA at any time. The DA is called with a link, which contains the reference to the DSTS to allow the called DA to load the DSTS, respectively, the already gained progress.

A management dashboard shows all DSTS, including the learners and their progress. In addition, it allows root users to maintain their progress and support the learners in completing their journeys [22, 53].

4. Proof-of-concept realization

This section of the chapter represents the results of the ROs for the SDP. First, the proof-of-concept (PoC) realization for the adaptive playout of CQs with CQPs will be presented, and afterward, the realization of the DSTs components.

4.1 Realization of the adaptive playout of CQs with CQPs

This section will describe the realization of the combination of both concepts of [23, 24]. Because Moodle is the target platform for the described extensions, the implementation will be done with PHP [57] in combination with JavaScript [58], respectively, jQuery [59]. For the prototypical implementation in [24], Moodle had to be extended to different surface components, which are presented with different code snippets and sequence diagrams to show how the prototypical implementation will work. The prototypical implementation in [23] is presented with different code snippets and screenshots to display the layout of the extended pages in Moodle. The conceptual part of this paper shows how the two separate works [50, 55] can be combined. The prototypical implementation of this part is open and will be presented in a separate paper [29].

4.2 Realization of the didactical structural template for the PAGEL project

Based on the concept for the DST, the DSTM was opened in the KM-EP. The corresponding structures from the concept were created in the DSTM. The finished DST is shown in **Figure 4**.

4.3 Realization of the learner adaptive flow based on didactical structural templates

For ACTs and elements below that hierarchy, possible learning section skips are provided to offer an adaptive learner flow. The learners' CP is compared with the goal CQs of the DST learning elements. If the learners' CP contains the goal CQs, the element is a

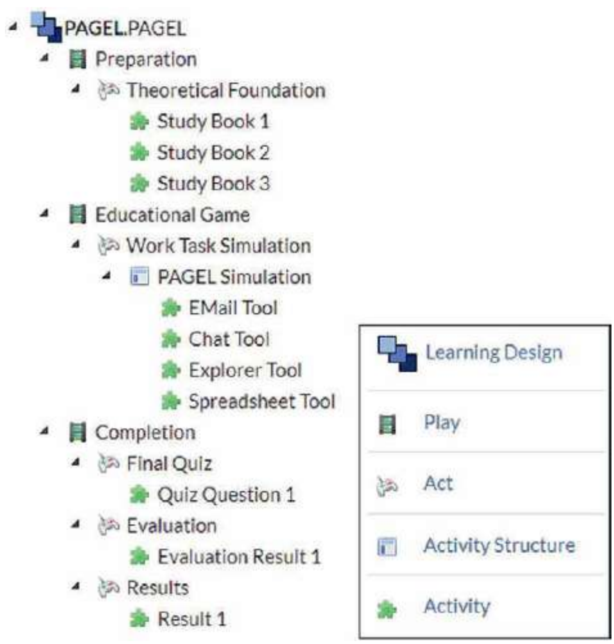

Figure 4.
Realized DST for the PAGEL project.

candidate for a skip. The possible learning section skips are provided to the learners, and they decide whether the learning section skip is executed or not. The skip is reflected as a preset of the learning elements' ACTIVITIES to "completed" in the DPT [22, 53]. A detailed overview and description of the implementation can be found in [22, 53].

4.4 Realization of the didactical progress tracking

The introduced DPT tracks the progress of the learners based on ACTIVITIES. The DAs have to send a progress update to the KM-EP after finalizing an ACTIVITY. From inside the running DA or with a control panel, the learners can switch to another DA. The learners only lose their progress within an ACTIVITY [22, 53]. A detailed overview and description of the implementation can be found in [22, 53].

5. Evaluation

In the form of a cognitive walkthrough (CW) [26], an initial evaluation of the proof-of-concept implementation was accomplished by domain experts in the field of education in computer science. The evaluation's primary goal is to estimate the productive capacity of the implementation and orientate future development. The developed DST for the PAGEL project for RQ1 was presented and accepted by all project participants during a CW. The CWs for RQ2, RQ3, and RQ4 have been documented in [22–24, 29, 50, 53, 55]. The occurred errors and misbehaviors have been defined and fixed accordingly. Based on the evaluation, improvements and renewals were identified. These will be implemented and considered in future work.

6. Conclusion and future work

We have demonstrated in this chapter how it is possible to extend Moodle with CQPs, and a dynamic outplays of courses. In the past, both parts were not combined; we have shown how a combination of both concepts is possible through a conceptual model. The remaining challenge is the prototypical implementation of the combination of the CQPs, the dynamic outplays of courses, and an evaluation of this combination.

The DST is independent of the DAs. Multiple DAs implement the same DST received by the XML export, the endpoint, or the CAT. Afterward, the author can register the DA as a DAC in the KM-EP. In addition, the DAC contains characteristics about the DA as well as a link to redirect learners to the DA.

Before starting into a DA to execute the learning journey, learners have to enter their preferences into a UI. The preferences are the restriction flags (visual impairment, hearing impairment, and plain language requested), the learners' VARK profile values, and the media type of the learners' device. These are compared with the characteristics of the available DACs related to the requested DST. The DA recommendation provides a rating for the DACs. The learners can then select from the sorted list a DA to start the journey.

The introduced DPT tracks the progress of the learners based on activities. The DAs have to send a progress update to the KM-EP after finalizing an activity. From inside the running DA or with a control panel, the learners can switch to another DA. The learners only lose their progress within an activity.

For acts and elements below that hierarchy, possible learning section skips are provided to offer a learner adaptive flow. The learners' CP is compared with the goal CQs of the DST learning elements. If the learners' CP contains the goal CQs, the element is a candidate for a skip. The possible learning section skips are provided to the learners, and they decide whether the learning section skip is executed or not. The skip is reflected as a preset of the learning elements' activities to be "completed" in the DPT.

For the PAGEL project, we have shown a DST concept and the DST definition in the DSTM.

The learners' CQP, used for the adaptive playout, is placed in Moodle and does not interact with the KM-EP. On the other hand, the learner adaptive flow is based on the learners' CQP placed in the KM-EP. To make the learner adaptive flow possible within the KM-EP, the learners' CQP has to be synchronized with the learners' CQP placed in Moodle (and other systems when other systems are involved in the process).

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References

[1] Fernuni Hagen. Fernuniversität Hafen [Internet]. 2022. Available from: https://www.fernuni-hagen.de/ [Accessed: May 8, 2022]

[2] Fernuniversität Hagen. Lehrgebiet Arbeits- und Organisationspsychologie [Internet]. 2022. Available from: https://www.fernuni-hagen.de/arbeitspsychologie/index.shtml [Accessed: May 8, 2022]

[3] Kolb D-A. Experiential learning: Experience as the source of learning and development. Creative Education. Upper Saddle River, New Jersey: Prentice Hall; 1984. p. 272

[4] Erdfelder E, Anoni C, Bermeitinger C, Bühner M, Elsner B, Fydrich T, et al. Empfehlungen zur Qualitätssicherung in Studium und Lehre. Psychologische Rundschau. 2021;**1**:19-26

[5] Spinath B, Anoni C, Bühner M, Elsner B, Erdfelder E, Fydrich T, et al. Empfehlungen zur Qualitätssicherung in Studium und Lehre. Psychologische Rundschau. 2018;**3**:183-192

[6] Ulich E. Arbeitspsychologie. 6th. ed. Stuttgart: Schäffler-Poeschel Verlag; 2005. p. 854

[7] GDA. Leitlinie Beratung und Überwachung bei psychischer Belastung am Arbeitsplatz [Internet]. 2018. Available from: https://www.gda-portal.de/DE/Downloads/Downloads_node.html [Accessed: May 8, 2022]

[8] Lohman-Haislah A. Psychische Belastungen was tun? Verhältnisprävention geht vor Verhaltensprävention. BAuB: Aktuell. 2012;**2**:6-7

[9] Marr A. Serious Games für die Informations- und Wissensvermittlung – Bibliotheken auf neuen Wegen [Internet]. 2010. Available from: https://books.google.de/books/about/Serious_Games_f%C3%BCr_die_Informations_und.html?id=U-UlvDkoad8C&redir_esc=y [Accessed: May 8, 2022]

[10] Srbecky R, Winterhagen M, Wallenborn B, Then M, Vu B, Fraas W, et al. Towards a work task simulation supporting training of work design skills during qualification-based learning. In: Proceedings of the 14th International Conference on Computer Supported Education. Vol. 2. Scitepress Portugal: CSEDU; 2022. pp. 534-541. Online Conference. ISBN 978-989-758-562-3. ISSN 2184-5026. DOI: 10.5220/0011072800003182

[11] Anderson J-R, Schunn C-D. Implications of the ACT-R learning theory: No magic bullets. In: Glaser R, editor. Advances in Instructional Psychology: Educational Design and Cognitive Science. 5th ed. Lawrence Erlbaum Associates Publishers; 2000. pp. 1-33

[12] Woolfolk A, Schönpflug U. Pädagogische Psychologie. 10th ed. Pearson Education; 2008. p. 864. ISBN: 978-3827372796

[13] Urhahne D, Dresel M, Fischer F. Psychologie für den Lehrberuf. Deutschland: Springer-Verlag GmbH; 2019. p. 630 ISBN: 978-3-662-55754-9

[14] Albert D, Hockemeyer C, Mayer B, Steiner CM. Cognitive structural modelling of skills for technology-enhanced learning. In: Proceedings of the 7th IEEE International

Conference on Advanced Learning Technologies (ICALT). Niigata, Japan: IEEE; 2007. pp. 322-324

[15] Vu BA. Taxonomy Management System Supporting Crowd-Based Taxonomy Generation, Evolution, and Management [Thesis]. Deposit_Hagen. Hagen: Fernuniversität Hagen; 2020

[16] Moodle.org. Was ist Moodle? [internet].2019. Available from: https://bit.ly/3wYOETU [Accessed: May 8, 2022]

[17] Wallenborn B. Entwicklung einer innovativen Autorenumgebung für die universitäre Fernlehre [thesis]. Deposit_Hagen. Hagen: Fernuniversität Hagen; 2018

[18] Then M. Supporting Qualifications-Based Learning (QBL) in a Higher Education Institution's IT Infrastructure [Thesis]. Deposit_Hagen. Hagen: Fernuniversität Hagen; 2020

[19] Srbecky R, Krapf M, Wallenborn B, Then M, Hemmje M. Realization of a framework for game-based learning units using a unity environment. In: Proceedings of the 15th European Conference on Game Based Learning; 23-24 September 2021. Online conference. England: ACI; 2021. pp. 680-690

[20] Winterhagen M, Hoang M-D, Lersch H, Fischman F, Then M, Wallenborn B, et al. Supporting structural templates for multiple learning systems with standardized qualifications. In: EDULEARN20 Proceedings, 12th International Conference on Education and New Learning Technologies. Online Conference. Palma de Mallorca: IATED; 2020. pp. 2280-2289. DOI: 10.21125/edulearn.2020.0705

[21] Winterhagen M, Hoang M-D, Wallenborn B, Heutelbeck D, Hemmje M. Supporting qualification based didactical structural templates for multiple learning platforms. In: Advances in Software Engineering, Education, and e-Learning – Proceedings from FECS'20, FCS'20, SERP'20, and EEE'20; 26-28 July 2021. Las Vegas, USA: Springer; 2020. pp. 793-808

[22] Wetzel S. Supporting Dynamic Learning Modalities Enabling Personalised Learner Experience Based on Didactical Structural Templates [Thesis]. Hagen: Fernuniversität Hagen; 2022

[23] Ochsendorf I. Implementierung einer Kompetenzprofilverwaltungs (CQP)-Komponente für Lernende für Moodle zur benutzerspezifischen Speicherung von Kompetenzdaten [thesis]. Hagen: Fernuniversität Hagen; 2022

[24] Hedderoth A. Entwicklung eines Moodle-Plugins für adaptive Kurse [thesis]. Hagen: Fernuniversität Hagen; 2022

[25] Nunamer J-F, Chen M, Purdin T-D. System development in information system research. In: Twenty-Third Annual Hawaii International Conference on System Sciences; 1990. Kailua-Kona, HI, USA: IEEE; 1990. pp. 631-640. DOI: 10.1109/HICSS.1990.205401

[26] Wilson C. User Interface Inspection Methods: A User-Centered Design Method. 1st ed. Morgan Kaufmann Publishers Inc; 2013. p. 146. ISBN: 978-0-12-41048-8

[27] Lersch H. Implement an Extension of the KM-EP Course Authoring Tool (CAT) to Associate Competencies with Learning Activities and an Interface to Export Competencies to the LMS Moodle [Thesis]. Hagen: Fernuniversität Hagen; 2020

[28] Hoang M-D. Management of Structural Templates in Association with Competence-Based Learning and the LMS Moodle [Thesis]. Hagen: Fernuniversität Hagen; 2020

[29] Srbecky R, Winterhagen M, Hedderoth A, Ochsendorf I, Fischman F, Then M, et al. Automatic dynamic and adaptive playout of competency-based learning units based on data in learners' competency and qualification profile. In: Springer Nature SPRINGER NATURE - Research Book Series: Transactions on Computational Science & Computational Intelligence; Proceedings of the 21st International Conference on e-Learning, e-Business, Enterprise Information Systems, & e-Government (EEE22); 25-28 July 2022. Las Vegas. USA: Springer; 2022

[30] Winterhagen M, Then M, Wallenborn B, Hemmje M. Towards structural templates for learning management systems taking into account standardized qualifications. Hagen: Technical Report Fernuniversität Hagen; 2019

[31] I.G.L.-Consortium. Learning design specification [Internet]. 2003. Available from: https://www.imsglobal.org/learningdesign/index.html [Accessed: May 8, 2022]

[32] Winterhagen M, Heulbeck D, Wallenborn B, Hemmje M. Integration of pattern-based learning management systems with immersive learning content. In: CERC 2020 Proceedings. Belfast, Northern-Ireland: CERC-WS.org; 2020. pp. 211-221. Available from: http://ceur-ws.org/Vol-2815/CERC2020_paper13.pdf

[33] Sun Microsystems Inc. E-Learning Interoperability Standards [Internet]. 2021. Available from: http://proyectosuricata.cicei.com/sites/default/files/mapa_de_conocimiento/eLearning_Interoperability_Standards.pdf [Accessed: May 8, 2022]

[34] Rustici Software LLC. SCORM vs the Experience API (xAPI) [Internet]. 2022. Available from: https://xapi.com/scorm-vs-the-experience-api-xapi/ [Accessed: May 8, 2022]

[35] AICC. Welcome to aicc.org [Internet]. 2022. Available from: https://www.aicc.org/ [Accessed: May 8, 2022]

[36] IMS Global. IMS Learner Information Package Accessibility for LIP Information Model [Internet]. 2022. Available from: https://www.imsglobal.org/accessibility/acclipv1p0/imsacclip_infov1p0.html [Accessed: May 8, 2022]

[37] Dolog P, Nejdl W. Challenges and Benefits of the Semantic Web for User Modelling. 2003. Available from: https://www.researchgate.net/publication/2564039_Challenges_and_Benefits_of_the_Semantic_Web_for_User_Modelling [Accessed: May 8, 2022]

[38] McDonald W-A, Hyde J, Montgomery A. CMI Guidelines for Interoperability AICC. AICC [Internet]; 2004. Available from: https://github.com/ADL-AICC/AICC-Document-Archive/releases/tag/cmi001v4. [Accessed: June 18, 2022]

[39] Srbecky R, Wallenborn B, Then M, Hemmje M. Towards learning analytics in higher educational platforms in consideration of qualification-based learning. In: Edulearn 21 Proceedings; 5-6 July 2021. Online Conference. Spain: IATED; 2021. pp. 5067-5076

[40] Rustici Software LLC. xAPI Overview [Internet]. 2022. Available from: https://xapi.com/overview/ [Accessed: May 8, 2022]

[41] IMS Global. IMS Learner Information Package Specification [Internet]. 2022. Available from: https://www.imsglobal.org/profiles/index.html [Accessed: May 8, 2022]

[42] selfHTML. XML [Internet]. 2022. Available from: https://wiki.selfhtml.org/wiki/XML#:~:text=XML%20(Extensible%20Markup%20Language)%20ist,f%C3%BCr%20die%20Anwendung%20im%20Web [Accessed: May 8, 2022]

[43] IMS Global. IMS Learner Information Packaging Information Model Specification Final Specification Version 1.0 [Internet]. Available from: https://www.imsglobal.org/profiles/lipinfo01.html [Accessed: May 8, 2022]

[44] Bakhouyi A, Dehbi R, Talea M, Hajoui O. Evolution of standardization and interoperability on E-learning systems: An overview. In: 16th International Conference on Information Technology Based Higher Education and Training (ITHET). Instanbul, Turkey: IEE; 10-12 June 2017. pp. 1-8.

[45] Rustici Software LLC. xAPI - Tech Overview [Internet]. 2022. Available from: https://xapi.com/tech-overview/ [Accessed: May 8, 2022]

[46] ADL Initiative. Experience API - Advanced Distributed Learning (ADL) Co-Laboratories [Internet]. 2022. Available from: https://github.com/adlnet/xAPI-Spec/blob/master/xAPI-Data.md [Accessed: May 8, 2022]

[47] W3C. Internationalized Resource Identifiers (IRIs) [Internet]. 2022. Available from: https://www.w3.org/International/O-URL-and-ident.html [Accessed: May 8, 2022]

[48] Rustici Software LLC, "Verbs: The Registry, "[Online]. 2022. Available from: https://registry.tincanapi.com/#home/verbs [Accessed: May 8, 2022]

[49] Rustici Software LLC. Activity Types: The Registry [Internet]. 2022. Available from: https://registry.tincanapi.com/#home/activityTypes [Accessed: May 8, 2022]

[50] Srbecky R, Ochsendorf I, Then M, Winterhagen M, Wallenborn B, Hemmje M. Implementing a competence and qualifications profile component to support competence and qualification based learning in higher educational institutions. In: Edulearn22 Proceedings; 4-6 July 2022. IAETD: Palma de Mallorca, Mallorca; 2022

[51] Rey G-D. E-Learning – Theorien, Gestaltungsempfehlungen und Forschung. 1st. ed. Bern: Huber; 2009. p. 240. ISBN: 978-3456847436

[52] Bay Atlantic University. 4 Types of Learning Styles: How Do Students Learn Best? [Internet]. 2020. Available from: https://bau.edu/News/types-oflearning-styles/ [Accessed: September 6, 2021]

[53] Winterhagen M, Wetzel S, Srbecky R, Heutelbeck D, Wallenborn B, Hemmje M. Didactical structural templates enabling learner adaptive flow. Edulearn22 Proceedings; 4-6 July 2022; Palma de Mallorca, Mallorca: IAETD; 2022

[54] Moodle.org. Communication Between Components [Internet]. 2022. Available from: https://docs.moodle.org/dev/Communication_Between_Components [Accessed: May 8, 2022]

[55] Winterhagen M, Hedderoth A, Srbecky R, Fischman F, Wallenborn B, Then M, et al. Enabling adaptive courses in moodle. In: Edulearn22 Proceedings; 4-6 July 2022. IAETD: Palma de Mallorca, Mallorca; 2022

[56] RedHat. Was ist eine REST API? [Internet]. 2020. Available from: https://www.redhat.com/de/topics/api/what-is-a-rest-api [Accessed: May 8, 2022]

[57] PHP. Was ist PHP [Internet]. 2022. Available from: https://bit.ly/3ITEeaG [Accessed: May 8, 2022]

[58] JavaScript. JavaScript [Internet]. 2022. Available from: https://bit.ly/3JXmNXU [Accessed: May 8, 2022]

[59] jQuery. What is jQuery [Internet]. 2022. Available from: https://jquery.com/ [Accessed: May 8, 2022]

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This book examines how gamification is designed and implemented today, particularly within our transmedia world. This process requires balancing the narrative elements and the gamification mechanics used within the scenario that leads to the target objectives. Therefore, it is important to examine how exemplar case studies have been developed to learn from those implementations and advance this research and applications in this area. We approach the interdisciplinary design of gamified systems both as a deterministic and a creative process. From the deterministic perspective, one must design the system functionality as well as the rules and the mechanics that govern the functionality. However, the creative process is often an important factor for the success of an implementation. This includes all aspects of a gamified system, including its aesthetics, storyline and narration, and in more technologically advanced systems that are not limited to one medium. An important development in the field is the ability to use both gamification and ludification techniques within an implementation, a process that can create systems that are enjoyable and can dress up the scenario in our attempt to reach a state of "Flow"(In Csikszentmihalyi's words, flow is "a state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will continue to do it even at great cost, for the sheer sake of doing it"). Contemporary gamified systems utilize a wide variety of technologies that allow the extension from cross-media to transmedia scenarios. The availability of so many technologies and media platforms that one may use to design a gamified process is phenomenal, extending our capacity to create new gamified realizations that were not possible in the past as they can combine the complete reality–virtuality continuum.

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