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MYSTERY OF A SUPER BALL: A PERSONAL ACCOUNT ON A CHEMISTRY GAMIFICATION IN PROMOTING SOFT SKILLS AMONGST PRE-SERVICE TEACHERS

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ABSTRACT

Gamification becomes trending to increase learning engagement. Yet it is rarely attempted by teachers for flipped classroom approach due to time constraint, the need for creativity and technology literacy. In this paper, I share my experience in gamification design to promote communication, collaboration, critical thinking, and creativity (4Cs) among students. Faced with stagnancy in using traditional cooperative strategies, I took on the challenge of designing the game "Mystery of Super Ball" for the Polymer topic, involving a group of pre-service teachers as Agents in a mystery-mission game. The study design was motivated by the gap in action research's reflective practitioner philosophy. Data was gathered through video recording, semi-structured interviews, and student reflections. The findings indicate that students demonstrated strong communication and collaboration skills

while immersing themselves in their detective roles. Triangulating with quantified episodes, communication (31.01%) and collaboration (25.58%) were substantively prevalent in the students' problem-solving tasks. However, critical thinking (22.79%) and creativity (20.62%) showed relatively lower occurrences, suggesting the need for revising my strategies. Among the 24 subconstructs of the 4Cs themes, two were minimally observed: 'Create new and worthwhile ideas (both incremental and radical concepts)' and 'Analyze and evaluate major alternative points of view', falling under creativity and critical thinking, respectively. These insightful findings strongly advocate for reevaluating the current critical essay assessment on the Polymer topic. A more innovative approach is needed, one that challenges students to showcase their creative and critical problem-solving abilities. Noteworthy, students' perceptions of my creativity shed light on my strengths and weaknesses in game design, providing valuable insights for future research recommendations. This study highlights the importance of being a reflective practitioner, both for my pre-service student-teachers and myself as a lifelong learner.

Keywords: Flipped learning, Game-based Learning, Instructional Technology, collaboration, action research.

INTRODUCTION

Trends in 21st century learning designs indicate an increasing interest in flipped learning approach. Many activities have been employed by educators while flipping their lecture-style or preach-style to a more student-centred learning activity. Despite the proliferation of interest to flip the class, the challenge is to design one that could promote engagement while nurturing values amongst students. Gamification, has increasingly been incorporated in learning (Bulut et al., 2022*;* Parody et al., 2022; O'Grady-Jones and Grant, 2023; Robberts & Van Ryneveld, 2022) as well as in flipped classroom during in-class session (Hung, 2018; Algayres & Triantafyllou, 2019; Sailer & Sailer, 2021). In Malaysia and other Asian countries alike (Chan & Yuen, 2014), the revamp of new curriculum clearly emphasizes the importance of students' creativity development. As a result, teachers are encouraged to develop or adopt innovative teaching methods to foster students' creativity in the classroom (MoE, 2016; Yunus et al., 2014). Designing a game-based learning (GBL) is one of the trending innovations many teachers are adopting.

Despite the trending development and the advantages of game-based learning, on contrary, some scholars (Deterding, 2011; van Roy & Zaman, 2017) did not find strong evidence which supports the association between game-based learning and students' soft skill development. Particularly, in how it nurtures the learner traits concerning the basic soft skills namely communicating, collaborating, critical thinking and creativity skills. These soft skills are fundamental in the 21st century in ensuring students' survival for their future career undertakings. Currently, there are about 41,467 unemployed graduates in Malaysia (Malaysian Department of Statistics, DoSM, 2021a).

This scenario signifies the urging need for education that can nurture soft skills for students so that they are able to adapt to a changing labour market. This study focuses on the students' development of the basic 4Cs namely communicating, collaborating, critical thinking and creativity skills, in the perspective of the learners while they underwent the gamification experience.

PROBLEM STATEMENT

Despite the great potential to facilitate students' 21st century skill development, game-based learning is often neglected by teacher educators. The reason being constraint of time to prepare or design a creative or innovative lesson plan. Heavy workloads and unskilful to use technology are also along the excuses to apply game-based learning or gamification in classroom (Bulut et al., 2022; Parody et al., 2022; O'Grady-Jones & Grant, 2023; Robberts & Van Ryneveld, 2022; Hung, 2018; Algayres & Triantafyllou, 2019; Sailer & Sailer, 2021).

Hence, game-based learning which requires people to be familiar with media and technology, and requires people to be creative and critical thinkers, is often feared to be trialled out. These excuses seem to deprive teachers from being creative designer for an engaging lesson. The overarching question arose is, why do teacher-educators fear or refuse to use game-based learning?

Due to limited empirical data and studies on GBL in Malaysia, the potential it offers in the Malaysian educational context to influence

students' 21st century skill development is poorly examined (Sanmugam et al., 2016; Ab. Rahman et al., 2018; Tamrin et al., 2022). One of gaps identified lies in the research design when many studies in Malaysia neglects students' narrative as the subject of the lesson or game-design. To the best of the researcher's knowledge, the common conventional research methodology employed currently favours numerical data as opposed to the narrative of the learners (eg, Tamrin et al., 2022; Ab. Rahman et al., 2018). Here, teachers or researchers rarely reflected their own competency as the game designer hence neglected the association between players' narrative who were learners with the development of their soft skills. Within the discourse of teacher professional development and against the backdrop of action research paradigm, this scenario is worrying as lack of reflective skills detriment the professional enhancement to become competent teachers (McNiff, 2016; Schon, 1987). Hence, this study seeks to understand the impact of the gamification learning on the four aspects of the soft skills using student's reflections.

Reflection on Previous Teaching Practice

The Organic Chemistry course was a significant component of the sixth semester in the teacher preparatory programme. The course comprised 30 hours of theoretical lectures, 15 hours of tutorials, and 12 hours of laboratory work. It was divided into three main parts: aliphatic compounds, aromatic compounds, and polymer and its benefits. The final topic focused on exploring the applications, issues, and weaknesses of polymers in our daily lives. The ultimate learning outcome of the course was for students to write a critical essay on the usage and advantages of polymers, which was assessed at the conclusion of the course.

In the past, I used cooperative learning strategies, implementing various structures such as Jigsaw, Round Robin, and 3 stray one stay, based on Kagan's protocols (1990). However, over time, I noticed a decline in the students' enthusiasm for group work. They seemed disengaged during discussions, resorting to individual work on their gadgets to find information. The group presentations became lackluster, and peer learning seemed less active. My attempts to motivate them with encouraging words didn't have the same impact as before; it goes thinned in the air. It was a turning point for me to

reflect on my teaching practices and question how well I was fostering the 4Cs values in my students.
During informal interviews with the participants, they expressed their desire for a more challenge-oriented approach in chemistry classes, indicating that the Kagan's cooperative learning structures had become repetitive after prolonged use. This prompted me to explore alternative strategies that I hadn't tried before.

After researching online and reviewing literature, I came across the concept of gamification, which aims to enhance learner engagement through fun learning experiences. Taking into consideration the unstable internet connection at the learning premise, I decided to design a lesson that incorporated elements of gamification, combining both digital and non-digital components. This led to the creation of the game-based learning activity titled 'Mystery of a Super Ball.' I embraced the challenge of redesigning my teaching approach to captivate the students' interest and make the learning experience more enjoyable and enriching.

Research Objective:

Explore the extent to which the Mystery of the Super Ball engaged students in communication, collaboration, creativity and critical thinking?

Research question:

To what extent students feel engaged in communication, collaboration, creativity and critical thinking during Mystery of the Super Ball mission?

LITERATURE REVIEW

Gamification

Gamification is the utilization of game-like design elements in a non-game context (Deterding et al., 2011; Schobel et al., 2020; Zimmerling et al., 2018) to motivate people and solve problems (Zichermann & Cunningham, 2011). It has emerged as promising pedagogical

approach that leverages the engaging nature of games to enhance learning experiences for students hence its' increasing wide spread usage in a range of fields such as education and learning, health, and science (Ahn & Dabbish, 2004). By using game components as a means to deliver educational content, promote learning, and support the development of various cognitive, social, and emotional skills (Connolly et al., 2012), studies have highlighted a number of game advantages (Binkley et al., 2014; van Roy & Zaman, 2017; Bado, 2019). Among them are, making learning less intimidating as it encourages trial-and-error (Hanus & Fox, 2015), hence less worrying (Lee & Hamer, 2011), and allowing for regular and quick feedback (Kapp, 2012).

Additionally, game-based learning offers customised difficulty progression, enabling training to be scaffolded based on specific student needs (Hanus & Fox, 2015); visible representations of achievement (such as through badges); competition-based motivation (such as leaderboards) (Camilleri et al., 2011; Binkley et al., 2014), all of which increase class participation, interest and motivation development (Bado, 2019). These findings explain why there are a growing number of researchers committed to developing educational games to support the teaching of essential 21st century skills (Boyle et al., 2014; Bado, 2019).

Nevertheless, it's noteworthy that gamification is not immune to criticism. While many studies have supported the benefits of Game-Based Learning (GBL) (Deterding, 2011; van Roy & Zaman, 2017), the existing body of research on gamification in education is diverse and covers a wide range of game design elements and implementation contexts. As a result, the findings from these studies can often be distinct and even contradictory (Dicheva et al., 2015; Nah et al., 2014). Indeed, Mayer (2020) underlines the necessity for more in-depth study by claiming that studies comparing traditional techniques with game-based learning activities in the literature have reached a saturation point. This poses a challenge in designing game-based learning and research design alike, that enable both educator cum researcher to assess the impact of the narrative aspect on students' participation. Hence, this study aims to capture students' perspectives on their 4Cs skills by taking account on their narratives during their gameplay experience.

Related Theories of GBL

Theories related to game-based learning seem diverse. Numerous reviews show that motivational theories are the most frequently used. Exemplifying these are the Self-determination Theory by Recci and Ryan Flow Theory, Situated Learning and Experiential Learning (Ozdamli, 2018). From the review, it seems that self-regulatory learning (SRL) is rarely used. In my study, I proposed SRL theory to illustrate how a student controls himself including his motivation to retain in the learning process via the gameplay. How students indulge and manoeuvre the learning process by accomplishing the game goal became part of the study's interest. To set the context, a brief review on SDT and Experiential Learning is presented here before elaborating on the Self-regulated learning (SRL).

Self-Determination Theory advocates the role of intrinsic motivation in driving human behavior (Deci & Ryan, 1985). Game-based learning can tap into students' intrinsic motivation by offering autonomy, competence, and relatedness within the game environment (Ryan et al., 2006). When learners feel a sense of control, competence, and connection to the learning process, their motivation to engage and succeed increases (Plass et al., 2015). While Experiential Learning Theory emphasizes the importance of learning through concrete experiences, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). Game-based learning provides a platform for students to engage in all these stages of experiential learning, making the educational process more immersive and meaningful (de Freitas & Oliver, 2006).

While Self-regulated learning (SRL) refers to student actions in which they actively govern their own learning (Schunk & Zimmerman, 2003). More precisely, SRL models are composed of strategic, metacognitive, and motivational components that appear as one's capacity to analyse and successfully govern cognitive and motivational processes throughout learning within a certain domain (Zimmerman 2000; Pintrich 2000; Winne 2001). Self-regulated learners, for example, frequently set their own learning goals and effectively work toward them by carefully assessing their progress and using adaptive tactics as needed (Zimmerman 2000). As a result, self-regulated learners not only have a sufficient collection of learning techniques, but also the

willingness to exert the required effort to participate in these cognitive processes (Pintrich, 2000, Sabourin et al., 2013). In game-based learning learners who play part as the players will have to control their learning regime including motivation, interest, as well as attitude to ensure the game is accomplished. Lack of these qualities, learners are at risks of abandoning their tasks, and subsequently found themselves disengaged. Equally important in avoiding this circumstance is the understanding that the game-design requires teachers to carefully select and combine the game elements.

It is obvious that designing effective game-based learning experiences is a complex task that involves incorporating various educational theories to foster engagement, motivation, and meaningful learning. By applying theories such as constructivism, flow theory, situated learning, self-determination theory, cognitive load theory, experiential learning, and self-regulated learning, educators can create game-based learning environments that maximize student learning outcomes. Understanding these theories helps educators tailor game-based learning experiences to meet the diverse needs of learners, making the integration of games into the educational landscape a promising and impactful approach.

The Elements in Gamification

The review emphasizes three values in designing game-based learning (GBL): aesthetics, dynamic, and mechanistic (Plass et al., 2015). Aesthetics refers to principles related to the appreciation of beauty (Oxford online) and how players are attracted to the game based on sensory and emotional experiences while playing. These emotions arise from players' subjective appreciation of the game's "beauty," which can influence their engagement and retention. Aesthetics may include game characters, attire, background, music, and other beauty-related aspects.

Game mechanics holds contesting definitions. One may see it as systems of interactions between the player and the game (Rubin, 2010, Boller, 2013), rules and procedures that guide the player's behavior and the game response to the player's moves or actions, (Fullertoon et al., 2004). Levels of difficulty is one of the examples that excite players to react accordingly to the game-triggers.

While dynamic means a game is not exhaustive, the end-result is always changing even though players experienced it several times. How the game is crafted and designed to let players end with different result ensures that playing the game is full of suspense. These three elements inter-correlate with each other to make a game indulging for players.

Gaps in Methodological Design in Gamification Studies

Evidence on the effectiveness of gamification is limited or contradicting due to methodological limits in study designs and analytic approaches (Huang & Hew, 2018; Hamari, 2017; Sailer et al., 2017; Seaborn & Fels, 2015). Many previous studies, which is also the case for Malaysia, rely entirely on self-reported survey data, a class intervention with no pre-test, or a two-class comparison study that does not compare students from the same course (Hamari et al., 2014; Çakıroğlu et al., 2017). Other studies were correlational in nature, providing indirect evidence that gamification can enhance "time on task" and that "time on task" is related to improved academic attainment (e.g., Landers & Landers, 2014) which is argued incapable of proving causal consequences.

The above review shows that many researchers inclined to use numerical data as the evidence of students' behavioural or cognitive changes. For instance, studies that used the quiz results as the measurement of the academic achievement. This method has been questioned as this technology-based assessment systems (Pellegrino et al., 2001) raised questions on its impact on learning and quality criteria (e.g., reliability and validity). While that does not violate the value of the empirical data, the narrative of the player as the learners in the 'game' who are the primary subjects of the study were somewhat neglected.

I argue that the observed scenario is due to the quantitative reputation as opposed to the qualitative in convincing readers. The lopsided weight in adopting the research design for gamification study is evidenced by a search on the Scopus database as of 19 July 2023 that yielded 19,370 results on conventional research design to 417 results on action research design adapted for game-based learning. To date, much of the studies was conducted through conventional research design that

favours quantitative data. While this does not jeopardise the quality of the research done, as a response to Mayer's (2020) suggestion for an in-depth investigation on gamification, a revised way of investigating gamification that allows for more practical issues in classroom to be addressed using qualitative approach is apt. According to proponents of qualitative research design, rich and thick data are obtainable via qualitative information which allows the researcher to get into the respondent's head in order to better understand the phenomenon.

In this regard, teachers should view themselves as reflective practitioners (Schon, 1987; McNiff, 2016; Yalcin Arslan, 2019). This study suggests that teachers adopting a self-developed game-based approach can benefit from using action research design, leveraging students' narratives and teacher reflections. Action research design enables teachers to reflect systematically on their practices, providing rich data for transforming, changing, and improving classroom practices. It empowers teachers to explore their strengths, weaknesses, and areas for improvement, allowing for relevant competency-based enhancements (McNiff, 2016). Emphasizing reflective practice is crucial in game-based learning design by teachers, fostering deeper understanding and connections to other experiences and ideas. The value of reflective practice has been affirmed for decades (Schon, 1987; McNiff, 2016; Yalcin Arslan, 2019), aligning with the action research paradigm that views teachers as the main instrument. However, gamification studies using action research design remain limited, particularly in Malaysia.

Hence, as a reflective practitioner, this paper advocates the suitability of action research design for gamification studies.

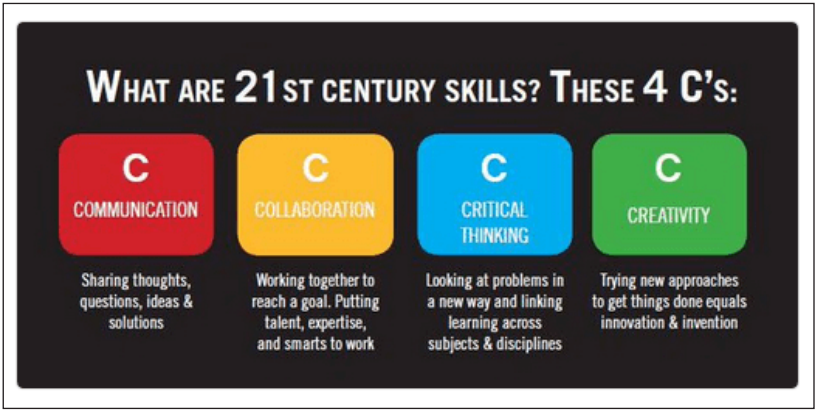
Variables of Learning in 21st Century Learning: The Four Basic Elements

Communication skill is basically about articulating and conveying ideas to others, while collaborating defines the togetherness to achieve a mission. Meanwhile critical thinking is defined in many different ways, with no universally agreed definition (Brookfield, 1987; Cassel & Congleton, 1993) and in the same way, the term creativity is so widely used that there are diverse definitions (Lucas, 2001; Cropley,

2001). This observation is partially contributed by the absence of full understandings on the creative power of the brain (Sternberg, 1999). The definition of 4Cs in this study is informed by The Partnership for 21st Century Learning (P21) as referred by the Curriculum Development Division, Ministry of Education, Malaysia.

Figure 1

The Definition of 4C's Skills in the 21st Century Learning



In this study, it is proposed that students who are self-regulated, can manoeuvre their behavior, motivation and attitude towards positive learning outcomes during gameplay. While so doing, a self-regulated learner would be able to portray and exercise these skills to accomplish the learning mission.

The Partnership for 21st Century Skills (P21), a coalition of education nonprofits, foundations, and businesses, is dedicated to promoting 21st-century education for all students. In their document (P21), they define various skills relevant to modern education. For this study, nine subconstructs were selected based on their alignment with the study's objectives and were assigned codes to guide the analysis process.

Table 1

Definition and Subconstructs of 4C's Applied in the Study

No	Definition and subconstructs	Code
	Communicate Clearly	
1	Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts	C1
2	Listen effectively to decipher meaning, including knowledge, values, attitudes, and intentions	C2
3	Use communication for a range of purposes (e.g. to inform, instruct, motivate, and persuade)	C3
4	Use multiple media and technologies	C4
5	Communicate effectively in diverse environments	C5
	Collaborate with Others	
6	Demonstrate ability to work effectively and respectfully with diverse teams	C6
7	Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal	C7
8	Assume shared responsibility for collaborative work, and value the individual contributions made by each team member	C8
	Think Creatively	
9	Use a wide range of idea creation techniques (such as brainstorming)	C9
10	Create new and worthwhile ideas (both incremental and radical concepts)	C10
11	Elaborate, refine, analyze, and evaluate original ideas to improve and maximize creative efforts	C11
	Work Creatively with Others	
12	Develop, implement, and communicate new ideas to others effectively	C12
13	Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work	C13
14	View failure as an opportunity to learn; understand that creativity and innovation are part of a long-term, cyclical process of small successes and frequent mistakes	C14
	Critical Thinking	
15	Reason Effectively	C15
16	Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation	C16

(continued)

No	Definition and subconstructs	Code
	Use Systems Thinking	
17	Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems	C17
	Make Judgments and Decisions	
18	Effectively analyze and evaluate evidence, arguments, claims, and beliefs	C18
19	Analyze and evaluate major alternative points of view	C19
20	Synthesize and make connections between information and arguments	C20
21	Interpret information and draw conclusions based on the best analysis	C21
22	Reflect critically on learning experiences and processes	C22
	Solve Problems	
23	Solve different kinds of unfamiliar problems in both conventional and innovative ways	C23
24	Identify and ask significant questions that clarify various points of view and lead to better solutions	C24

As we can see, critical thinking has the most items (10) than other constructs. This relates to the complexity in defining creativity and the broad definition it compasses. Creativity has 6, while subconstructs for communication and collaboration is 5 and 3 respectively.

METHODOLOGY

This action research used qualitative data gathered through multiple techniques. The instructor of this lesson was the researcher herself adapting a participatory observation. A class observation for a two-hour duration, interview with students and students written reflection (exit slip) were analysed using thematic analysis employing the 4Cs definition and themes. The data was also quantified to depict the frequency occurred.

Video was chosen as the primary data collection method for this study due to its advantages in providing interaction analysis, especially in a teacher preparatory program. Initially, it was used during microteaching sessions, but later gained popularity as a mechanism for teachers to learn from watching themselves and others. While

video use remains common in many institutions, it is less seen in higher education institutions in Malaysia.

Video enables analysis of the links between teacher behavior and student responses. In this study, video recording was used to capture the learners' behavior for reflective purposes. Video footage was divided into four 30-minute segments, further clipped into ten-minute segments using iMovie amounting to 12 clips. The highest level of 4Cs expression in each segment was coded and annotated every 10 minutes. A score of 1 was given when a student demonstrated a particular behavior based on the construct definition. Additionally, students were asked to write reflective notes (Exit Slips) in response to prompts shared on the Telegram messaging platform after the game session. These reflections offered essential insights on their communication experiences, interesting aspects of the game, dislikes, and expectations for the course.

The utilization of reflection aligns with the concept of teacher professional development, as emphasized in previous research (Schon, 1987; Schon, 1991; McNiff, 2016). By encouraging critical analysis of their learning experiences, students are better prepared for their future careers. In real-world teaching settings, they will need to collect, analyze, interpret, and evaluate evidence to continuously improve their teaching methods (Suphasri & Chinokul, 2021; Cirocki & Farrell, 2017; Mathew & Peechattu, 2017).

Additionally, ten volunteers were interviewed after the lesson to gain further insights into their experiences as Agents. The interviews used open-ended questions to elicit their narrative experiences, providing rich data for analysis. The transcription of the interviews was carefully annotated when the 4Cs were captured. Validation of categorization was done by two independent researchers using a sample of categorized texts. For the purpose of this paper, back to back translation was conducted. A colleague who taught English for 15 years and a native speaker of Malay Language was appointed to translate the excerpt to English while retaining the meaning. Another colleague was appointed to do back translation to Malay Language. Then, thematic analysis was employed to extract meaningful patterns and themes. To ensure accuracy, the annotated excerpts were shared

with the students for validation, enhancing the credibility of the findings. These measures were taken to ensure the robustness of its results.

To present the qualitative results more straightforwardly, the study opted to quantify the data using Excel's 'find' feature to count the frequency of phrases or keywords for each 4Cs definition in the Exit slips and interview excerpts.

Participants and Design of the Game

Sixteen pre-service teachers, comprising eleven females and five males, participated in the study. With an average age of 22, they had completed pedagogical and science courses, as well as a three-month teaching practicum in their fifth semester. Their experiences made them mature enough to evaluate the strategies used in the course.

The game, titled 'Mystery of a Super Ball: Who's the Father?', centered around a polymer topic. In the game, students assumed the roles of Chem-Agents, tasked with solving a mystery related to a super ball's chemical structure and its inventor, known as the 'Father of the Super Ball.' The game featured an aesthetically designed storyboard inspired by popular TV series and 'Mission Impossible Force (MIF)' and 'Men in Black,' movies theme, encouraging students to dress as secret agents.

Various videos were created using iMovie and Powtoon, and augmented reality applications like HP Real and Zapper were used to provide interactive content. The in-class session began with a Mission Impossible theme, and the Mystery Box was dramatically delivered by a real Messenger. Students formed teams and assumed different roles, enhancing the immersive experience of the game. Figure 2 summarises the game plot.

Figure 2

Extract of the game flow/story board in Mystery of a Super Ball

Mystery of a Super Ball: Who's the Father?

Story board: Agent to investigate an accident that makes a ball rolls out in town bouncing continuously with a strong momentum destructing a parked car.

PLOT

Pre-class:

Curiosity value: A TV news of a ball that destructed a parked car and an advert by a toy company showing a ball bounce continuously. The video watched during pre-class. Student watched at their own pace via EPuzzle link given.

In class:

Aesthetic value: Agent dresses in black (blazer), with a sunglass on (like Men in Black). They are to receive a message from THE BOSS *(a Mission Impossible simulation)* during orientation phase *(induction set).*

Crisis value: The BOSS INSTRUCTION:

You have no choice than to accept this mission. This mission is a requirement for you to graduate from this 'detective institution' (our course and programme). Upon agree to accept the job, you would find a file and a box with the mission instructions. Follow the instruction in the file and the box. *(this is given in a video received from THE BOSS (cast by the instructor) through a mystery messenger (cast by the lab assistant).*

The messenger brings in THE BOSS ORDER on a mission to solve.

The mission is to investigate an incident (Crisis value):

- A destruction of a car parked knocked by a giant ball.
- What was it? Who's behind it.
- The ball was claimed as a breakthrough invention by the toy company.
- What was it really about? Find as much details as possible.

Further instruction in the message box:

- Agents to find what is 'Zectron', the ingredient, the problems with the ball
- Agents to find out the inventor, how 'he' transformed the material, and the process to transform (the gulvanication process for rubber)

The 'case materials' provided: in the Mystery Box:

- Augmented reality videos with triggers (printed on multiple cards) to bring agents to clues on the company background, the inventory history and the gulvanication process
- Links to different content-rich websites to gather information (printed QR codes)
- QR codes on multiple cards that bring to EdPuzzle (contains clues to information on the Ball, the inventor and polymer uses) and Quizziz (solve quiz based on information found in EdPuzzle)
- The crossword puzzle sheet: complete the activity using the information and clues.
- The whisperer card: once they completed the crossword successfully, they need to open a locked box to get a slogan in it and whisper the slogan to the unknown recipient who they need to find (Aesthetic value, competitiveness, sense of victory)
- Lanyards with MI casts photos and names: Ethan Hunt (Chief of the Mission), Carol, Jim, Eugene and Benji

Data Analysis

The diagrams below depict the analysis done on the exit slips. In Figure 1 and 2 annotated exit slips display the coding and interpretation based on the themes of 4Cs. Noteworthy, certain codes overlap with other constructs leading to the conclusion that these constructs are interconnected and mutually informative. This observation vividly emphasizes the significance of these four fundamental skills for students. In addition, even though it is not the main aim of the study, the elements of aesthetics, mechanics and dynamics were also observed to complement the analyses.

Figure 3

Excerpts from Exit Slips (R1) Showing the Emergence of the Themes

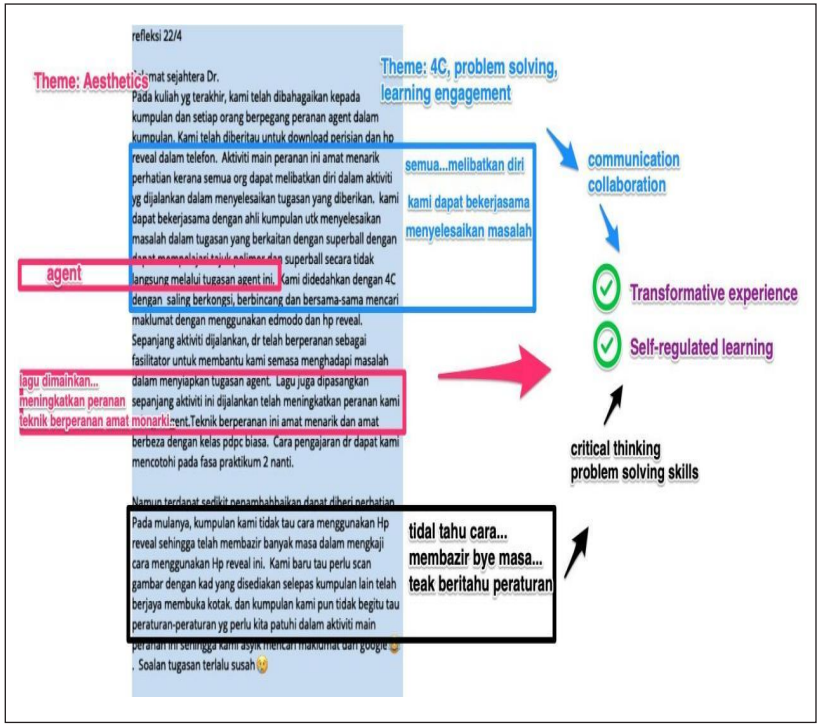
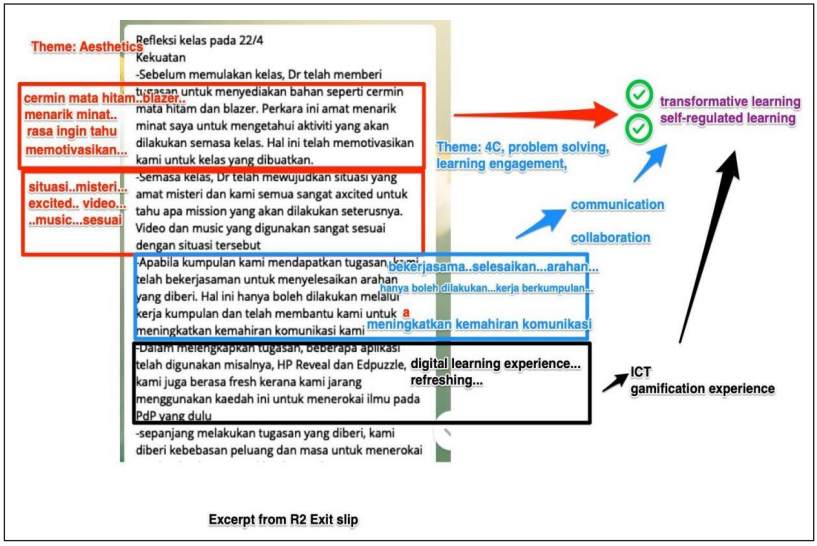


Figure 4

Excerpts from Exit Slips (R2) Showing the Emergence of the Themes



A matrix is built to summarise and illustrate the analysis Table 2.

Table 2

Sample of Analyses on the Video Clips and on the Excerpts from the Reflection and Interview

Minute	Scene from the video	Annoted students' behavior	Samples of Excerpts from Exit Slips and interview data
Clip1	Clip: 	Student excited while putting on their detective gear. (aesthetics)	Feel like Tom cruise. Actually, I admire him…

(continued)

Minute	Scene from the video	Annoted students' behavior	Samples of Excerpts from Exit Slips and interview data
Clip 3	 Agents identify themselves, put on the lanyard containing name and photos (Ethan, Claire, Benji, Eugene, Luther)	Student excited. Student laugh with amusement. (aesthetics  Discussion. Enthusiastic. Explaining. Questioning Curious expression. Series of asking questions About three students just listened quietly. Laughing. Worriness expression.	This activity was really interesting. Everybody can involve themselves while completing the tasks. We can cooperate as a team member to solve the mystery about polymer and superball…indirectly we learn something about polymer in the game. Coding: C2, C3, C5, C6, C7, C8
Clip 6-9	Study the case materials. Scan **Clue 1**.   Agents answer **Part B- The secret recipe**) using the info from certificate. 	 Questions are raised. Some looked puzzled. Some started to ask their friends. Students me were seen opening their mobile phone to scan the trigger AR image. Deep in conversation. struggles to find the clues, Confusion expression. Started to talk to each other.	Quite challenging...we need to scan using our phone for the AR. We haven't used HP reveal before [laugh] Coding: C11, C16, C18, C20, C22, C23, C24

(continued)

Minute	Scene from the video	Annoted students' behavior	Samples of Excerpts from Exit Slips and interview data
		Some seen completing the word puzzle. Some groups wandered around to find whisperer Class became quite noisy. Students broke onto yell once whisperer found ran to the The Boss to get signature. Victory-Class became noisy with laughter and amusement.	

FINDINGS AND DISCUSSION

From the analysis, it is obvious that students were exposed to challenging moments to complete the mystery. Most of the 4C's were demonstrated and found interrelated to each other. To aid discussion, the analysis discussed here is organised in such a way to reflect the relationship between communication with collaboration and critical thinking with creativity since they help inform each other. It is found that studies that document the significant relationship between these skills have spanned over decades (Barron & Harrington, 1981; Glassner & Schwartz, 2007; Wechsler et al., 2018; Akpur, 2020).

Collaboration and Communication

The analysis clearly revealed the presence of collaboration and communication skills. Communication skills were evident when students had to carefully select case materials to gather the correct information and start solving the mystery. They needed to initiate discussions and organize tasks collaboratively as confessed by R15 "We can only do this in a team" and R13 "Yea..I asked other members' opinions...when I stuck...cause we have distributed the tasks but I felt confused initially... luckily we did in a group". Responses from interviews indicated that communication and collaboration skills were effectively used for a range of purposes, including motivating

and persuading others, as exemplified by excerpt "I helped clarify the opinion of other members...when I think that they were confused (in using Hp Reveal)" (R5).

There was also a feeling of comfort and acceptance of others' opinions, leading to consensus among group members which had been anticipated if collaboration was exercised accordingly as other studies have shown (Hanus & Fox, 2015; Kulgemeyer, 2018; Le, Janssen, & Wubbels, 2018). However, disagreements also arose as exemplified by "we did not agree at first...", but effective communication eventually led to consensus as exemplified by excerpts R3, R5, R7, R8, R11:

"We had several confusion and argument [laugh]...everybody seemed want to win [laugh]..but it was like...okayyy...they were all sporting"(R8). A triangulation with the annotated video clip also revealed the behavior of cohesiveness among group members (clip 4, 6, 7, 8, 11 and 12).

The game-design successfully encouraged trial-and-error and allowed for series of rectification, training students to scaffold their understanding with good exercise of communication as evident in previous studies (Lee & Hamer, 2011, Kulgemeyer, 2018; Le, Janssen, & Wubbels, 2018).

Overall, the design nurtured student engagement through communication and collaboration, allowing them to practice skills like good listening and effective articulation of thoughts and ideas. Increased communication and collaboration during the mission led to increased class participation, interest, and motivation development (Acedo & Hughes, 2014; Lin, 2015; Bado, 2019).

Critical Thinking and Creativity

The game's conflict was designed to create puzzles for the mission, allowing for multiple solutions. Students organized their ideas and reached a consensus on the solution through discussion. Early clips showed that students initially didn't know how to proceed, triggering discussions and reflective thinking:

"Initially we didn't know that we need to scan the card; that it was actually a trigger picture [augmented reality]" *(*R11)

Creativity and critical thinking were evident as students used various idea creation techniques like brainstorming to solve the mystery by expressing "we tried different ways", and "we wasted a lot of time there":

"At first I thought there is only one way to solve...like being structured...but I saw my mate did it another way ...and finally we reached the same end...it's just that the completion time was different" (R10).

They encountered arguments that were resolved through communication and collaboration, highlighting their problem-solving skills, by mentioning "...we had different ideas to solve the mystery", "we did not agree at first...". This tone is obvious in most of the excerpts. Their responses also suggest their creativity was being tapped to analyze how parts interact with each other to produce overall outcomes in completing the game mission.

In addition, self-regulated learning was observed as students had the choice to continue with the game or opt out.

"Well, when I felt confused, feel like demotivated... I asked others and finally we understood what needs to be done". (R16)

There also confessed on their weaknesses which signifies the element of reflection: "Maybe we didn't sufficiently discuss enough on the task." (R3)

These findings contribute to the ongoing discussion in the Ministry of Education in Malaysia about incorporating thinking skills in the science curriculum. By minimising the "recipe" or "dictation of what to do", my design deemed successful to train students to solve problem in ways they taught logic. The science curriculum should include thinking skills to help students navigate complex problems in life.

The study emphasizes the importance of creative lesson plans in nurturing critical thinking and creativity in students, with teachers needing to be creative and critical themselves to impart these skills effectively. The findings add to the current dialogue in Ministry of

Education in Malaysia of making the science curricula a resolution to the thinking skills.

To visualise the findings, the codes were quantified whereby frequency was counted for each construct of 4C found in the data. Quantifying qualitative data can often be impactful to provide objectivity (Hannah & Lautsch, 2011) to the 'messy' qualitative findings.

Table 3

Number of Participants (with percentage) and Frequency of Quotations

	Themes and coding	No of participants performing the behavior in the video at least once	Frequency of quotations from interview and Exit Slips
	Communicate Clearly		
1	Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts	16 (100%)	45
2	Listen effectively to decipher meaning, including knowledge, values, attitudes, and intentions	16 (100%)	37
3	Use communication for a range of purposes (e.g. to inform, instruct, motivate, and persuade)	16 (100%)	45
4	Use multiple media and technologies	11 (68.8)	26
5	Communicate effectively in diverse environments	9 (56.3%)	45
	Collaborate with Others		
6	Demonstrate ability to work effectively and respectfully with diverse teams	16 (100%)	49
7	Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal	11 (68.8%)	46
8	Assume shared responsibility for collaborative work, and value the individual contributions made by each team member	7 (43.8%)	41
	Think Creatively		
9	Use a wide range of idea creation techniques (such as brainstorming)	7 (43.8%)	33

(continued)

	Themes and coding	No of participants performing the behavior in the video at least once	Frequency of quotations from interview and Exit Slips
10	Create new and worthwhile ideas (both incremental and radical concepts)	0	0
11	Elaborate, refine, analyze, and evaluate original ideas to improve and maximize creative efforts	15 (93.8%)	18
	Work Creatively with Others		
12	Develop, implement, and communicate new ideas to others effectively	6	30
13	Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work	15 (93.8%)	45
14	View failure as an opportunity to learn; understand that creativity and innovation are part of a long-term, cyclical process of small successes and frequent mistakes	15 (93.8%)	32
	Critical Thinking		
15	Reason Effectively		30
16	Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation	8 (50%)	35
	Use Systems Thinking		
17	Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems	3 (18.8%)	23
	Make Judgments and Decisions		
18	Effectively analyze and evaluate evidence, arguments, claims, and beliefs	9 (56.3%)	24
19	Analyze and evaluate major alternative points of view	0	0
20	Synthesize and make connections between information and arguments	7 (43.8%)	30
21	Interpret information and draw conclusions based on the best analysis	16 (100%)	40
22	Reflect critically on learning experiences and processes	16 (100%)	42
	Solve Problems		
23	Solve different kinds of unfamiliar problems in both conventional and innovative ways	16 (100%)	42
24	Identify and ask significant questions that clarify various points of view and lead to better solutions	16 (100%)	44
		Total codes	802

Note: Columns indicate number of participants (with percentage) and frequency of quotations.

Noteworthy, two subconstructs were not obviously observed in the analysis which are 'Create new and worthwhile ideas (both incremental and radical concepts)' and 'Analyze and evaluate major alternative points of view', falling under creativity and critical thinking, respectively.

The frequency for each theme was calculated for percentage of occurrences by summing all the occurrences for each theme and then calculating the average for each.

Table 4

The Frequency of Occurrences (in percentage) on the 4C Themes Calculated from the Interview Excerpts and Exit Slips

Communication	Collaboration	Critical thinking	Creativity
31.01%	25.58%	22.79%	20.62%

Communication (31.01%) shows high percentage followed by collaboration (25.58%), critical thinking (22.79%) and creativity (20.62%). This finding illuminates the critical status of creative ability amongst students who are pre-service teachers.

Teacher's Competency in Game-design

Although it is not the main purpose of the paper, the perceptions of the students pertaining to the strategies I used in teaching was also scrutinised. This decision was made due to the rich information given in their reflections which resulted in thick description they could offer about the teaching design I developed. For instance, the aesthetic value which was obviously expressed by the students, such as structuring the game components in stages, giving points, badges, and avatars (Barata et al., 2017; Lister & College, 2016), fighting, content unlocking, questing, social graphics, and certifications (Buckley & Doyle, 2017).

There is evidence on feeling aesthetics playing the role as agents triggered by the blazer and glasses they were about to bring along to the class, exemplified by excerpt "created curiosity in me, excite of what is going to happen in class". The mysterious sense was successfully

created as exemplified in: “in class, you have successfully created the mysterious sense (suspense) in the air”, “what is the mission?” “the trailer video with music and props (referring to me wearing the Black jacket and glasses, baretta-like cap) are so thrilling’’.

Other excerpts also illustrated the appreciativeness in their tone:

Throughout the activity, you acted as the facilitator to assist me in being the ‘agent” ...the background music has boosted our feeling as agent. This role play is very attractive and differs from other lesson/ class we normally have. We can follow your style of teaching when we go to our 2nd phase of the practicum” (R1)

“You are so cool..relax..we don’t feel stress in your class. Even though this is chemistry [laugh]” (R8)

“Actually, I don’t like on-way lecture, it’s sleepy. But you always use 2-way interaction between us, the pop quiz the tutorials always in 2-way discussion” (R12)

“Student can also be a teacher in your lecture. You gave us the opportunity to master the content and explain to others in group to consolidate our understanding. Simply state, in your class we learn and also teach” (R15-exit slip) Science.

Science teaching emphasises on intense collaborative activities as the contents are generally hard and difficult. The process of absorbing knowledge while studying (Chi et al., 1989) needs peer support. This design aligns with ‘Guru Muda’ initiative being called for teachers to apply in class to increase student’s capability in solving problem and become active learners (MoE, 2016).

Future Recommendation

The innovation is an attempt to cater to issue of teachers’ support for students’ learning engagement. As it is still at its’ infancy stage, more work needs to be done along the way. The next avenue is to closely examine the teacher’s competency in designing the game in relation to the principles of instructional design. The assessment on the academic achievement through this mystery-game mission could also be investigated.

CONCLUSION

This study explores students' experiences during Chemistry gamification titled 'Mystery of the Super Ball,' focusing on communication, collaboration, creativity, and critical thinking skills. The respondents were future primary school science teachers who participated in the game as Chem-Agents, investigating a mysterious ball with a polymer topic. The game's engaging and enjoyable nature proved to be an effective way for students to grasp organic chemistry concepts, moving away from traditional, stereotyped assignments.

The application of the game-based learning approach positively impacted students' creative thinking skills. Most students reported an improvement in their ability to generate ideas and creatively solve problems both in their social lives and school environment. Additionally, their communication skills with peers improved, and they became more adaptable in using various objects for different purposes. This highlights the importance of teachers using innovative and engaging methods to cater to their students' preferences and enhance their learning experience.

Reflecting on this study, it becomes evident that teachers play a crucial role in nurturing essential skills in their students through creative lesson planning. As technology advances and education landscapes evolve, teachers must embrace gamification as a pedagogical approach to foster critical thinking and creativity. Furthermore, being reflective practitioners and lifelong learners, teachers can effectively design engaging learning experiences and build global professional networks to empower their students with essential soft skills.

While gamification holds promise for achieving Sustainable Development Goals set by the United Nations, academic attainment should not be compromised in the pursuit of excitement derived from gameplay. Teachers must ensure their competency as learning designers to strike a balance and deliver meaningful educational experiences. This study reinforces the significance of embracing gamification as a tool to meet the challenges of modern education and equip students with essential skills for their future endeavours.

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