

A Serious Game That Builds Energy Literacy Through Communication and Collaborative Gameplays

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Abstract: We developed a serious educational card game on renewable and alternative energy sources called "Fact or Fiction: Energy Edition". This game aims to bridge the learning gap between Singapore school's science curriculum and our national commitment to reach net-zero emissions by 2050. The original gameplay is a hybrid between two familiar games: "Trivial Pursuit" and "Mafia". Each player, depending on their assigned roles, will have to read either a factual or fictitious statement relating to alternative energy sources. Collectively, players must determine who is the Fraudster, i.e. the player reading the fictitious statement, and ban him/her from the game. Three additional gameplays, "Team Challenger", "Presenter Challenger" and "Quiz-Quiz-Trade" were created to be played in a classroom setting and meet the learning needs of different students' profiles. "Team Challenger" and "Presenter Challenger" are collaborative gameplays aims to enhance communication and collaboration among students. "Quiz-Quiz-Trade" is designed to promote communication in younger, or lower-progressing students. We conducted a pilot test for three gameplays, "Role-Playing", "Team Challenger" and "Presenter Challenger" in a Secondary school (six classes, 232 students). The "Quiz-Quiz-Trade" was trialled with one class of 25 Primary Six students. We received promising results that highlighted the game's potential to increase students' content knowledge on renewable and alternative energy but also promote communication and collaboration among students.

Keywords: Card game, Renewable energy, Alternative energy, Collaborative gameplay, Science curriculum

1. Introduction

Climate change is increasingly affecting many countries worldwide as global average temperatures reach new highs annually. Since 2015, addressing climate change has been the primary focus of the UN Climate Change Conference, with the Paris Agreement legally binding countries to limit their carbon emission. As part of Singapore's Long-Term Low-Emissions Development Strategy (LEDS), the government has developed a nationwide plan to achieve net zero emissions by 2050 (NCCS, 2022). This decision was made to meet the national commitment to climate action under the Paris Agreement (MFA, no date).

1.1 Learning Gaps Identified in Formal Science Curriculum

Singapore's formal science curriculum introduces renewable energy concepts progressively across educational levels. Primary science (Grades 3-6) covers three basic renewable energy sources: solar, wind, and hydroelectric energy (MOE, 2023). The lower secondary science curriculum (Grades 7-8) expands this knowledge to include geothermal, biofuel, and nuclear energy sources (MOE, 2024). Both curricula emphasise the scientific principles behind energy conversion and environmental impacts, with increasing complexity at higher grades. While civic literacy education at the secondary level specifically focuses on solar energy's advantages and limitations in Singapore as this emphasis reflects the nation's geographical constraints. Being a small, densely urbanised country, Singapore has limited access to wind, hydroelectric, geothermal, and biomass resources, making solar energy the most viable renewable option (MSE, 2019).

As Singapore embraces low-carbon economy, we have identified the following learning opportunities that could bridge the formal curriculum with fast-growing and fast-changing alternative energy sources:

- Describe the advantages, challenges, and limitations of different energy sources;
- Appreciate STEM concepts in the context of energy production;
- Demonstrate awareness of environmental and social impacts of energy productions; and
- Identify examples of local, regional and global initiatives, issues, and trends in energy transition.

By presenting a diverse range of facts and scenarios related to various energy sources, including those not extensively covered in the textbook such as hydrogen, the game seeks to deepen students' understanding and increase their appreciation of this critical energy topic.

2. Theoretical Perspectives

The implementation of educational games in student learning has been demonstrated to enhance learning outcomes and increase student engagement (Fonseca et al, 2023). Game-based learning and gamification create

student-centric environments that facilitate the comprehension of broader concepts. Our team adopted this approach to engage students more effectively in learning about complex topics that they rarely encounter in their daily lives, such as clean and/or renewable energy sources.

2.1 Game Mechanism for Fact or Fiction: Energy Edition

The game “Fact or Fiction: Energy Edition” (FoF) presents players with the chasm between a factual statement and a fictitious statement on alternative energy sources. For example, in Figure 1a, the *Fact* and *Fiction* are: “The smoke coming from the top of a nuclear power plant is just steam” or contains radioactive waste. This dichotomy is reinforced with contrasting colour schemes: dark background for facts, and light background for fictions (see Figure 2). The fictitious statements were crafted to highlight common misconceptions, in this Figure 1 example, it addressed the public fears on the safety of nuclear power generation.

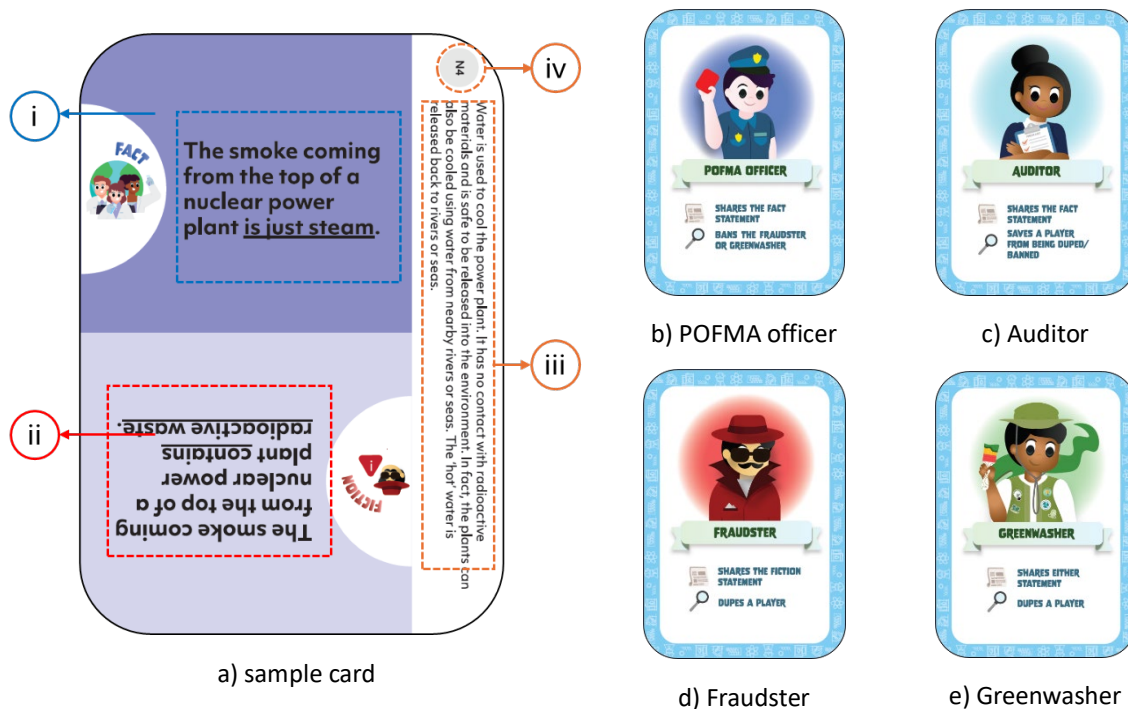


Figure 1: a) Info card's features (i) fact, (ii) fiction, (iii) background information, (iv) reference; and b-e) sample roles: POFMA officer, Auditor, Fraudster and Greenwasher

The game consists of 120 information cards (i.e. Info cards) organised into eight energy-related categories, each distinguished by a unique colour scheme to facilitate visual organisation and thematic representation (Figure 2). The content spans across eight themes: local (Singapore), regional (Association of Southeast Asian Nations, i.e. ASEAN), global, technology, science, environment, social, and policy. For instance, Figure 2b illustrates an Info card explaining the global environmental impact of solar panels, while Figure 2c highlights Singapore's decarbonisation policies and regional initiatives.

Similar to the game mechanics in “Trivial Pursuit”, students take turns to ask and answer *trivia* questions relating to alternative energy sources (Salen and Zimmerman, 2004). This game design of FoF aims to increase the general knowledge of students by serving them with a wealth of factual statements on this topic rarely encountered in their daily lives.

The distribution of themes across FoF card deck is shown in Table 1. The three most prevalent themes across all energy sources are technology (57 instances), science (43 instances) and local context (30 instances). This distribution aligns with our objective of providing a comprehensive understanding of renewable energy, emphasising technological advancements, scientific principles and local relevance.

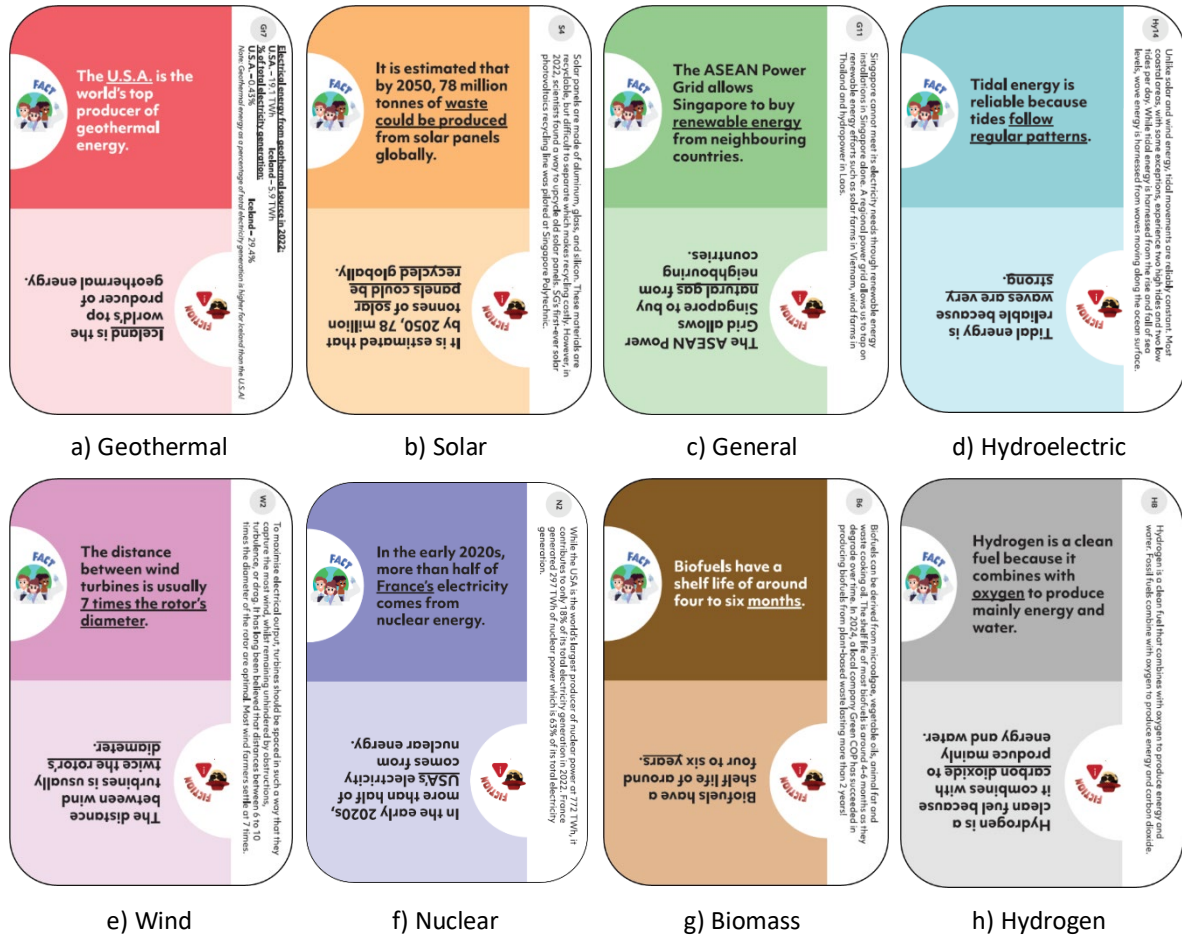


Figure 2: A sample Info card from eight energy categories: a) geothermal, b) solar, c) general information, d) hydroelectric, e) wind, f) nuclear, g) biomass, and h) hydrogen

Table 1: Distribution of themes across FoF card deck

	ASEAN	Local	Global	Technology	Science	Environment	Social	Policy
Geothermal, red	2	2	1	9	8	5	2	1
Solar, orange	3	6	4	11	4	5	0	1
General, green	3	7	3	0	2	2	2	5
Hydroelectric, blue	2	2	2	8	5	3	2	1
Wind, lilac	1	2	0	11	3	5	1	1
Nuclear, purple	1	1	5	7	8	5	4	2
Biomass, brown	2	8	0	5	5	2	2	2
Hydrogen, grey	0	1	1	6	8	3	0	2
Total	14	29	16	57	43	30	13	15

The FoF card deck features a modular design that allows for flexible content management. This adaptability enables primary school teachers to curate age-appropriate content. For example, a primary school teacher can select Info cards such as those shown in Figure 2a, b, d and f, while excluding more complex content (such as those shown in Figure 2c, e, g and h). Furthermore, this versatility facilitates regular updates to reflect current

energy trends, as exemplified by the Info card in Figure 2g, which incorporates 2024 technological advancement in biofuel.

Each Info card includes background information to explain the context of its factual statement. For instance, the statement in Figure 1 clarifies that the visible steam is actually cooling water for the power plant. Facts were derived from multiple sources and tagged with alphanumeric identifiers for systematic categorisation (e.g. N4 represents the fourth card in the nuclear category). The icon “a network of scientist” serves as a visual reminder that all factual statement should be backed by peer-reviewed scientific research, whereas information without scientific backing is considered fraudulent and denoted with a fraudster icon.

Apart from the six alternative energy sources covered in Singapore’s lower secondary science syllabus, the game incorporates two additional categories: general information and hydrogen energy (Figure 2c and h). The general information category introduces broader energy related facts that could not be classified into any of the energy categories. For example, the Info card in Figure 2C describes countries endowed with abundance of renewable energy can export their excess energy via the regional power grid. The hydrogen energy category was included as it was identified as a key economically viable low-carbon technology for Singapore to achieve net zero emission goal by 2050.

3. Four Gameplays

3.1 Original gameplay: Role-Playing Gameplay

The original gameplay adapted mechanics from the social deduction game Mafia (Salen and Zimmerman, 2004). FoF game simulates conflict between two groups: an informed minority, the Bad Guys, and an uninformed majority, the Good Guys as detailed in Table 2. This structure was chosen to mirror the inherent conflict between *Fact* and *Fiction*. This gameplay requires a moderator and multiple participants who take on roles including Greenwasher, Fraudster, Whistleblower, Auditor, POFMA officer, and Citizen, each representing real-world actors in an environmental discourse. The Greenwasher and Fraudster roles embody different forms of misinformation: the former exaggerates environmental initiatives without substantial impact, while the latter deliberately disseminates false information about renewable energy. The POFMA officer role was inspired by Singapore's Protection from Online Falsehoods and Manipulation Act (POFMA). This adaptation reflects contemporary efforts to combat misinformation, particularly relevant during the COVID-19 pandemic (POFMA, no date). The Whistleblower and Auditor roles emphasise individual responsibility in reporting wrongdoing and doing fact-checking. This reinforces learners that everyone can play their part to maintain information integrity.

Table 2: Summary of the Good Guys and Bad Guys roles for Role-Playing gameplay

Good/Bad Guy	Role	Similar to Mafia role	Description of role
Good Guy	POFMA Officer	Police officer	Has the power to ban Bad Guys
Good Guy	Auditor	Doctor	Has the power to save any player
Good Guy	Whistleblower	Detective	Has the power to check identity
Good Guy	Citizen	Villager	No special power
Bad Guy	Fraudster	Mafia	Has the power to dupe a player
Bad Guy	Greenwasher	Mafia	Has the power to dupe a player and read either the Fact or Fiction statement

The gameplay begins with each player receiving a role card explaining their responsibilities (Figure 1 b–e, Table 2) and drawing three Info cards. The game progresses through three stages: publication, voting, and review. In the publication stage, players take turns to read out either a *Fact* or a *Fiction* from one of the three Info cards, as determined by their assigned role. This stage includes an open discussion period where players can interrogate each other’s statements and defend their claims using the background information provided on the cards. This interactive component serves as the game’s educational cornerstone, enabling students to simultaneously learn about alternative energy sources while developing communicating skills. The voting stage follows, where players nominate and vote to ban suspects for the Fraudster or Greenwasher roles. In the subsequent review stage, players with special roles can exercise their special powers to save, dupe or ban players. E.g. Auditor can save a player from being duped (see Figure 1c).

These three stages repeat until one of two conditions is met: either Bad Guys equal the Good Guys in number, or both the Fraudster and the Greenwasher have been banned.

3.2 Collaborative Gameplay: Team Challenger and Presenter Challenger

3.2.1 Rationale for collaborative gameplay

In the Role-Playing gameplay, the opportunity for active discussions and debates relied on students' ability to speak convincingly and think spontaneously. Unlike their counterpart in the West, Singapore students generally do not actively participate in class discussions for the following reasons identified by Sim (2018):

- If a student speaks well, he/she might be afraid that speaking out might make one appear outstanding, thereby making their peers look bad by comparison. This may cause their peers to be embarrassed, or even worse, leads to resentment from them.
- If a student volunteer to speak up yet reveals his/her "true abilities" as worse than one's peers, it might lead to embarrassing oneself and thereby inhibiting himself/herself from attempting to speak up again.

To address students' public speaking anxieties, we redesigned the gameplay by eliminating individual roles and developed two new gameplays: Team Challenger and Presenter Challenger. This modification shifted from individual competition to group-versus-group dynamics, fostering collaboration rather than personal confrontation. The design choice of three to four members per group was informed by research on optimal group interactions (Laughlin et al, 2006). While a two-person group may face decisional deadlocks, and a larger group size of five or more may risk passive participation, a three- to four-person group maintain dynamic conversations while ensuring each member's active engagement. This optimal group size maximises learning and conversational opportunities from all members.

3.2.2 Team Challenger gameplay

In this gameplay, teams of three to four students each receive five Info cards. Teams have to strategically select one member to present a *Fiction*, while other members present a *Fact* each. The presentation sequence is determined by team consensus, with three to four statements read depending on team size. The additional Info cards serve as strategic alternatives rather than required reading material. After the sharing team presents, the guessing team must identify which team member in the sharing team presented a *Fiction*. Correct identification results in the sharing team forfeiting a token to the guessing team, while incorrect guesses lead to token loss for the guessing team. This process continues for four additional rounds with different team combinations, and victory is determined by the highest token accumulation.

3.2.3 Presenter Challenger gameplay

The Presenter Challenger format maintains most elements of Team Challenger but introduces a whole-class dynamic. In each round, one group (sharing group) presents their statements to all other groups simultaneously. After each presentation, non-presenting groups (guessing group) can question the statements. These guessing groups then independently vote to identify which presenter delivered the *Fiction*. Each guessing group that correctly identifies the *Fiction* presenter earns one point.

Table 3: Summary of Gameplay instructions for Team Challenger and Presenter Challenger

	Team Challenger	Presenter Challenger
Size of group	Groups of 3 or 4	Groups of 3 or 4
Fraud mechanism – Sharing phase	One player in the group will share a <i>Fiction</i> , while the remaining players in the group will each share a <i>Fact</i> .	
Detecting mechanism – Guessing Phase	As a group, players decide who amongst the sharing group is telling the <i>Fiction</i> , i.e. the Fraudster. If the group guessed correctly, they score a point (token). If they guessed wrongly, they lose a point (token).	
Game procedures	In each round, two teams face off each other. One team will 'share', while the other will 'guess'. Determine the winning team and exchange token. Teams will swap roles, i.e. sharing team becomes guessing team while guess team becomes sharing team.	In each round, a sharing group will read out their statements at the front. The remaining guessing groups can question the statements. Each guessing group will have to deliberate on who the Fraudster is with one vote. Groups who get the most points from guessing the Fraudster wins.

	Team Challenger	Presenter Challenger
Size of group	Groups of 3 or 4	Groups of 3 or 4
	The teams will face off other teams in the next round. Teams who get the most token wins.	

3.3 Gameplay Suitable for Younger Students: Quiz-Quiz-Trade

During one of our initial teacher engagement sessions, a primary school teacher working with lower-progressing Primary Six students proposed a new format called "Quiz-Quiz-Trade" (QQT), designed to be more accessible for her students. This format adapts a cooperative learning strategy where students engage in paired knowledge assessment through an interactive quiz format (Wong et al., 2022). In our adaptation of QQT for the FoF game, each student receives one Info card and several tokens. Students work in pairs, taking turns to share statements while their partners determine whether these are *Fact* or *Fiction*. Correct deductions result in token exchanges between partners. After completing their exchange, students find new partners, creating multiple opportunities for peer-to-peer learning and content review. This simplified format maintains the game's educational objectives while reducing cognitive load through one-to-one interactions.

Table 4: Summary and breakdown of the game mechanics in all four gameplays (Upshall, 2020).

	Avatar/ Role-playing	Competition	Cooperation/ Collaboration	Points/ Scoring System	Trade/ Economy
Role-Playing	✓	✓	✓		
Team Challenger		✓	✓		✓
Presenter Challenger		✓	✓	✓	
Quiz-Quiz-Trade		✓			✓

4. Methods

4.1 Pilot Test #1: Role-Playing, Team Challenger and Presenter Challenger

A pilot study was conducted at an all-girls' secondary school, involving six classes of mid- to high-ability Secondary One students (Grade 7, ages 12 – 13). Each class had between 38 to 39 students. Two classes were assigned each of the three gameplays: Role-Playing, Team Challenger and Presenter Challenger. A post-game electronic survey was administered. The survey questions and type of questions were:

- Educational value of the game, 1 – 5 rating
- Entertainment value of the game, 1 – 5 rating
- "What did you like about the game?", short answer
- "What did you not like about the game?", short answer

Out of 232 students that participated in the survey, 155 students (response rate of 66.8%) completed the online questionnaire due to the lack of access to electronic devices and time (see Table 6).

4.2 Pilot Test #2: Quiz-Quiz-Trade

The Quiz-Quiz-Trade format was piloted with a class of lower-progressing Primary Six students (Grade 6, ages 11 – 12, n=25; 16 boys, 9 girls). The science teacher curated age-appropriate Info cards based on students' reading capabilities and facilitated both the gameplay session and subsequent discussion. Student feedback was collected through verbal responses during the post-game discussion period.

5. Results and Discussion

5.1 Role-Playing, Team Challenger and Presenter Challenger

Our hypothesis predicted that Role-Playing would yield the highest entertainment value but lowest educational impact, while Team Challenger and Presenter Challenger gameplays demonstrating higher educational outcomes. However, the data presented in Table 5 contradicted these expectations: Role-Playing achieved the highest educational rating (4.45), while Team Challenger and Presenter Challenger formats received comparatively lower ratings (3.80 and 3.81 respectively).

Students' responses to questions (3) and (4) were grouped into three broad categories: (1) content knowledge, (2) affective aspect, and (3) game mechanism. For the purpose of this article, only responses pertaining to content knowledge were analysed. Nonetheless, the feedback from students were used to further refine the gameplays.

Table 5: Observations and results from students' survey

	Role-Playing	Team Challenger	Presenter Challenger
Venue	Students were in their home classroom	A combination of two classes of students in a multi-purpose room.	Students were in their home classroom
Grouping	7 to 8 students, 5 groups per class	3 or 4 students, 20 teams	3 or 4 students, 10 groups
Observation	One student from each group was assigned as moderator. Students who had not played Mafia before required assistance from the teacher.	The room was noisy as many teams of students were talking simultaneously. To facilitate transition after each round, only the even numbered teams move	Groups took turns to present at the front. The teacher in-charge moderated the discussion and voting rounds after the group had presented.
Educational rating	4.45 / 5	3.80 / 5	3.81 / 5
Entertainment rating	4.76 / 5	4.22 / 5	3.70 / 5

Analysis of student feedback across all three gameplay formats revealed consistent themes regarding content engagement (see Appendix). Role-Playing and Team Challenger generated positive content-related comments from 28.6% and 26.0% of participants respectively (Table 6). Presenter Challenger received both the highest percentage of positive content comments (38.1%) and negative content comments (30.2%), suggesting this format heightened students' awareness of both their content learning and knowledge gaps in renewable energy concepts. Role-Playing received notably low negative content comments (4.8%) suggesting that its higher entertainment value may have masked knowledge gaps, potentially inflating perceived educational value.

While both Team Challenger and Presenter Challenger formats facilitated in-depth content discussions, Team Challenger achieved a notably higher entertainment rating (4.22 compared to Presenter Challenger's 3.70). This difference may be attributed to Team Challenger's kinaesthetic elements, where students could physically move between teams, and therefore create more opportunities to engage in strategic discussions. In contrast, Presenter Challenger's structure limited each group to a single presentation opportunity, potentially reducing engagement during non-presenting periods when students were passive listeners.

Table 6: This table shows the a) the total numbers of students who participated in the pilot test, b) number of students who participated in the survey and c) the number and percentages of students' who provided positive and negative feedback regarding content across three gameplays

	Role Playing	Team Challenger	Presenter Challenger
Number of students that participated in game	77	77	78
Number of students that participated in the survey	42	50	63
Number of participants who provided positive remarks on content, derived from question (3)	12 (28.6%)	13 (26.0%)	24 (38.1%)
Number of participants who provided negative feedback on content, derived from question (4)	2 (4.8%)	6 (12.0%)	19 (30.2%)

Teachers' feedback from the pilot study emphasised the importance of post-game discussions in consolidating students' learning outcomes and meeting the game's learning objectives. In addition, science teachers were identified to be ideal facilitators of the game sessions as they have the subject expertise and ability to guide content-specific discussions effectively.

In conclusion, the Role-Playing gameplay achieved the highest entertainment rating while enhancing students' perceived educational value. This aligns with research showing that student enjoyment significantly influences

their self-efficacy in learning (Lu & Lien, 2019). Team Challenger gameplay achieved a balance between engagement and learning, despite students encountering some challenges with content complexity. While Presenter Challenger gameplay was praised for its knowledge gained, students noted difficulties with content comprehension and fact verification. These results suggest that although Presenter Challenger gameplay may promote deeper learning, Role Playing's engaging nature potentially led to better overall student engagement and perceived educational value. This insight underscores the critical balance between educational content and gameplay mechanics in educational game design, which informed our subsequent iterations and game improvements.

5.2 Quiz-Quiz-Trade

The teacher who conducted the trial provided feedback on the QQT format:

"For the Lower Progress group, they can use the cards to test partners - Quiz and Response followed by gain/lose a token. Then move on to another partner, quiz the next partner with the same card or a different card. For my class, each student was given an info and 5 tokens. The students liked guessing Fact or Fiction and then win a token."

The QQT format had demonstrated as an engaging cooperative learning strategy that combines student movement and interaction with knowledge synthesis. Students work with multiple partners in a short period of time, and the tactile and kinesthetics aspects of this strategy support and engage a variety of learning styles (Wong, 2022). The gameplay structure facilitated students to develop academic language and encourage peer to peer interactions. Given its effectiveness, particularly with lower-progress students, QQT was incorporated as an additional gameplay option in the final product of the educational card game.

6. Conclusion

6.1 Limitations

The first Pilot test for Role-Playing, Team Challenger and Presenter Challenger were conducted exclusively at an all-girls secondary school. This presented limitations in a good demographic representation of local schools that significantly impacts the generalisability of our findings. The absence of primary schools, mixed-gender secondary schools, and students with diverse ability levels restricts the applicability of our results to broader educational contexts. This narrow focus may have introduced gender bias and overlooked challenges that could arise in different education environments. The lack of diversity in the test population limits our ability to assess how the game might perform across varied educational settings and student demographics, potentially missing important insights that could emerge from a more heterogenous sample.

The value of QQT is to promote peer-to-peer teaching, incorporates discussion and practice, and provides students with physical movement. Even though QQT is a well-established learning strategy and formative assessment for classroom (Wong, 2022), the second pilot test was conducted at a single class of lower-progressing Primary Six students. There is no comparison between the effectiveness of QQT and other gameplays.

6.2 Future Plans

The team plans to expand this research work and broaden the range of participating schools and student populations to enhance the robustness and applicability of the findings. Each school will be offered two to three gameplays (Role-Playing, Team Challenger, Presenter Challenger and QQT) that meets the learning needs of students' profile. We plan to analyse students' discussions to answer the following questions:

- Were the learning goals achieved through students playing the FoF card game?
- How does the FoF card game promote communication and collaboration among students?

This would provide a more comprehensive evaluation of the game effectiveness in promoting renewable energy education across varied educational contexts.

Notes

Refer to the website, <https://for.edu.sg/factorfiction>, for a) the moderator guide and video instructions for Role-Playing gameplay; b) the infographic for Team Challenger gameplay; and c) references for *Fact*.

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Appendix

Table 1: Selected responses about the educational value retrieved from the questions (3) "What you like about the game"; 4) "What you not like about the game"

Game mode	Selected positive responses retrieved from question (3) "What you like about the game?"
Role-Playing	I liked how I was able to learn new information and clear up doubts like when I thought a fact was right but it's actually fiction. I got to learn many interesting facts about science The way it relates to real life situations knowing the different knowledges while playing the game

Game mode	Selected positive responses retrieved from question (3) “What you like about the game?”
Team Challenger	We got to know about STEM related things through a fun game I liked that I learned facts about this game and it was also fun. We can learn fun facts about science. We get to learn a lot about our environment
Presenter Challenger	It was very educational and we learnt a lot of new things. It was very interesting and we learned a lot of new things while it being fun. I could learn more about the use of technology in different parts of the world We also are able to gain some general knowledge while playing the game
	Selected negative responses retrieved from question (4) “What you did not like about the game?”
Role-Playing	Add in some simpler facts about science The topics were a bit difficult to comprehend, so it was hard to defend yourself in game too, but that somewhat made the game more intense, forcing you to reason with the fact and explain it. Some facts and fiction were common knowledge so everyone knew the correct answer
Team Challenger	The terminology of the cards are confusing Some of the cards had complicated terminology, so we didn't understand and our guesses were made entirely off assumptions. Having zero idea on what the card is talking about. (Too complex terminology.) I don't understand some of the facts
Presenter Challenger	The statements were a bit hard There's no speck is however I wish that there would be more topics such as; Cells, Biology, Atoms etc. I did not understand some of the information told to me so it was hard to tell whether it was a fact or fiction Some of the facts are hard to guess and my group had to do wild guesses, which meant that we didn't actually know what it meant