THE ROLE OF GAME-BASED LEARNING IN ENHANCING CRITICAL THINKING DISPOSITION IN TECHNICAL AND VOCATIONAL LEARNERS

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Critical thinking is an essential life skill in Technical and Vocational Education and Training (TVET), as it empowers learners to analyse situations and make informed decisions, both in academic settings and the future workplace. In recent years, the need to cultivate critical thinking has become increasingly important, particularly within a volatile, uncertain, complex, and ambiguous (VUCA) environment shaped by rapid technological advances. This study examines learners' critical thinking disposition (CTD) – the tendency to engage in critical thinking – using a game-based learning (GBL) approach.

First-year students from diverse disciplines at Singapore Polytechnic participated in a classroom intervention using a custom-designed educational game, the Game of Trade-offs (GTO). Played in timed, competitive rounds, GTO required teams to collaboratively tackle real-world scenarios by analysing information and considering diverse perspectives to derive reasoned decisions. The game's immersive and interactive format encouraged active engagement and peer interaction to synthesise ideas—fostering CTD development.

A mixed-method approach was employed to examine students' CTD before and after playing GTO. Quantitative data were gathered through self-perception surveys, which assessed components of CTD, such as openness to divergent views and willingness to consider alternative perspectives. Qualitative data were gathered through post-gameplay focus group interviews (FGIs), offering deeper insights into the study. Findings indicated a substantial positive impact of GBL on students' CTD development, with 61.38% of participants showing improved CTD scores after gameplay. Together with other insights gathered through data analysis and FGIs, this study informs TVET educators on how game-based learning can enhance student engagement and cultivate CTD, a key competency for navigating an increasingly dynamic and uncertain future.

Keywords: *Game-based learning, Critical thinking disposition, multiple perspectives, Game of Trade-offs*

Introduction

According to the UNESCO (2015) report, Technical and Vocational Education and Training (TVET) encompasses 'education, training and skills development relating to a wide range of occupational fields, production, services and livelihoods." Rapid advancement in technology, particularly in the field of automation and the use of artificial intelligence, has raised concerns about the essential skillset necessary for TVET learners (Felipe L. et al., 2023). The Future of Jobs Report (2025) emphasises that beyond technical competencies, core skills such as critical and analytical thinking and problem-solving abilities are crucial for workplace success.

As institutes of higher learning, polytechnics in Singapore deliver practise-based learning through hands-on experience. Technical training and industry experiences form the cornerstone of polytechnic education, ensuring graduates possess industry-relevant technical capabilities. However, recognising that technical proficiency alone is insufficient, Singapore Polytechnic (SP) implemented the Common Core Curriculum (CCC) in 2021. CCC aims to equip students with transferable human and digital skills essential for the evolving workplace environment.

One of the first CCC modules students encounter when they enter SP is Thinking Critically about the United Nations Sustainable Development Goals (TCU). The module fosters critical thinking through the examination of local and global issues. When TCU was first introduced, critical thinking was taught through a structured approach, with teachers providing comprehensive explanations of local and global issues to guide student understanding. While students showed good comprehension and active participation in class discussions, opportunities existed to enhance the learning experience of students beyond teacher-led instruction.

The Game of Trade-offs (GTO) was launched in Academic Year 2022/23 for all Year 1 students in SP. Through this interactive game-based approach, students evaluate information and make reasoned judgements in various scenarios, encouraging critical thinking in complex contexts.

For many students in SP, TCU serves as their first extensive exposure to the critical thinking discourse. In the TVET context, where workplace success increasingly demands the ability to think critically and make informed decisions, developing these skills is crucial. This study examines the effectiveness of game-based learning (GBL) in developing critical thinking disposition (CTD) among TVET students, guided by the primary research question: What is the impact of game-based learning on students' critical thinking disposition? (CTD)?

Critical Thinking Disposition (CTD) and Game-based Learning (GBL)

Critical thinking comprises two fundamental aspects: skills and disposition. Facione (1990) defined critical thinking as "purposeful, self-regulatory judgment" involving interpretation, analysis, evaluation, and inference. Building on this, Fasko (2003) characterised critical thinking as "the propensity and skills to engage in mental activity with reflective scepticism." Both definitions emphasise that effective critical thinking requires not only the ability to think critically but also the inclination to do so.

Research examining the relationship between GBL and critical thinking development has yielded promising results. A comprehensive meta-analysis by Mao, et al. (2021), examining 20 empirical studies, demonstrated that GBL has a particularly strong effect on developing the dispositional dimension of critical thinking. This finding suggests that game-based approaches can effectively nurture students' tendency to engage in critical thinking processes.

For first-year polytechnic students newly introduced to the critical thinking discourse, developing the disposition to think critically provides an essential foundation. While critical thinking skills will be progressively developed throughout their diploma programme at SP, fostering CTD early in their academic journey is crucial. This study therefore employs the Game of Trade-offs (GTO) as a GBL intervention to investigate how educational games can cultivate students' disposition towards critical thinking.

The Game of Trade-offs (GTO)

GTO is a facilitator-led classroom game that immerses students in complex dilemmas faced by Singapore. It fosters critical thinking by encouraging players to prioritise, make decisions, and reflect on their consequences. The goal is to achieve the highest score by earning points from decisions made in each scenario.

The game starts with a compulsory scenario set in the Singapore context. Lecturers then select three additional scenarios from a pool of five, based on class profile and learning needs. Each scenario presents a dichotomous policy decision—framed as a "Yes" or "No" option—each with distinct trade-offs. Table 1 outlines the scenarios, options and trade-offs.

Table 1: GTO Scenarios, Options and Trade-offs

Scenario	Option	Score and Trade-offs
Should the construction of the Cross Island Line be halted?	Stop	Economic (-5) Environment (+2)
	Proceed	Economic (+5) Environment (-2)
Should we implement National Service for women in our military and defence forces?	Implement	Economic (-5) Socio-political (+3)
	Don't implement	Economic (+5) Socio-political (-3)
Should the carbon tax be increased?	Increase	Economic (-2) Environment (+3)
	Don't increase	Economic (+2) Environment (-3)
Should we post recording on casual racism online?	Post	Socio-political – Stems out racism (+2) Socio-political - Highlights racism (-3)
	Don't Post	Socio-political - Does not solve problem (+3) Socio-political - Empower people (-2)
Should we restrict who set up 5G technologies in Singapore?	Restrict	Economic (-3) Diplomatic (+2)
	Don't restrict	Economic (+3) Diplomatic (-2)
Should we encourage the implementation of ONE Pass?	Encourage	Economic (+5) Social (-2)
	Discourage	Economic (+5) Social (-2)

Teams have three mins to discuss, reach consensus and prepare a justification for their decision. A representative then presents their choice and reasoning to the class, emphasising critical thinking, negotiation, perspective-taking and communication. This process emphasised not only critical thinking but also negotiation, perspective-taking, and communication.

After teams shared their decisions, facilitators revealed the scores for each option and explained the rationale. To simulate the unpredictability of real-world outcomes, some scenarios introduced "breaking news" events - unexpected developments that modified the existing trade-offs. These could result in bonus points or hidden costs. This demonstrated how new information or changing contexts can reshape earlier decisions.

The final gameplay segment introduces a taxation mechanic (Figure 1). After four rounds, the top two teams roll a die to determine a random tax penalty, the "Deficit Roll,", which reduces the final scores. This mechanic reinforces the idea that policies could be subjected to changes in the broader context of social equity and fiscal responsibility.

Figure 1. Taxing the Top 2 Highest Scoring Teams

The game concludes with a structured reflection and debriefing session. Facilitators invite students to examine how trade-offs influenced their decisions, how differing values shaped perspectives, and understand that real-life policies often involve no perfect solutions and hence there are no clear winners. Figure 2 shows the steps in playing GTO.

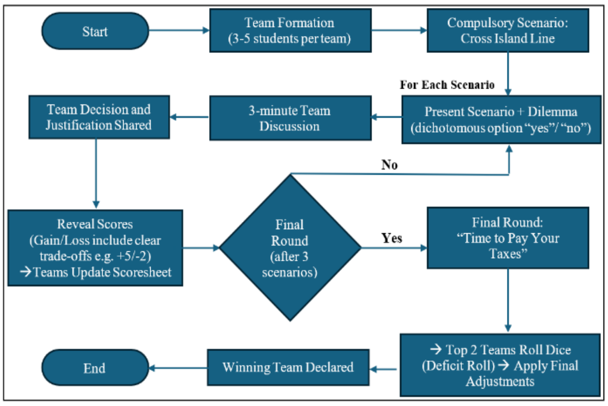

Figure 2. Gameplay flowchart for GTO

Methodology

This study employed a convergent mixed-methods design (Creswell & Plano Clark, 2018), combining a one-group pre-test/post-test survey with post-hoc FGIs to evaluate the impact of GTO, a GBL intervention, on the development of CTD in Year 1 SP students. The quantitative data measured changes in CTD, while the qualitative data explored learning processes.

All first-year students were invited to participate in this study. Informed-consent protocols emphasised voluntariness, confidentiality and assurance of no grade impact. A total of 3,941 completed the pre-test survey (86.5%) and 3,206 completed the post-test survey (70.4%). After listwise matching, 2,882 paired cases (63.3%) formed the analytic sample; 29 students were selected and participated in the FGIs.

Sosu's (2013) 11-item Critical Thinking Disposition Scale (CTDS) was selected as the measurement instrument due to its psychometric reliability (Cronbach's Alpha, α = 0.81), free accessibility, and emphasis on affective and motivational aspects that aligned with TCU's pedagogical aims. Table 2 illustrates the 11 items used in the survey for students.

Table 2: CTD Survey for Students based on CTDS (Sosu, 2013)

Domain	Item	Statement
CO	1	I usually try to think about the bigger picture during a discussion.
CO	2	I often use new ideas to shape (modify) the way I do things.
CO	3	I use more than one source to find out information for myself.
CO	4	I am often on the lookout for new ideas.
CO	5	I sometimes find a good argument that challenges some of my firmly held beliefs.
CO	6	It's important to understand other people's viewpoint on an issue.
CO	7	It is important to justify the choices I make.
RS	8	I often re-evaluate my experiences so that I can learn from them.
RS	9	I usually check the credibility of the source of information before making judgements.
RS	10	I usually think about the wider implications of a decision before taking action.
RS	11	I often think about my actions to see whether I could improve them.

Note: CO = Critical Openness; RS = Reflective Scepticism

Students rated each of the 11 items on a 5-point Likert scale with a possible maximum CTDS score of 55 and minimum CTDS score of 11. These scores were further categorised into low (11 - 34), medium (35 – 44) and high (45 – 55) bands.

Data were collected during the TCU lesson where GTO was played (surveys in week 3) and two weeks after (FGIs in week 5) (Figure 3).

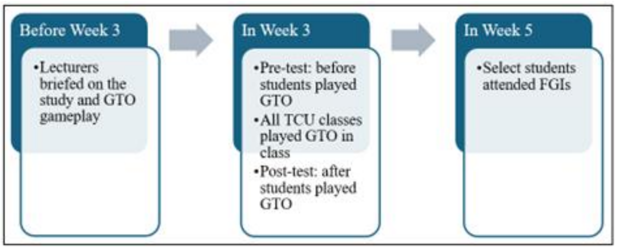

Figure 3. Data Collection Timeline

Quantitative Findings

Change in CTDS scores after Intervention

Analysis of the CTDS scores, pre- and post-intervention revealed that more than half of the participants (61.38%) demonstrated improvement in their CTD after GBL, while 20.06% showed no change and 18.56% showed a decrease in their CTDS scores after playing GTO (Figure 4).

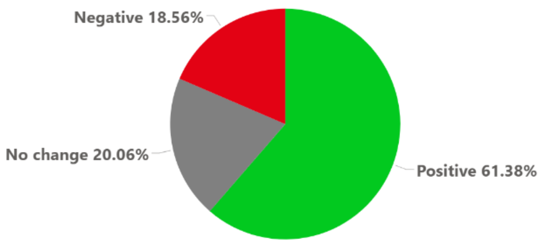

Figure 4. Change in CTDS scores after playing GTO

Comparative analysis of students' CTDS scores indicated significantly higher post-intervention scores (M = 45.70, SD = 6.09) compared to pre-intervention scores (M = 43.51, SD = 5.50). Mean CTDS increased by 2.19 points and a paired-samples t-test confirmed this difference was statistically significant, $t(2881) = 25.57$, $p < .001$. A Pearson correlation coefficient revealed a strong and statistically significant relationship between pre- and post-intervention scores ($r = .690$, $p < .001$), demonstrating consistency across paired observations.

To quantify the intervention's effectiveness, Cohen's d was calculated, yielding an effect size of $d = 0.48$. According to Cohen's (1988) guidelines, this represented a moderate positive impact, indicating that the intervention had a meaningful impact on students' CTD.

These findings provided evidence of a significant improvement in CTDS scores following the intervention, emphasising the effectiveness of the intervention.

Change in CTD Bands after Intervention

Analysis of movement between CTD bands revealed the following patterns (Table 3).

Table 3: Change in CTD bands

	Number of Students (N)	Percentage (Sub-total)	Percentage (Total)
No change			
Low-Low	83	3.97%	2.88%
Med-Med	1096	52.44%	38.03%
High-High	911	43.59%	31.61%
Sub-total	2090	100%	72.52%
Increased by 1 band			
Low- Med	52	9.90%	1.80%
Med-High	473	90.10%	16.41%
Sub-total	525	100%	18.21%
Increased by 2 bands			
Low-High	12	100%	0.42%
Decreased by 1 band			
Med-Low	61	24.90%	2.12%
High-Med	184	75.10%	6.38%
Sub-total	245	100%	8.50%
Decreased by 2 bands			
High-Low	10	100%	0.35%
Total	2882	100%	100%

72.52% remained within the same CTD band after the intervention, indicating general score stability. A larger proportion of students, 18.63%, moved up in CTD bands compared to 8.85% who moved down, suggesting a net positive trend. Among the upward movers, 0.42% (n = 12) of students demonstrated substantial improvement, progressing directly from the low to the high CTD band. In contrast, 0.35% (n = 10) experienced a marked decline, dropping from the high to the low band.

Change in CTDS scores by School

A one-way ANOVA did not reveal any statistical differences in the pre-intervention CTDS scores [$F(7, 2874) = 1.01$, $p = 0.425$)], and post-intervention CTDS scores ($F(7, 2874) = 1.99$, $p = 0.056$)] between schools. All schools showed positive changes in CTDS scores after the intervention, with the School of Chemical and Life Sciences exhibiting the highest mean improvement ($M = 2.67$) and the School of Mechanical and Aeronautical Engineering showing the lowest mean improvement ($M = 1.69$) (Figure 5).

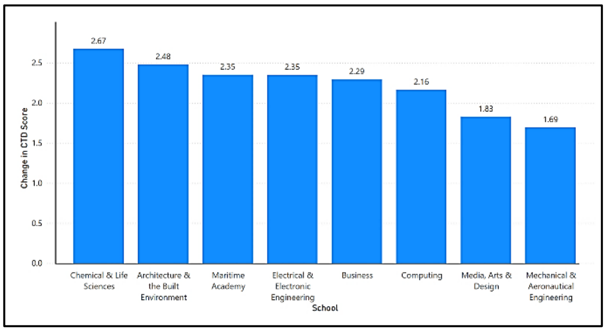

Figure 5. Change in CTDS scores by School

One-way ANOVA comparing the change in CTDS scores across schools also showed no statistically significant differences between the schools [$F(7, 2874) = 1.95$, $p = 0.057$)].

Differences in CTDS scores by domains

Sosu's (2013) CTDS framework conceptualises CTD through two key domains: critical openness (CO) and reflective scepticism (RS). CO was measured using the first 7 items and RS using the next 4 items on the CTDS 11-item instrument. Cronbach's α results indicated a high level of internal consistency for the overall scale and for each subscale pre- and post-intervention (Table 4).

Table 4: Measurement of CO and RS and internal reliabilities (Cronbach's Alpha)

Sosu's (2013) CTDS (11 items, $\alpha_{pre} = 0.87$ and $\alpha_{post} = 0.94$)	
Critical Openness (7 items, $\alpha_{pre} = 0.81$ and $\alpha_{post} = 0.90$)	**Reflective Scepticism (4 items, $\alpha_{pre} = 0.78$ and $\alpha_{post} = 0.89$)**
• I usually try to think about the bigger picture during a discussion. • I often use new ideas to shape (modify) the way I do things. • I use more than one source to find out information for myself. • I am often on the lookout for new ideas. • I sometimes find a good argument that challenges some of my firmly held beliefs. • It is important to understand other people's viewpoint on an issue. • It is important to justify the choices I make.	• I often re-evaluate my experiences so that I can learn from them. • I usually check the credibility of the source of information before making judgements. • I usually think about the wider implications of a decision before taking action. • I often think about my actions to see whether I could improve them.

Figure 6 illustrates the average change in CTDS scores across domains. Most schools showed greater gains in RS than in CO domain. A paired-samples t-test confirmed a significant difference between the two scores [$t(2881) = 2.496$, $p = 0.013$], suggesting that the intervention had a stronger impact on developing RS compared to CO.

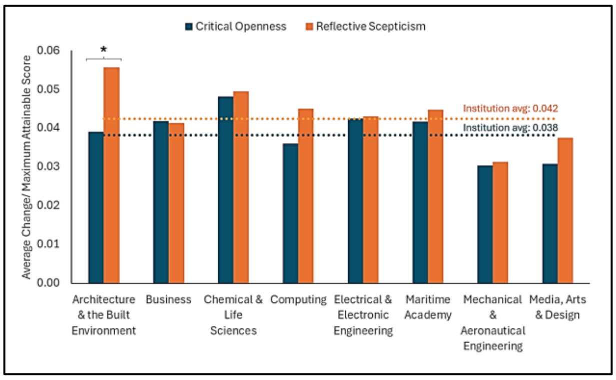

Figure 6. Average Change in CTDS scores by Domains by School. *Denotes significant difference, $p < .05$.

The difference in CO and RS improvements was most pronounced in the School of Architecture and the Built Environment, where students showed greater improvements in RS compared to CO.

A paired-samples t-test confirmed this difference was statistically significant [$t(247) = 2.686$, $p = .008$] at the 99% confidence level, indicating the intervention had a differential impact on these two domains of CTD.

Conversely, students from the School of Business demonstrated greater improvements in CO compared to RS post-intervention. However, a paired-samples t-test indicated that this difference was not statistically significant [$t(419) = 0.14$, $p = 0.887$]. The intervention's impact on both domains within the School of Business cannot be conclusively differentiated.

Qualitative Findings

The FGIs revealed three key insights into how GTO influenced students' approach to critical thinking.

First, students found GTO engaging and collaborative, highlighting how its real-world scenarios and group discussions made learning relevant and enjoyable. The game encouraged them to consider diverse perspectives and reflect more deeply than in typical lessons. One student shared, "*Getting to be in groups and discussing…you get to hear everybody's opinions. So you can rethink and reflect on your own opinions.*"

Second, some students felt that time pressure and the competitive scoring system limited deeper thinking. The fear of losing points for taking too long often led to rushed decisions or groupthink, where dissenting opinions were avoided. One student explained, "*If there's sufficient time, maybe we'll be able to think different, not just on the surface, but really go deep and understand why we think so*."

Third, students suggested improvements, such as adding reflection time and revising the scoring system to reward thoughtful discussion over speed. Others emphasised keeping the game's face-to-face interaction. One student point out "*I feel like it (the point system) was a bit unfair because points should be based on how constructive you are answering on*".

Overall, students appreciated GTO's engaging design but noted that certain mechanics could be refined to better support critical thinking. Their feedback highlights the need to balance competition with reflection to maximise both learning and engagement.

Discussion

Overall impact of GTO on students' CTD

Results confirmed a statistically significant, medium-sized gain ($d = 0.48$) and a net upward band shift in students' CTDS scores after intervention, affirming that GBL is an effective pedagogical tool for critical thinking development, consistent with prior research on GBL benefits.

Analysis of CTD band movement revealed a net positive shift, with most upward movers transitioning from medium to high CTD bands (16.41%). This pattern aligns with Vygotsky's (1978) Zone of Proximal Development, where learners progress with guidance and scaffolding. The structured design of GTO, combined with peer interactions and facilitated discussions, likely provided this scaffolding, especially benefiting those poised to advance.

Despite generally positive outcomes, some students either maintained or showed a decline in their CTDS scores, indicating the need for refinement in some areas:

1. Game Design and Learner Profiles: GTO's competitive, group-based format encouraged quick decision-making under time pressure. While engaging for students who thrive in fast-paced, collaborative settings, FGIs revealed that time constraints limited research and discussion. Additionally, some students felt constrained by the scoring system, which focused on "right or wrong" answers, potentially discouraging the sharing of diverse viewpoints and hindering critical discourse. The text-heavy interface, relying on slides and facilitator narration, may not resonate with students who prefer visual or hands-on learning. Prior knowledge, such as familiarity with the scenario content, also influenced engagement levels and learning outcomes. Adapting the game to better accommodate diverse learning preferences and profiles could improve both inclusivity and effectiveness in the intervention.
2. Game Implementation: Facilitator expertise and classroom dynamics can also influence the intervention's effectiveness. While skilled facilitation fostered open discussion, unclear instructions or poor rapport hindered engagement. Lesson timing and student readiness may also affect the gaming experience.
3. Survey Limitations: The reliance on self-perception surveys as the sole measurement tool may explain limited or negative changes in CTDS scores. Kruger and Dunning (1999) found that less competent individuals tend to overestimate their abilities. After the intervention, increased self-awareness may have led students to give more modest self-ratings, even if their actual abilities improved. This suggests that CTDS scores reflect shifts in perception, not just ability, pointing to a need to complement self-reports with other assessments.

Consistent Impact across academic disciplines

The lack of statistically significant differences across academic schools ($p = 0.057$) suggests that GTO's effectiveness is relatively consistent across different academic disciplines. This finding is valuable as it indicates that game-based approaches to developing CTD can be effectively implemented across diverse academic contexts without significant loss of impact. This consistency aligns with Gee's (2003) assertion that well-designed games support learning across disciplines, regardless of subject matter.

Differential Impact Across CTD Domains

Domain analysis (Sosu, 2013) showed greater gains in RS than CO [$t(2881) = 2.496$, $p = 0.013$], suggesting that GTO more effectively fosters evaluation and reflection than openness to new ideas. This disparity may stem from the game's competitive and time-pressured structure, which tends to encourage rapid judgments over deep exploration. Interestingly, the School of Business deviated, showing greater CO gains, possibly reflecting discipline-specific tendencies. Further research may explore how disciplinary differences influence CTD development through GBL.

Limitations and Future Research

The findings demonstrated the effectiveness of GBL in enhancing students' CTD. However, several limitations need to be considered:

1. A single intervention may not fully capture the relationship between GBL and CTD. Long term studies may help establish a clearer link between these variables.
2. As mentioned earlier, the reliance on self-perception surveys introduce biases. Further studies should complement self-reports with other methods to provide a more comprehensive understanding.
3. Limited insight into disciplinary differences across the eight schools may have constrained the analysis of how diploma-specific factors influenced students' responses. Further studies could explore how variations in curricula across diplomas impact students' engagement with GBL.
4. Factors such as game design, learner characteristics and implementation style can significantly affect learning outcomes. Future research should explore these factors to better tailor GBL approaches to different learners.

Conclusion

This mixed-methods study demonstrates that a carefully scaffolded, single-session analogue game can moderately enhance first-year students' CTD, particularly in the reflective scepticism domain. The increase in CTDS scores across all eight schools indicates that GBL is an effective pedagogical tool for enhancing CTD, regardless of discipline. However, variation in student responses suggests that both game design and implementation can shape learner behaviour.

These findings are especially relevant in the context of TVET, where preparing students for a VUCA world requires not only technical competence but transferable, higher-order thinking skills. GBL's capacity to engage learners in collaborative, real-world problem-solving aligns well with TVET's evolving mission to cultivate adaptable, critically minded graduates.

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