Master thesis

From gaming to decision-making:

Design-based research to foster critical thinking in a game-based learning environment

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Abstract

Abundant and unverified information challenges individuals' cognitive processes to make optimal decisions. Critical thinking has proven to be a skill that could support optimal decision-making. Also, both critical thinking and decision-making were studies in DGBL environments. Nevertheless, it was unknown that how to foster critical thinking to improve decision-making in a DGBL environment. Thus, this design-based research tried to facilitate critical thinking for decision-making by designing a learning dashboard in a digital game-based learning environment, using the case of The Dilemma Game. The learning dashboard was designed and evaluated through three phases: investigation, designing, and evaluation. In Phase 1, data were collected by using Questionnaire 1, assessing six participants' critical thinking experience, which included four levels: awareness, self-reflection, sense-making, and impact from eight participants. In Phase 2, the design learning dashboard was designed based on participants' responses and literature suggestions. In Phase 3, the design learning dashboard was evaluated by Questionnaire 2 with The Dilemma Game's end-users. The outcome of this study confirmed that a learning dashboard could promote critical thinking by reminding learning goals, explaining in-game behaviors, and giving personalized suggestions. Follow-up research could focus on the examination of this research results. Also, the skill transition between digital game-based learning and real-life decision-making could be investigated.

Key words: decision-making, critical thinking, crisis response, learning dashboard, digital game-based learning, design-based research

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1. Introduction

1.1. Problem Statement

With the Internet and continuous technological development, convenient access to information is the norm. Thus, individuals can easily access information by clicking or scrolling on portable devices like laptops or mobile phones. Consequently, there are excessive information sources, including unverified data. People risk accepting this data as truth, even though it might not be accurate, and using it as input for important decisions. For example, during the COVID-19 pandemic, citizens faced various sources of recommendation regarding COVID-19, including unverified news from social media (Depoux et al., 2020). Facing various sources of information, some individuals refused vaccinations or social distancing based on unverified advice from social media and as a result, prolonged the COVID-19 pandemic and public panic (Wang et al., 2020). Citizens need to decide which recommendation to believe among excessive sources of information. Ideally, that decision would lead to a lower COVID-19 impact on societies. The COVID-19 case shows that decision-making is crucial when people face different sources of information, as they need to make decides for uncertain health consequences.

In order to make the right decision, critical thinking is essential. Metaphorically, if decision-making is an engine and information is energy supply, critical thinking is the process of selecting the correct type of fuel to power the engine. Critical thinking can help individuals to value data correctly when they process it (Facione, 2011). Critical thinking means that individuals verify and evaluate received data to eliminate irrelevant or unverified information For example, individuals who thought critically and valued information from public health institutions were more likely to decide to accept the COVID-19 social distancing and vaccine (Tam et al., 2022). On the contrary, people who lacked critical thinking skills tended not to eliminate unverified news or rumors. Consequently, these individuals made decisions based on false information and tended to reject vaccines or social distancing (Tam et al., 2022). The information validation of COVID-19 is an example that instruction in critical thinking is becoming highly important. That is because critical thinking, as a 21st-century skill, allows individuals to gain a more accurate understanding of the information they encounter, therefore enhancing good decision-making in real-world applications (Dwyer et al., 2014).

Researchers (Chang et al., 2020; Cicchino, 2015; Mao et al., 2022) have already experimented with approaches of critical thinking instruction. Results confirmed that digital game-based learning could more significantly improve students' critical thinking tendencies than traditional instructions. Studies also confirmed the values of digital game-based learning for decision-making which is one of the desired results of critical thinking. A study (Nino et al., 2015) believed that game-based learning is a verified tool to facilitate decision-making training. Therefore, researchers (Sung et al., 2015; Sousa et al., 2019; Terri et al., 2019) have applied game-based learning to decision-making training in various disciplines, such as education, healthcare management, and crisis management. As mentioned in the previous section, critical thinking is vital for decision-making. Although digital game-based learning has been verified as a learning approach for both critical thinking and decision-making,it is still unclear how to foster critical thinking in digital game-based learning environments for decision-making. Therefore, this study investigates designing factors in digital game-based learning environments to trigger learners' critical thinking that leads to better decision-making.

1.2. Theoretical Framework

Decision-making: In general, decision-making is a cognitive process every individual applies, from choosing a dining restaurant to voting for a political party. In crisis management, such as COVID-19 response, decision-making is situational, urgent, and cognitively complex (vd Hulst & Ruijsendaal, 2012). In other words, decision-making is in uncertainties and opposed opinions between options with different outcomes and consequences, and it is influenced by multi-aspect information (Bakker et al., 2009). In order to make the decision that leads to the desired consequence, individuals should first select verified and accurate information for their decision-making processes. Thus, individuals should be able to evaluate the information they receive, which requires critical thinking skills to choose the right fuel for their decision-making engine.

Critical thinking: As discussed in the previous section, in crisis management, individuals require critical thinking skills to first select the reliable information then proceed their decision-making. This study follows the definition of critical thinking by Ennis (1993): critical thinking is "the reasoned and reflexive thinking that focuses on deciding what to believe

and what to do " (p. 179). Critical thinking is an essential cognitive process for individuals to select and reflect on the information they receive. However, individuals might neglect critical thinking while decision-making due to tendencies, bias, and distractions (Turan et al., 2019). When facing various information, critical thinking can assist individuals in identifying their tendencies, biases, and distractions that are related to this information. Then, through the filters of reason and logic, individuals foresee the consequences and decide whether this information is valuable and applicable. Therefore, explicit instruction on critical thinking can help reduce possible negative impacts of these tendencies, biases, or distractions in decision-making.

To investigate the theoretical foundations of critical thinking instructions, Snyder & Snyder (2008) concluded that instructions should stimulate learners' thinking processes instead of emphasizing rote memorization. Also, instructions should promote learners' thinking processes rather than solely on the learning contents, as critical thinking is a cognitive skill rather than merely knowledge (Snyder & Snyder, 2008). Besides, the assessments should also target learners' thinking processes but memory recall. (Snyder & Snyder, 2008).

Researchers (Haynes and Bailey, 2003) investigated critical thinking training. They agree that some questions can be asked to learners to guide them to think critically. By answering particular questions, learners must reflect on their thinking or decision-making process and verify the knowledge or information they apply, leading them to critical thinking (Haynes & Bailey, 2003). According to Haynes & Bailey (2003), these questions include:

1. What do you think about this?
2. Why do you think that?
3. What is your knowledge based upon?
4. What does it imply?
5. Should it be understood differently?

Based on instructional guidelines by Snyder & Snyder (2008) and critical thinking guidelines by Haynes and Bailey (2003), the U.S. Army developed a digital game-based program to practice and enhance military leaders' critical thinking skills in simulated combat scenarios (Fischer et al., 2009). According to Fischer et al. (2009), this digital game-based learning program was effective in critical thinking training and facilitated training remotely. The digital game-based learning training program confirmed that critical thinking could be optimally

facilitated and practiced in a digital environment. The U.S. army's critical thinking instruction confirmed the effectiveness in promoting critical thinking of digital game-based learning, which cannot always be found in traditional paper-based or lecturing training approaches (Fischer et al., 2009).

Digital Game-Based Learning: Digital Game-based Learning (DGBL) describes a learning environment where decision-making and critical thinking can be significantly promoted compared to traditional instructions. Specifically, a DGBL environment includes game contents to promote learners' knowledge and skills acquisition, applies game elements to challenge learners' problem-solving (Qian & Clark, 2016).

Regarding its relation to decision-making, DGBL can provide a safe alternative to crisis management decision-making training (Schaaf, 2012). For example, Nur et al. (2020) designed a flood disaster DGBL environment that provides interactive learning for preschool students. This application helped promote awareness by guiding learners on making optimal decisions to survive during flood disasters. This DGBL design improved these preschool students' motivation and engagement by using animations to attract their attention and help them remain focused (Nur et al., 2020). As for DGBL critical thinking, DGBL is a verified medium for facilitating critical thinking skills. Chang et al. (2020) tested a digital educational game designed for Electrocardiogram training among nursing students. The experimental results revealed that nursing students who trained in this DGBL environment showed better learning performance and critical thinking skills than in studying in conventional classroom settings (Chang et al., 2020).

However, Kiili (2005) stressed that an instruction needs to provide learners instant and personal feedback, goal reminders, and moderate challenges to trigger their critical thinking in DGBL environments. In DGBL, some instructions applied scoring, the simplest approach, to give feedback. For example, in a digital money management training game, for every spending decision, the player increased or reduced in score as the form of performance feedback (Hwang et al., 2015). However, scoring as feedback approach does not provide personalization or goal reminders. Therefore, scoring might not significantly foster learners' critical thinking in GDBL environments. In addition to scoring, DGBL environments can include coaching to provide learning performance and instructions to learners as feedback (Tsai et al., 2015). But coaching might lead to information redundancy, and specific instructions can reduce learners' self-reflection, which results in less critical thinking. Learning dashboards are proven to be a more

effective feedback tool to trigger learners' critical thinking in DGBL environments, compared to scoring or coaching (Verbert et al., 2013).

Learning Dashboard: A learning dashboard describes an application to summarize and visualize students' learning performance patterns in a digital learning environment (Verbert et al., 2013). In other words, a learning dashboard is one way to provide learners feedback in DGBL. A learning dashboard usually includes charts, colors, line graphs, tables, pie charts, and network graphs to visualize or summarize data on learning performance (Verbert et al., 2013). It can also include corrective guidance on learning (Verbert et al., 2013).

As mentioned in the previous section, feedback can be challenging for DGBL to facilitate critical thinking. A learning dashboard is proven to be a practical approach to trigger critical thinking for learners (Tan et al., 2017). This is because learning dashboards capture and visualize traces of personalized learning performance and in-game data. By checking personalized data from a learning dashboard, learners can spontaneously reflect on their decisions and how they process received information (Freitas et al., 2019). Furthermore, learning dashboards can be a tool to help learners track their progress and keep motivated in learning (Verbert et al., 2014). Tan et al. (2017) implemented a 16-week experiment with a learning dashboard among Singaporean high school students to investigate students' reading performance, and the results confirmed that learning dashboard could benefit students critical thinking skills. Specifically, students' critical thinking skills were enhanced regarding information awareness, self-reflection, sense-making, and behavior changing, which were the four aspects of the learning analytic model by Verbert et al. (2013).

Learning analytic model: In order to measure and define critical thinking levels, evaluation criteria are needed. After looking into the literature, this paper used the learning analytic model (Verbert et al., 2013) to define critical thinking levels and created questionnaires. The Verbert et al. (2013) learning analytic model studied critical thinking and the implementation of a learning dashboard in a digital game-based learning environment, which closely matches this study's purpose. Thus, this study chose the learning analytic model (Verbert et al., 2013) to evaluate the learning of The Dilemma Game (will be introduced in section 2.3.) with questionnaire participants.

Specifically, the learning analytic model defines critical thinking into four layers: information awareness, self-reflection, sense-making on information, and behavior-changing

(Park & Jo, 2019). As such, this study's questionnaire was designed based on these four layers of critical thinking. According to the learning analytic model, the results presented to which degree a learning dashboard can foster learners' critical thinking.

1.3. Research Question

This design-based research answered the question: How to foster critical thinking for decision-making by using a learning dashboard in a digital game-based learning environment? To answer the research question, this study used the learning analytic model (Verbert et al., 2013) generating evaluation themes. Based on the evaluation themes, questionnaires was designed to collect data from participants who would play the decision-making game. After data collection, the dashboard was improved according to the literature and participants' feedback. Lastly, the design was evaluated by external experts based on the learning analytic model (Verbert et al., 2013). It was expected that the discussion and feedback from participants could explain how to foster critical thinking for decision-making in a game-based learning environment.

1.4. Scientific & Practical Relevance

This study can be both scientifically and practically relevant. In terms of scientific relevance, this study narrows the gap between critical thinking and decision-making in digital game-based learning environments. Moreover, these design principles can benefit future design-based research. Regarding practical relevance, this research provides a functional learning dashboard for a decision-making game. Last but not least, this study investigates how to use a learning dashboard as a feedback tool in a game-based learning environment, which can be a reference for future dashboard designs.

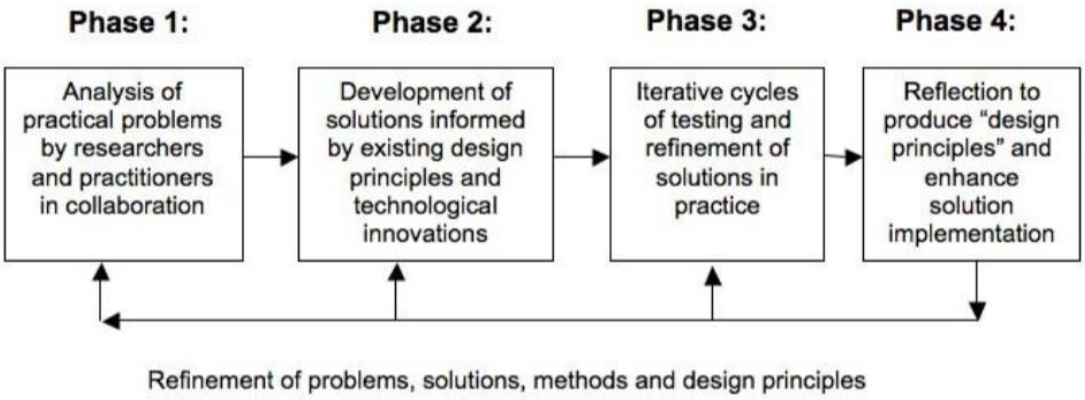
2. Method

2.1. Research Design

The research was designed following the four-phase design-based research model presented by Reeves (2006), depicted in Figure 1 below.

Figure 1

Phases of design-based research (Reeves, 2006, p. 59)



Each phase, together with the original learning dashboard of The Dilemma Game, is described in brief below. Nevertheless, due to time limitations and discontinuation of The Dilemma Game designing, this research cannot follow iterative testing cycles or implement design learning dashboards in a new game.

Phase 1: Six participants were invited to play The Dilemma Game. These participants were selected because they have backgrounds in educational science, game-based learning, and/or designing. The procedures in phase 1 are as follows: First, participants played the game's first scenario. After they finished the first scenario, the researcher generated a stimulated learning dashboard and showed participants their gaming performance. Then, participants played the second scenario of the game. In the end, participants filled in Questionnaire 1 to reflect on their critical thinking triggered by the original dashboard and suggested improving the dashboard design regarding critical thinking fostering.

Phase 2: The researcher designed an outline for the learning dashboard of The Dilemma Game based on the literature and participants' suggestions and feedback.

Phase 3: Two potential game users were invited to join this research as external participants. These participants compared The Dilemma Game's original learning dashboard and this study's design, then responded to Questionnaire 2 to evaluate the improvement of the design learning dashboard regarding critical thinking promotion functions.

Phase 4: Summarize the results of this research. Reflect on the research process and findings, discussed the limitations of design theories, and suggest future learning dashboard design solutions.

2.2. Participants

Phase 1: In Phase 1, six participants took part in data collection. Participants in Phase 1 came from four different programs at the University of Twente: Educational Science and Technology, Psychology, Industrial Engineering and Management, and Industrial Design Engineering. One participant had nine-year experience in DGBL designing. The participants were aged from 21 to 45. Three of the participants were female, and three of them were male. Participants had various nationalities: three Dutch, one Chinese, one Lithuanian, and one Aruban. The group of participants was in many ways diverse and were a suitable sample group for DGBL testing

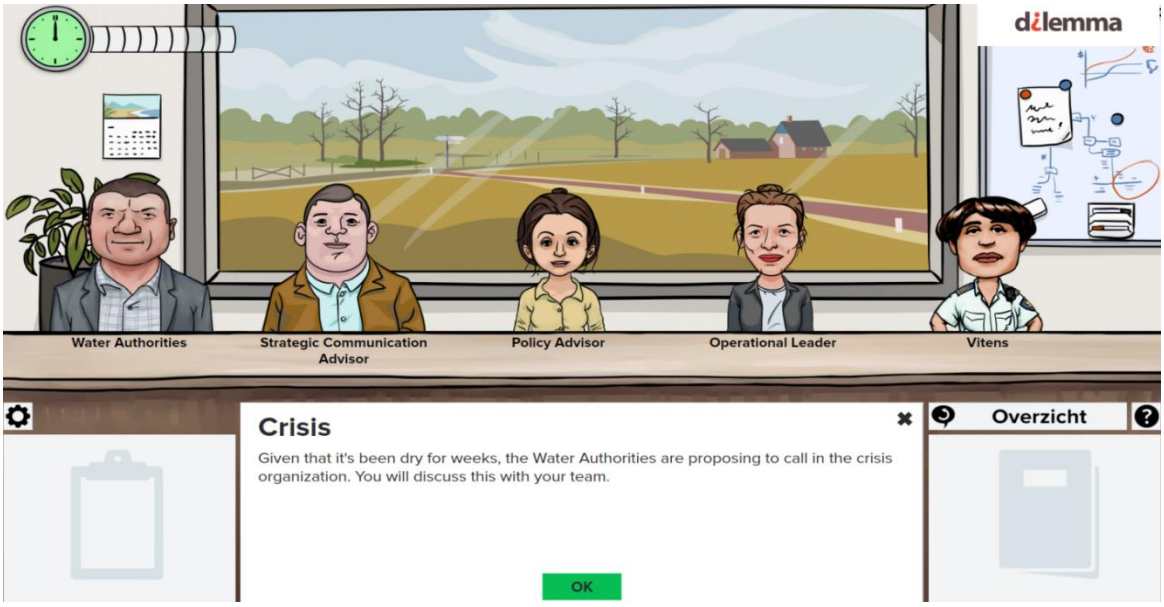
Phase 3: In Phase 3, two external experts participated in data collection. These two external experts worked in Brandweer Twente, the fire security department in the Twente region, the Netherlands. One participant has been working for nine years as the team leader in the knowledge center of Brandweer Twente. The other participant has been working as a learning specialist for two years. Both participants have experience in decision-making for crisis response. Therefore, their experience can be valuable in evaluating a serious decision-making game from a practical perspective. The researcher's first supervisor, Dr. J. Steinrücke, helped with getting in touch with external participants.

2.3. The Dilemma Game

The Dilemma Game is a digital serious game aiming to improve crisis management decision-making. The potential end-users of The Dilemma Game are mayors or decision-makers responsible for urgent crises, such as drought, flooding, or explosion. Specifically, the game creates dilemmas for players by providing different information from different positions, such as water authority, strategic communication advisor, policy advisor, operational leader, and the Vitens). It is named "dilemma" because the information can be reasonably opposed. A player needs to evaluate and follow in-game information correctly in a limited time. Figure 2 is a screenshot of The Dilemma Game.

Figure 2

Screenshot of The Dilemma Game

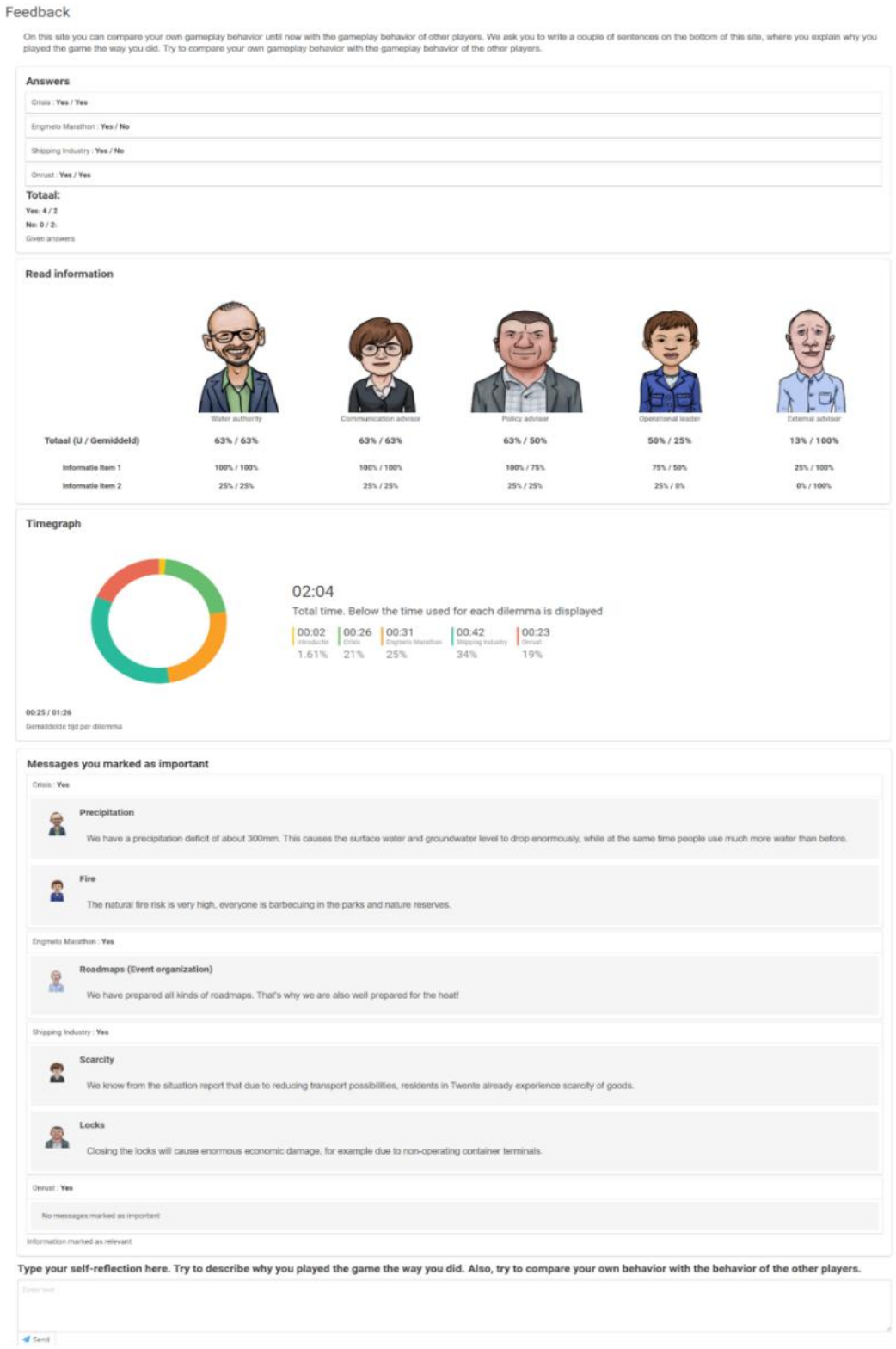


The Dilemma Game's original learning dashboard shows players the visualized summary and analysis of their answers, reading the information, the response time (in total and in each dilemma), and messages players marked as important. The dashboard also includes a section that encourages players to write self-reflections on their in-game behaviors and compare them with fellow players. Figure 3 depicts the original learning dashboard of The Dilemma Game.

However, due to the discontinued online operation of The Dilemma Game, the original learning dashboard could no longer be generated for players. Based on the original learning dashboard in The Dilemma Game, the researcher simulated a learning dashboard and used it to summarize and demonstrate players' performance. The stimulated learning dashboard can be found in Appendix C.

Figure 3

The Original Learning Dashboard in The Dilemma Game

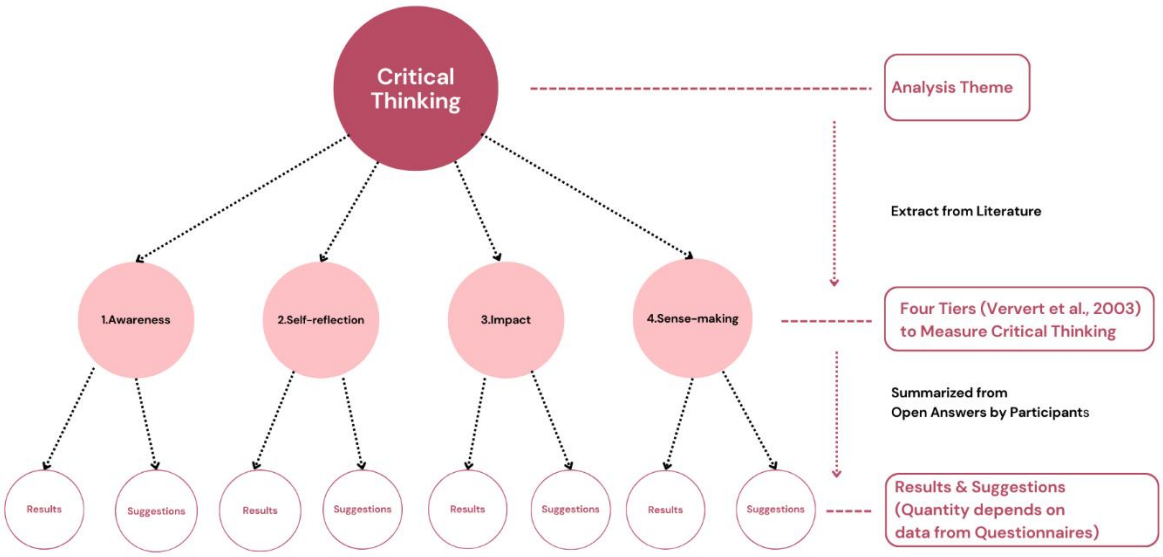


2.4. Data Collection Tool

Figure 4 indicates the outlines of data collection and procedure in this study. This research conducted Questionnaire 1 in Phase 1, and Questionnaire 2 in Phase 3. Both Questionnaire 1 and Questionnaire 2 are provided in Appendix A and Appendix B.

Figure 4

Data Collection and Procedure



Phase 1: Questionnaire 1 was designed based on the learning analytic model (Verbert et al., 2013). As described in the theoretic framework, the learning analytic model defines critical thinking into four tiers: awareness, self-reflection, sense-making, and impact (Verbert et al., 2013). Specifically, the implications of these four tiers are as follows:

1. Awareness: People are aware of the indicated information from the dashboard.
2. Self-reflection: People reflect on their in-game behavior data and ask themselves questions to assess their behaviors.

3. Sense-making: People create new insights on their way of solving in-game problems or update their understanding of data.
4. Impact: People change their in-game behaviors or decisions on gaming.

Questionnaire 1 asked participants nine questions regarding the four tiers of the data analytic model by Verbert et al. (2013). Under each tier, two questions were asked about participants' experiences and suggestions. At the end of the questionnaire, an open question aimed to evaluate the original dashboard and advise on its improvements. In order not to bias participants, Questionnaire 1 asked open questions. Specifically, depending on which tier, the first question under each tier inquired about participants' experience regarding information awareness, sense-making, self-reflection, or impact from playing The Dilemma Game and checking the original learning dashboard. The second question under each tier asked participants for their suggestions, depending on which tier, on improving information awareness, self-reflection, sense-making, or impact of the dashboard design. The following section demonstrates the explanations and example questions under each tier of Questionnaire 1:

Awareness: The first question inquired to which degree a participant noticed his/her in-game data after checking the original learning dashboard: “After checking the learning dashboard, which kind of data did you keep in mind while playing the second scenario?” The researcher would compare the data provided in the original dashboard and the participant’s answer to evaluate to which extent the original dashboard triggered information awareness in the participant.

The second question asked the participants for suggestions on improving information awareness of the original dashboard. The second question also requested participants to provide reasons for their feedback. Thus, the researcher would justify the input based on the reasons. The second question was: “Do you have any suggestions for improving the dashboard’s information presentation to help players be aware of the data? If yes, please specify with reasons.”

Self-reflection: After checking the original dashboard, the first question checked whether participants asked themselves questions about their in-game behaviors or the information they used for decision-making. Specifically, participants were asked to answer which questions did they ask themselves to self-reflect. The first question was: “Based on the information in the

dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify."

The second question inquired about the input on improving the self-reflection of the original dashboard with specific reasons. The second question of this section followed the same structure as the second question of the awareness section but with a different target on self-reflection. This made the second question in the self-reflection section: "Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons."

Sense-making: The first question checked whether participants generated new gaming strategies or new understandings on evaluating the in-game information for their decisions. In other words, this question investigated whether participants self-answered their self-reflection questions from the self-reflection tier. The first question in the sense-making question was: "According to the learning dashboard data, do you think you were inspired and generated any new insight on your way to solving problems in the second scenario? If yes, please describe." The second question followed the same structure with awareness and self-reflection but focused on sense-making.

Impact: The first question investigated whether participants changed their in-game behavior through awareness, self-reflection, and sense-making sequences. In other words, after checking the original dashboard, to what extent did participants change their behaviors to evaluate the in-game information for better decision-making? Therefore, the first question was formulated: "Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard? If yes, please specify." The second question followed the same structure with awareness, self-reflection, and sense-making but focused on impact.

Phase 3: Questionnaire 2 was designed based on the learning analytic model with nine questions (Verbert et al., 2013). Questionnaire 2 included four tiers of critical thinking (awareness, self-reflection, sense-making, and impact), with two open questions under each tier. At the end of the questionnaire, an overall open question asked participants for general evaluations and improvement suggestions on the design learning board. What made Questionnaire 2 differs from Questionnaire 1 is that Questionnaire 2 asked participants to compare the design learning dashboard with the original dashboard. Participants were also asked

to share their suggestions for further improvements to the learning dashboard. The following section explains and demonstrates the two questions of each tier.

Awareness: The first question asked participants to evaluate the original dashboard on information awareness. Specifically, participants were asked to judge if the original dashboard could nicely present players' in-game data. The first question was: "What do you think of the dashboard's information presentation of the original learning dashboard? Do you think it is well-designed to present player's data?"

The second question asked participants on the design learning dashboard to evaluate whether the adjustments had effectively promoted information awareness for players. Participants were also required to explain the reasons for their evaluations. Thus, the second question of the awareness section was: "Do you think the design dashboard can help players be better aware of their data? Please justify with reasons."

Self-reflection: The first question asked participants to what extent the original learning dashboard could trigger players' self-reflection. The participants were also asked to give reasons for their opinions. Thus, the first question was: "To what extent do you think the current learning dashboard can trigger players' self-reflection on their in-game behavior or decision-making?"

The second question followed the same structure as the second question of the awareness section but focused on self-reflection. Namely, participants were asked to evaluate and explain whether the adjustments had effectively promoted self-reflections for players. The second question was: "Do you think the intervention can potentially trigger players' reflection on their in-game behavior? Please justify with reasons."

Sense-making: The first question asked participants to determine to what extent the original dashboard helped players validate the in-game information or comprehend the in-game strategies. Therefore, the first question was: "To what extent do you think the current dashboard can help players understand interpreting data and changing their in-game strategies?" The second question focused on sense-making promotions of the design learning dashboard, following the same structures with awareness and self-reflection sections.

Impact: The first question asked participants to determine to what extent the original dashboard helped players validate the in-game information or comprehend the in-game strategies. Therefore, the first question was: "To what extent do you think the current dashboard can help players understand interpreting data and changing their in-game strategies?" The second question

focused on sense-making promotions of the design learning dashboard, following the same structures with awareness and self-reflection sections. “Do you think the intervention can enhance players’ decision-making by triggering their awareness, reflection, and sense-making? Please specify with reasons.”

2.5. Procedure

This study received ethical approval from the Behavioral Management and Social sciences Committee of the University of Twente. The Ethical Committee granted the permission in May 2021. Before data collection, all participants in Phases 1 and 3 provided active consent.

Phase 1: In this analysis & exploration phase, the researcher collected data from participants face-to-face to investigate the practical problems of The Dilemma Game’s original learning dashboard. In total, there were six data collection sessions, with each on an individual basis. Each session took 45 to 60 minutes. First, the researcher invited participants to the BMS Lab at the University of Twente. After introducing the research purpose, data collection procedure, and the concepts of critical thinking, decision-making, and learning dashboard in digital game-based learning, the researcher guided participants to become familiar with The Dilemma Game.

Second, participants started to play the first scenario: Drought. Due to the discontinuation of The Dilemma Game, a learning dashboard could not be automatically generated. To cope with this problem, the researcher generated learning dashboards manually by documenting and organizing participants’ in-game data. The researcher precisely timed and noted participants’ data of answers, time spent on each dilemma, and information marked as important. Then, the researcher calculated and documented the percentage of time spent on each scenario and presented participants’ in-game answers during their plays. Besides, the researcher asked participants to write down their self-reflection and included their answers to generate simulated learning dashboards for participants.

Third, the researcher demonstrated simulated learning dashboards to participants. Each participant 5 minutes to read their simulated dashboard and then reflect on their answers, the time they spent on each scenario, and the answers they marked as important. The researcher tried not to explain the information on the simulated dashboard but allowed participants to be aware, reflect, or understand the simulated dashboard.

Fourth, after trying to be aware, reflect, or understand their simulated dashboards, participants began to play the second scenario: Flooding. The researcher continued to observe the participant's in-game behavior, such as time spent on each scenario, answers, and information participants marked as important.

Lastly, after finishing the second scenario, participants filled in Questionnaire 1. Participants suggested improvements to The Dilemma Game's learning dashboard by thinking about how it could trigger their data awareness, self-reflections, understanding strategies, and chaining behavior.

Phase 2: First, the researcher organized and reviewed answers to Questionnaire 1 from the participants. As explained in 2.4, Questionnaire 1 asked open questions to not bias participants with their critical thinking experience. Therefore, to analyze data, the researcher needed to organize the transcripts and highlight the keywords from each answer. The researcher then compared the keywords from participants under each question and highlighted repeat keywords. Section 2.6. specifically explains the keyword screening method.

After summarizing the keywords, the researcher designed the learning dashboard based on participants' feedback and illustrated the design using the Canva design tool. Third, Participant C applied her design knowledge and experience in The Dilemma Game and assisted the researcher in refining the design learning dashboard. Lastly, the researcher checked and finalized the design learning dashboard and prepared it for Phase 3: Evaluation and Reflection.

Phase 3: In phase 3, the researcher used Questionnaire 2 to ask external experts open questions to compare the original dashboard and the design learning dashboard. The external experts also gave their suggestions for further design improvements. First, the researcher's first supervisor helped to contact two potential end-users of The Dilemma Game. These two external experts also had experienced The Dilemma Game with its original learning dashboard, which added practical value to evaluating the design learning dashboard.

Second, the researcher had two data collection sessions with participants separately via Microsoft Teams. Each session took 45 minutes. To begin with the sessions, the researcher introduced the research purpose and relevant concepts to the participant. Then, the participants compared the design learning dashboard to the original learning dashboard. Based on the learning analytical model by Verbert et al. (2013), both participants compared and evaluated the design regarding its improvements in triggering functions of awareness, self-reflection, sense-

making, and impact. Furthermore, the participants also shared their insights on improving the design learning dashboard from their work experience in decision-making.

2.6. Data Analysis

A thematic data analysis method was adopted (Bryan, 2016) to analyze to what degree The Dilemma Game's original learning dashboard corresponded to The Learning Analytics Model by Verbert et al. (2013). In order to identify the levels of critical thinking in the learning dashboard, the researcher selected awareness, self-reflection, sense-making, and impact as analysis themes.

Phase 1: Specifically, the researcher categorized the questionnaire answers based on tiers of awareness, self-reflection, sense-making, and impact in Phase 1 to measure critical thinking levels of The Dilemma Game's learning dashboard. As mentioned in section 2.4, the researcher summarized participants' answers into keywords. Then, the researcher compared and counted the keyword through the responses. A keyword would be included as a result of suggestion if:

1. The keyword appeared in more than half of the total (six) participants.
2. The keyword was repeated by the same participant in different questions.

Phase 3: Like the data analysis in Phase 1, the researcher first summarized the answers from external participants under each tier of questions. Then, the researcher counted each keyword's frequencies answered by the same external participant or answered under each tier. That was because the repeated keyword could be included in the results. Specifically, a keyword would be included as a result of suggestion if:

1. Both external experts mentioned the keyword.
2. The same external expert repeated the keyword in different questions.

3. Results

3.1. Phase 1

3.1.1. Awareness

Results: First, five out of six participants first noticed their "information marked as important" because that marked information directly influenced their decision-making. Second, three out of six participants were more aware of the "time spent in each scenario," as they believed it indicated some scenarios were more complex to analyze. Third, five out of six participants also realized other players' in-game behavior. That is because they tended to consider other players' decisions: "I did compare with others. I believe making decisions with the bigger population is better." Participant C. Fourth, all six participants perceived the reading information section. However, they did not comprehend it before the researcher's clarification.

Lastly, three out of six participants did not agree with the usefulness of reading information because it accumulated the reading times from all dilemmas. Participant D states, "it does not show how I agree with them."

Suggestions: First, participant B repeated three times to suggest the dashboard reminding the learning goals. In the original learning dashboard, there were no learning goals or goal-reminding. The lack of learning goals and its reminding could be confusing for learners. That was because learners need to be reminded why the learning dashboard displays certain information and the purposes behind this information. "The dashboard should remind you of the goals and add on every decision you made," suggested participant B, an experienced DGBL designer. However, the learning-specific learning or gaming objectives were missing in the original learning dashboard. The lack of specific learning objectives could be more confusing for learners to be aware of why the learning dashboard displays certain information and the reasons behind them.

Second, three out of six participants suggested improving the information visualization of The Dilemma Game's original learning dashboard. In the answers section of The Dilemma Game's original learning dashboard, numbers of "yes" or "no" were displayed, which might cause extra processing for learners. "Show how much percentage of people said 'yes,' how much percentage people said 'no,' that would be more comprehensive than giving several people who

said ‘yes or no.’” As advised by Participated B, who studied Industrial Design at the University of Twente.

3.1.2. Self-reflection

Results: The original learning dashboard triggered their self-reflections regarding decision-making strategies and in-game behaviors for five out of six participants. “Yes, I did reflect on my strategies and in-game behaviors. I realized that I counted the advice and took my values into account. I did not care much about the public image as a mayor.” Answered by Participant F, a master’s student of Industrial Engineering and Management from the University of Twente. However, one experienced DGBL designer participant shared the opposite opinion: “It does not help me to reflect on my behaviors because it is not a well-designed dashboard or game. I felt unmotivated by playing the game.”

One participant also believed the original learning dashboard lacked some data exploration. “The current dashboard is quite neutral, and it would be better to tell me how well I perform. Then I will reflect on what went wrong, what went well.” Answered by Participant D, a researcher in the Psychology Department at the University of Twente.

Suggestions: First, like the suggestion in Awareness, participant B repeatedly suggested reminding learners to align with their goals. In the original learning dashboard, goal setting, as well as goal reminding, were missing. Thus, learners might not be fully reflected on their current decision-making skills. Moreover, the learning dashboard could suggest to learners on “what to reflect on,” such as “did you count every aspect of advice?”, “What did you prioritize in decision-making as mayor?”, “Did you tend to make decisions based on your intuition or advice?”.

Second, three out of six participants suggested that the dashboard needed to highlight data exploration. As presented in the results section of sense-making, some specific information would trigger a participant to ask questions and self-reflect. In the original learning dashboard, only time-spending on each scenario applies visual data exploration but not other data, which might not help learners perceive their performance.

3.1.3. Sense-making

Results: Five out of six of the participants responded that the original learning dashboard did not greatly influence them in sense-making. Only Participant A said that he assumed that he had gained sense-making: "There are two factors that affect my final decisions the most: economical and citizen's essential needs. The best solution should be in the precondition of not causing massive damage to their basic needs to gain the most benefits. But to be honest, I am not sure." The ineffectiveness of sense-making promotion might also stem from the lack of goal-reminding or personalized feedback of the original learning dashboard. As Participant B explained: "It (the original learning dashboard) just counted messages. It did not make sense because it was over-simplified. It did not have a goal or tell me what my decisions mean."

Suggestions: According to five out of six participants, it is suggested that the original learning dashboard could include personalized feedback to enhance learners' sense-making in decision-making. Participant F agreed and suggested including: "Personalized feedback. For example, your decisions show your style of leadership and your concerns. Probably also suggests where to improve." Similarly, Participant A suggested including the reasoning of his decisions as thematic and personalized feedback. "(The learning dashboard should include) The reasoning for my decisions. It needs to be personalized, tells me what my decisions imply of myself: for example, it is based on moral standards or economic development."

3.1.4. Impact

Results: Three out of six participants believed that the original learning dashboard's feedback impacted their decision-making strategies from more intuition-based to advice-based. According to participant A, "Before reviewing my data, I normally just looked at the topic itself, and after, I already had a decision in my mind, and the advice could not affect me that much. After reviewing the feedback, I tried to think about the topic more objectively." On the other hand, one participant changed to less "advice-based" decision-making strategies. "In the first scenario, I made my decisions based on advisors' opinions. I anticipated a decision in the second half and then checked their opinions. I considered their advice and saw if I would change my mind or remain the same." However, Participant B and Participant C believed that the original learning dashboard did not impact their decision-making strategies or in-game behaviors.

Suggestions: Although participants experienced differences from the original learning dashboard regarding making impacts on their decision-making, their suggestions for improvements were surprisingly similar. All six participants suggested the original learning dashboard provide personalized feedback with explanations. Second, giving instructions or hints to learners on how to improve decision-making could be beneficial. As Participant D answered, "Receive personalized feedback. For example, based on my performance, what tendencies do I have while making decisions? Based on which kind of cues I tend to make decisions. Then tell me how to improve based on my feedback. Only presenting information might not let people understand." Third, Participant B repeated the importance of goal-reminding for the third time: "Again, remind goals. Explain their results according to goals. Give instructions on what people should do in real life."

3.2. Phase 2

Based on the results and suggestions from participants and literature, the researcher designed a learning dashboard for The Dilemma Game. As, Table 1 lists the design learning dashboard highlighted the following new features:

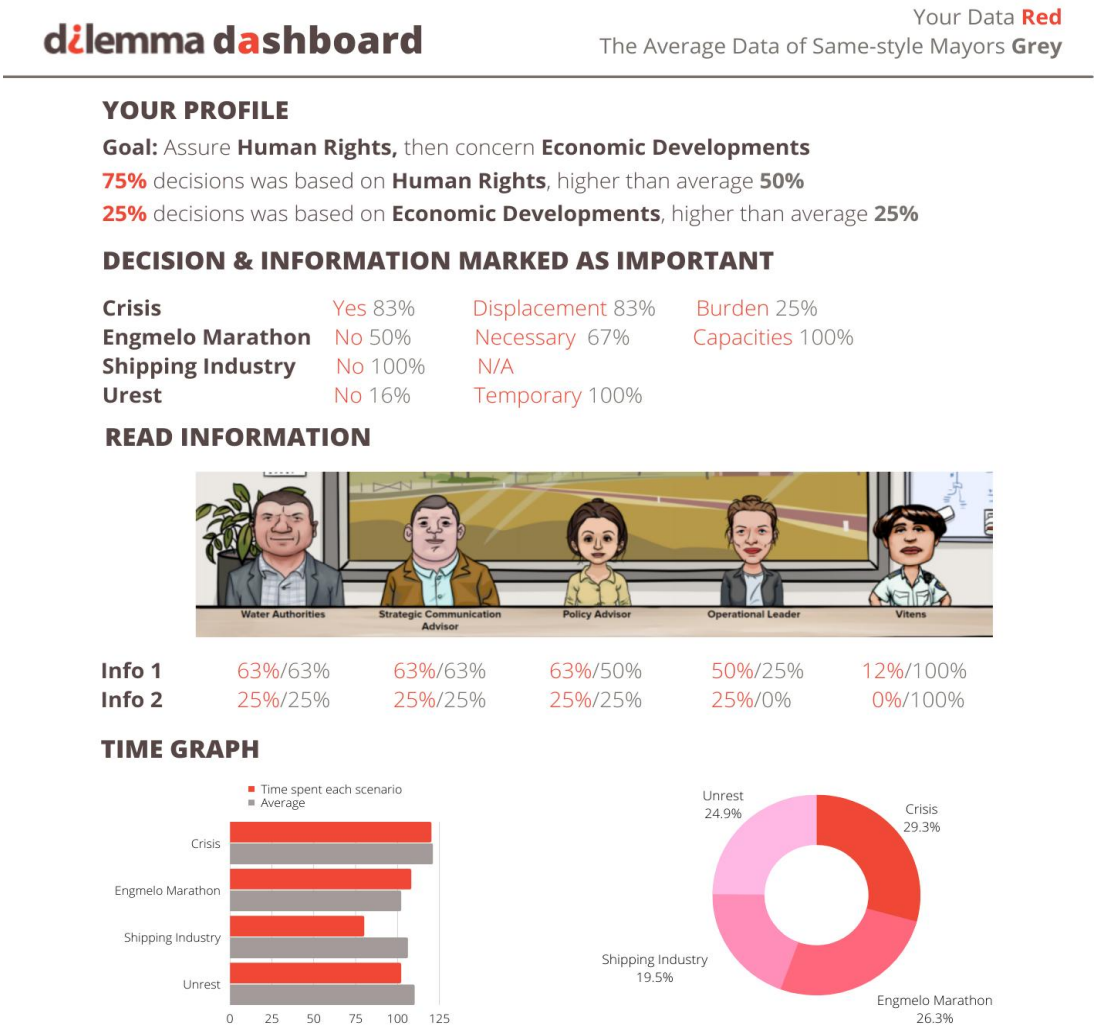
Table 1

Features of the Design Learning Dashboard

Features of the design learning dashboard
• Give personalized feedback by categorizing advises based on the themes of Economic Development of Engmelo, Essential Needs of Citizens, Public Image of the Mayor. • Ask learners to set a decision-making goal by prioritizing the themes. • Provide feedback on how well learners match their decisions with the learning goals. • Indicate the strengths and weaknesses of their decisions styles. • Give suggestions on how to improve their decision skills in real crisis situations. • Improved data visualization. • Figure 5 indicates the design learning dashboard of this research. This design learning dashboard was also used to collect external experts' feedback in Phase 3.

Figure 5

The design learning dashboard



3.3. Phase 3

This section presented the summarized keywords to Questionnaire 2 from two external experts. The results were presented based on the four tiers of critical thinking: awareness, self-reflection, sense-making, and impact.

3.3.1. Awareness

Results: In general, both external experts shared positive opinions on the awareness functions of the design learning dashboard. They believe the design learning dashboard contributed for two reasons: The more specific information and suggestions on behavior improvements. Participant G and Participant H stated that the ordinal learning dashboard was informative but should work on its readability. Therefore, it was not optimal for awareness facilitation. They wished the original learning dashboard had more explanation of their in-game information to help learners comprehend what the data means to them without too much effort. "I find it hard to figure out personalized performance. There were lots of numbers. I have to read very carefully. That is the wrong way. The dashboard needs to be clear and reader-friendly." Answered Participant H. The design learning dashboard, they find, could help learners better understand their performance and in-game behaviors. Participant shared his thoughts: "The specific information and explanations help me see what I am doing, how I can do better. It can trigger critical feedback for me".

Suggestions: Generally, the design dashboard could generate learner data awareness. However, participants also shared some concerns and suggestions. The first concern is regarding color indication: Red color indicates players' data, and gray color indicates average data. Although the red and gray color fits the logo of "The Dilemma Game," participant G thought using red to indicate a player's information might be confusing because he assumes that red color usually means mistakes.

On the contrary, Participant C, who has a design background, believed the red color could highlight players' data and therefore generate stimulation, which was aligned with a psychology study on color effects: warm colors such as red and orange could be stimulating in feedback among college students (Kaya & Epps, 2004). However, Participant G, as a senior

external expert, is prone to experience associating the red color with negative implications. Mammarella et al. (2016) studied the influence of color on seniors' memories and emotions and confirmed that the red color could easily trigger a negative impact among seniors.

3.3.2. Self-reflection

Results: According to the participants, the design learning dashboard made quite some improvement in terms of fostering self-reflection. Participant H believed the original learning dashboard did not help him self-reflect because he could not grasp his behavior analysis through the information. He answered: "No. It (the original learning dashboard) does not trigger me to have self-reflection. What did I do? Scenarios are more prominent than decision-making. This should indicate more about a learner's decision-making skills."

On the contrary, Participant H thought the design learning dashboard could make him self-reflective: "It is more clear about what I do compare to others." Participant G shared his opinions on self-reflection: "I am curious about the reasons behind the data. That made me ask questions about my way of playing and how the data get."

Suggestions: The feedback could be personalized based on players' prior knowledge of critical thinking or decision-making for further design learning dashboard improvement. The design learning dashboard indicated the information with comparison but judgment, and it also summarized players' decision-making styles and gave personalized conclusions. Participant H believed that judgment of performance might be beneficial: "It could add further information on judgments (good, bad, neutral) because I think judgment can trigger reflection for decision-making."

3.3.3. Sense-making

Results: The results indicate that explanations of in-game behavior or learning performance have improved to guide learners to answer the questions from self-reflection. Participant G provided this example: " In the Information Marked as Important Session, the N/A stood out. I was curious about it. I saw the explanation on the profile. Then I realized it might be because of bias." Participant H also confirmed the effectiveness of information explanations, who believed the original learning dashboard could not trigger his sense-making: "With the

explanation, it (the design learning dashboard) can help with sense-making. The dashboard needs some explanation to create critical feedback."

Suggestions: Despite personalized feedback and suggestions, Participant H suggested further improving the design learning dashboard from his work experience in decision-making responding to crisis events: "They could be further improved with referencing to related crisis decisions and effects, and the design learning dashboard could also include the worst scenario for each dilemma. This is because of our decision-making procedure: our group must react to a crisis within half an hour and consider the worst scenario and its lasting time. Also, we reference similar events to our decisions. But this could require changes in the game, not only for the dashboard." The Dilemma Game simulated crisis scenarios to let learners make decisions based on opposed advice. Therefore, process feedback on lasting effects and references on learning dashboards could facilitate learners' sense-making, particularly for potential learners familiar with real-life decision-making procedures.

3.3.4. Impact

Results: Both participants believe the design learning dashboard could impact changing learners' in-game behaviors and strategies. Indeed, the impact is more likely to happen after the generation of data awareness, self-reflection, and sense-making. According to the Learning Analytic Model, the effect is the fourth tier of critical thinking (Verbert et al., 2013). Furthermore, both participants stressed the importance of personalized feedback because they believe it could lead to behavior-changing: "Yes, personalized data. I reflected and followed the suggestions. Then I could try something new in the new game" Participant G shared his opinions. Besides, Participant H, who did not believe in the original dashboard, also confirmed the importance of suggestions for impacting learners: "There are clear feedback and suggestions, it can help to make an impact on my behaviors and ways of making decisions. I will focus on the feedback and suggestions."

Suggestions: Participant H believed that learners would benefit from the impact of the dashboard could provide emphasis on self-reflection to learners. Even though participants were optimistic about the impact facilitation of the design learning dashboard, they shared inputs on future design. Participant H believed that some learners tended to ignore the importance of

writing down self-reflection and therefore overlooked this section, which might have less impact on improving in-game behaviors. “People are not taking reflections seriously. The dashboard should be mandatory and create something to push players to reflect.” To cope with these potential problems, Participant H also proposed a solution: “When a player plays the game again, the game could start with this player’s self-reflection from last time.” Besides, he also emphasized the meaningfulness of optimizing real-life transition: “Make the game part of your work portfolio.

4. Conclusion & Discussion

4.1. Concluding Notes

In conclusion, this study aimed to investigate how to trigger critical thinking to improve decision-making by designing a learning dashboard in a DGBL environment. For an effective critical thinking fostering game, the learning dashboard in this game is recommended to consider the following factors:

4.1.1. Awareness

First, the learning dashboard is recommended to remind learners of their learning goals for data awareness promotion. According to research (Few, 2013), a dashboard is supposed to remind players of the specific learning goals of The Dilemma Game. Few (2013) studied learning dashboards based on theoretical foundations and practical experiments. They proposed the designing principles of learning dashboards: "Dashboards display the information needed to achieve specific objectives." According to Yoo et al. (2015), awareness in learning dashboards can be understood as knowing what information is vital for a particular goal." Therefore, awareness of learning dashboards should be the outcome of perceiving and comprehending gaming performance and analyzing this information. In other words, learners are supposed to understand the purpose and relevance of the information provided in a dashboard.

Second, a dashboard is recommended to increase readability to foster information awareness. According to Few's (2013) design principles: "Dashboards are visual displays, and dashboards are used to monitor information at a glance." Learners have limited working memories, and a learning dashboard should foster players' awareness and promote rapid information comprehension. To help learners comprehend information rapidly, graphic patterns, rather than individual numbers, are more efficient for rapid comprehension and memory retention (Yoo et al., 2015). As a consequence, higher readability help learners comprehend the gaming data they receive, which creates a foundation to evaluate the information they use to make decisions.

4.1.2. Self-reflection

First, goal-reminding can also effectively trigger self-reflection for learners in a dashboard. Matsuo et al. (2020) confirmed that coaching positively correlates with critical reflection in line with learning goals. That is because being in line with learning goals could remind learners "what they want to achieve," "where they are," and "are they in the right direction?" through critical thinking. Similarly, in the DGBL case, being in line with the goal in the learning dashboard could help learners understand their current decision-making skills and the gap between their learning goals. Therefore, learners could reflect on the information they use to make decisions and re-evaluate its reliability.

Second, a dashboard is recommended to include data exploration to facilitate self-reflection. According to research (Chloe et al., 2017), data exploration, such as peaks or trends, can effectively trigger learners to ask themselves questions and to recall their behaviors because they are eager to understand which information has made them achieve these unusual numbers or patterns. Also, learners could ask themselves if the information sources are trustworthy since the information leads to such data explorations.

Third, a dashboard can include personalized feedback to trigger learners' self-reflection. However, limited feedback could have different effects based on learners' prior knowledge levels: corrective feedback could hinder experienced learners but guide novice learners, and vice versa (Fyfe & Rittle-Johnson, 2016). Therefore, giving personalized feedback could be optimal based on players' content knowledge, such as critical thinking and decision-making.

4.1.3. Sense-making

First, personalized feedback could also help learners to gain sense-making from a dashboard. ". Research (Lim et al., 2020) confirmed that learning analytic-based personalized feedback could help learners with their self-regulated learning processes. Specifically, personalized feedback presents learners' data in themes and indicates their strengths and weakness. Thus, learners could make sense of their strategies and behaviors based on their styles, then re-consider their information sources.

Second, a dashboard could also increase its relevance to real work events to promote sense-making to learners. Although it might require a re-design of the digital learning game but not only the dashboard, but processing life-based events significantly influences learning

performance during simulation-related training (Astwood et al., 2008). That is because learners tend to reference work experience to the gaming-contents. Therefore, when the digital game learning is closely related to their working experience, they could easier comprehend the gaming information and select the more related information.

4.1.4. Impact

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4.2. Reflection on Outcomes

Feedback from end-users is vital for acquiring further development insights, although it has been stressed that the values of this feedback vary (Stade et al., 2017), as they might deviate from the research’s evidence or design values. In this study, outcomes from end-users confirmed the improvements of the design learning dashboard and added insights on the real-life transition. However, end-users constructive feedback did not always reflect standard views expressed by researchers:

First, the end-user outcomes focused on information elaboration. Both end-users suggested more detailed implications on in-game behaviors and information interpretation. However, research guided that a learning dashboard should not extend one page because "information should be read by a glance" (Verbert et al., 2013). The purpose of the learning

dashboard application in DGBL environments also supports self-regulated learning, which might be limited by extensive instruction or interpretation.

Second, the end-users outcome involved the re-development of The Dilemma Game, not only refining its learning dashboard. For example, Participant H believed the game and its learning dashboard should display data on critical thinking skills instead of scenario results. However, the re-development of The Dilemma Game was out of the scope of this study, although it might potentially facilitate critical thinking for learners.

The different perceptions between end users and literature might stem from various factors, such as an end user's cognitive style, professional background, and even gender might lead to perception differences in feedback (Juvina & Herder, 2017).

4.3. Limitations

Phase 1. As hinted in the previous sections, this study has limitations regarding the unexpected discontinuation of The Dilemma Game. Due to the unexpected discontinuation of The Dilemma Game, a learning dashboard could not be automatically generated for participants in Phase 1. The researcher manually developed learning dashboard based on participants' in-game behaviors to cope with this issue. However, the researcher could not generate personalized information on the Read Information section of the learning dashboard because it required counting a participant's advise-clicking times on each advisor per scenario, which was not manually feasible. Although participants shared their opinions on the Read Information section, it could be optimal if they could reflect on their Read Information data for more accurate results.

Phase 2. In Phase 2, restrictions regarding discontinuation and programming constrictions, the design learning dashboard could not be implemented and applied to The Dilemma Game. To cope, the researcher used a digital designing tool to illustrate the design learning dashboard outline based on results from Phase 1. However, whether the design learning dashboard could be fully achieved and implemented was unclear.

Phase 3. In the last Phase, as a consequence of Phase 1 and 2, participants could not assess design learning dashboard based on their personalized data by playing The Dilemma Game. Instead, they evaluated the original learning dashboard and the design learning dashboard by comparing the samples. Observing sample data could differ from reviewing personalized data after gaming was another limitation of this study.

4.4. Future Recommendations

As discussed in the previous section, this study's limitations might hinder the conclusions' accuracy. Therefore, future research could focus on evaluating the outcomes by implementing the design learning dashboard and assessing the critical thinking facilitation with learners. Based on the evaluation results, researchers could continue the iterative design-based research process by further improving a learning dashboard for The Dilemma Game. For more accurate research outcomes, future research is suggested to re-develop the game and allow prospective participants to receive their personalized in-game data in a digital learning dashboard format.

This study aimed to narrow the research gap between critical thinking and decision-making in DGBL environments. To further close this research gap, future research could design a learning dashboard in other themes of DGBL but crisis management. Besides, future research could investigate other feedback tools, such as coaches, but learning dashboards to evaluate critical thinking outcomes.

Moreover, as this study's results suggested, there was a gap between learning in DGBL and real-life skill transition. Thus, future research could investigate how to apply DGBL outcomes to real-life decision-making skills.

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Appendices

Appendix A: Questionnaire 1

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of data did you keep in mind while playing the second scenario?
2. Do you have any suggestions for improving the dashboard's data presentation to improve players' awareness? If yes, please specify with reasons.

Reflection:

3. Based on the data in the dashboard, could you reflect on your in-game behavior in future scenarios? (e.g., What did I do? How did I make decisions in the first scenario?) If yes, please specify.
4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior and decision-making strategies? If yes, please specify with reasons.

Sense-making:

5. According to the learning dashboard data, do you think you could be inspired and generate any new insight on your way to solving problems in the second scenario? If yes, please describe.

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making in problem-solving for learners? If yes, please describe with reasons.

Impact:

7. Could you potentially change your in-game behaviors for decision-making in future scenarios after viewing your data on the dashboard? If yes, please specify.
8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix B: Questionnaire 2

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please answer the following questions to evaluate this research's design learning dashboard outlines.

Awareness:

1. What do you think of the dashboard's information presentation of the current learning dashboard? Do you think it is well-designed to present players' data?
2. Do you think the design learning dashboard can potentially help players to be better aware of their data? Please justify with reasons.

Reflection:

3. To what extent do you think the current learning dashboard can trigger players' self-reflection on their in-game behavior or decision-making?
4. Do you think the design learning dashboard can potentially trigger players' reflection on their in-game behavior? Please justify with reasons.

Sense-making:

5. To what extent do you think the current dashboard can help players understand interpreting data and changing their in-game strategies?
6. Do you think the design learning dashboard can potentially promote players' sense-making on their in-game behavior and update their game strategies? Please elaborate on the reasons.

Impact:

7. To what extent do you think players can benefit from their decision-making on scenario two from critically thinking on the current learning dashboard?

8. Do you think the design learning dashboard can potentially enhance players' decision-making by triggering their awareness, reflection, and sense-making? Please specify with reasons.

Overall, what do you think of this research's design learning dashboard in promoting players' critical thinking? Do you have any suggestions for improvement?

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix C: Stimulated Learning Dashboard of The Dilemma Game

On this site, you can compare your own gameplay behavior until now with the gameplay behavior of other players. We ask you to write a couple of sentences at the bottom of this site where you explain why you played the game the way you did. Try to compare your own gameplay behavior with the gameplay behavior of other players.

Answers

Crisis /Yes

Engmelo Marathon /No

Shipping industry /No

Unrest /Yes

Total:

Yes /2

No /2

Read Information:

Time graph (A pie chart will be displayed after data collection of the first scenario)

Total time: Below, the time used for each dilemma is displayed:

Introduction:

Crisis:

Engmelo Marathon:

Shipping industry:

Unrest:

Your average time per dilemma/ Reference average time per dilemma

Messages you marked as important:

Crisis

Engmelo Marathon

Shipping industry

Unrest

Write your self-reflection here. Try to describe why you played the game the way you did. Also, try to compare your own behavior with the behavior of others.

Appendix D: Participants

Table 2

Participants in Phase 1

	Gender	Age	Nationality	Study	Occupation
Participant A	Male	21	Chinese	BSc Industrial Design Engineering, University of Twente	Student
Participant B	Male	45	Dutch	(Part-time) MSc Educational Science and Technology, University of Twente	Student; GBL Designer
Participant C	Female	23	Dutch	MSc Educational Science and Technology, University of Twente	Student
Participant D	Female	24	Lithuanian	MSc Psychology, University of Twente	Researcher at Psychology Department, University of

					Twente
Participant E	Female	28	Aruban	MSc Educational Science and Technology, University of Twente	Student; Research Assistant at BMS Lab, University of Twente
Participant F	Male	29	Dutch	MSc Industrial Engineering and Management	Student

Table 3

Participants in Phase 3

	Gender	Nationality	Occupation
Participant G	Male	Dutch	Learning Ability Specialist and Chief Duty Officer at the Brandweer Twente
Participant H	Male	Dutch	Team leader Knowledge at the Brandweer Twente

Appendix E1: Questionnaire 1 Answered by Participant A

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of data were you aware of?

Information I marked as important, time spent in each scenario.

5. Do you have any suggestions for improving the dashboard's data presentation to help players be aware of the data? If yes, please specify with reasons.

Categorize the information, Count time for every category, and summarize.
" Safeness, Capacity, Citizen" (information literacy), suggestion on which is the most important for making decisions.

Reflection:

6. Based on the data in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

I realized that I went through all the conversations first by order and read again to gain some extra impression and then picked the most important information to see what impact could be made for my final decision.

7. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

Same with the first one.

Sense-making:

8. According to the learning dashboard data, do you think you could be inspired and generate any new insight on your way to solving problems in the scenario "Drought"? If yes, please describe.

I guess. There are two factors that affect my final decisions the most, which are economic effect and citizens' essential needs. The best solution should be in a precondition of not causing massive damage to their basic needs s to gain the most benefits. But to be honest, I am not sure.

9. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

More specific statistics to time-spending on each kind of advice (economic, human rights, citizen's essential needs) per dilemma.

Impact:

10. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

Before reviewing my data, I normally just took a look at the topic itself, and after I already had a decision in my mind and the advice couldn't really affect me that much. After reviewing the feedback, I tried to think about the topic more objectively.

11. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Interpret information with hints. Mark which are more important ones to focus on between dilemmas.

Appendix E2: Questionnaire 1 Answered by Participant B

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of data were you aware of?

Time does not appear to be important for me. There seemed to be a "right or wrong" answer.
Marked important information

2. Do you have any suggestions for improving the dashboard's data presentation to help players be aware of the data? If yes, please specify with reasons.

First of all, the basic set of goals. The dashboard should remind you of the goals and add to every decision you make. It only shows your data without an explanation.
Differentiate the dashboard based on stakeholders (needs)
Result of the decision once made. It should say how good or bad the decisions are and also specify the reasons.

Reflection:

3. Based on the data in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

It does not help me to reflect on my behaviors because it is not a well-designed dashboard or game. I felt unmotivated by playing the game.

4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

Again, remind me of my goals and tell me where I am.
Give tips on what to reflect on.
Also, advise people what to do. That is why people need a coach.

Sense-making:

5. According to the learning dashboard data, do you think you could be inspired and generate any new insight on your way to solving problems in the second scenario? If yes, please describe.

It just counted messages. It did not make sense because it was over-simplified.

It did not have a goal or tell me what my decisions meant.

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

Make actual goals; tell people what to do, and give tips.

Impact:

7. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

It deepens my fundamental beliefs that people who design these kinds of games are unpredictably wrong. It did not make an impact.

8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Again, remind goals,

Explain their results according to goals.

Give instructions on what people should do ***in real life***

Appendix E3: Questionnaire 1 Answered by Participant C

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of information were you aware of?

Time but I did not care much about it. I did compare with others. I believe making decisions with a bigger population is better. I did not care about marking important information.

2. Do you have any suggestions for improving the dashboard's data presentation to help players be aware of the data? If yes, please specify with reasons.

Show how much percentage of people say "yes," and how many percent of people say "no" that would be more comprehensive than giving a number of people who said "yes or no."

Also, make reading information clear with "bigger text and pictures."

Reflection:

3. Based on the data in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

I realized that I did not find the advice very insightful or detailed. I read them and try to make sense out of them, also combined with common sense and intuition.

4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

More specific in-game indicator-related time. For example, show time-spending on different argument sights instead of only checking time-spending on a dilemma.

Sense-making:

5. According to the learning dashboard data, do you think you were inspired and generated any new insight on your way to solving problems in the second scenario? If yes, please describe.

Honestly, not really. It was nice to see that my opinions were similar compared to the others, but it will not influence me that much. Time or marking important messages does not really influence me.

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

Relate Time-spending with types of arguments.

Impact:

7. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

No.

8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

To show what effects those decisions have in real life.；Instructions on how to do it and how to analyze it. Personally, I would show the pros and cons of dashboards；Give suggestions on how to make a better decision under the game's scenarios.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix E4: Questionnaire 1 Answered by Participant D

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of information were you aware of?

Others' answers of yes or no, how much time I spent on each task, and how many answers I marked as important. not the read information because it does not show how I agree with the

2. Do you have any suggestions for improving the dashboard's data presentation to help players be aware of the data? If yes, please specify with reasons.

With whom I agree the most and whose answers I marked the most.

Reflection:

3. Based on the data in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

Yes, I reflected a bit. The difficult dilemmas took longer, and I marked more information as important.

4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

Make it a table, show answers per scenario, whether marked important.

Add outcome, show result.

The current dashboard is also quite neutral, and it would be better to tell me how well you perform. Then I will reflect on what went wrong and what went well.

Sense-making:

5. According to the learning dashboard data, do you think you were inspired and generated any new insight on your way to solving problems in the second scenario? If yes, please describe.

I think it did inspire me. It helped me to change my strategies. I tried to consider more opinions, even for the ones that were simple. I tried to spend an equal amount of time on each dilemma.

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

Present data based on per advisor also shows whether a decision is optimal or not.

It could help if there are some tips. For example, in the drought scenario, tips can be given regarding the importance of fire departments. Also, when someone does not mark any information as important, it would be nice to receive tips on doing so.

Impact:

7. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

Getting feedback midway did impact my in-game behavior. In real life, it does remind me to consider all-around opinions and choose to pay more attention to important opinions. I marked more information as important.

8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Receive personalized feedback. For example, based on my performance, what tendency do I have while making decisions. Based on which kind of cues I tend to make decisions. Then tell me how to improve based on my personal feedback.

Only presenting information might not let people understand.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix E5: Questionnaire 1 Answered by Participant E

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of information were you aware of?

How long do you take per dilemma, and what types of answers do I give. Information I marked as important

2. Do you have any suggestions for improving the dashboard's information presentation to help players be aware of the data? If yes, please specify with reasons.

The reasoning for my decision. It needs to be personalized. It tells me what my decisions imply about myself: for example, it is based on moral standards or economic development.

Reflection

3. Based on the information in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

After playing it more, I was better able to understand what information would be coming to me from the people, and thus instead of sorting out opinions, I was quicker at processing the information and choosing how I was going to vote.

4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

Same as the one in awareness.

Sense-making:

5. According to the learning dashboard data, do you think you were inspired and generated any new insight on your way to solving problems in the second scenario? If yes, please describe.

No

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

First of all, based on personal feedback, then gives a reflection on agreeableness per advisor, per dilemma, and in total.

Impact:

7. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

Yes. In the first scenario, I made my decisions based on my advisors' opinions. In the second half, I anticipated a decision, then checked their opinions. I took their advice into consideration and saw if I would change my mind or remain the same.

8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Same as the suggestions above: Personalized decisions. I do not see the need to compare with others. Maybe also give improvement suggestions with reasoning.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix E6: Questionnaire 1 Answered by Participant F

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please complete The Dilemma Game and answer the following questions:

Awareness:

1. After checking the learning dashboard, which kind of information were you aware of?

Rating the importance of advice.

Reflection on my strategies and in-game behaviors

2. Do you have any suggestions for improving the dashboard's information presentation to help players be aware of the data? If yes, please specify with reasons.

Maybe rate the statements the advisors gave. Sometimes the advisors/advice is not very important.

For example, the last dilemma festival. The police officer told me it is illegal to cancel this event. In this case, it won't make sense to cancel.

Reflection:

3. Based on the information in the dashboard, could you reflect on your in-game behavior in the first scenario? (e.g., What did I do? How did I solve a certain problem in the game?) If yes, please specify.

Yes, I did reflect on my strategies and in-game behaviors. I realized that I counted the advice and took my own values into account. I did not care much about the public image as a mayor.

4. Do you have any suggestions to improve the current dashboard, to trigger players' reflection on their in-game behavior? If yes, please specify with reasons.

Personalized feedback. For example, your decisions show your style of leadership and your mighty concerns. Probably also suggests where to improve.

Sense-making:

5. According to the learning dashboard data, do you think you were inspired and generated any new insight on your way to solving problems in the second scenario? If yes, please describe.

No

6. Do you have any suggestions to improve the current dashboard, to foster better sense-making on problem-solving for learners? If yes, please describe with reasons.

No

Impact:

7. Did you change your in-game behaviors for decision-making in the second scenario after viewing your data on the dashboard. If yes, please specify.

I was more assertive with my own reasoning.

8. Do you have any suggestions to improve the current dashboard for triggering players' positive behavior changes?

Personalized feedback. For example, your decisions show your style of leadership and your mighty concerns. Probably also suggests where to improve.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix F1: Questionnaire 2 Answered by Participant G

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please answer the following questions to evaluate this research's design learning dashboard outlines.

Awareness:

1. What do you think of the dashboard's information presentation of the current learning dashboard? Do you think it is well-designed to present players' data?

Yes and no. There are lots of information, it needs more explanations.

2. Do you think the design learning dashboard can help players be better aware of their data? Please justify with reasons.

Yes, I like it. After playing it your way, you get the feedback with suggestions. But it requires specific prior knowledge. Color

Red might let me think they are mistakes.

Reflection:

3. To what extent can the current learning dashboard trigger players' self-reflection on their in-game behavior or decision-making?

It is suitable for this function. I am curious about the reasons behind the data. That made me ask questions about my way of playing also how the data get. When I get disappointed, I get triggered.

4. Do you think the design learning dashboard can potentially trigger players' reflection on their in-game behavior? Please justify with reasons.

For example, the viten 0% compared to 100%. I was triggered and asked myself what I did do so. The N/A, I realized it was because of personal experience, or bias.

Sense-making:

5. To what extent do you think the current dashboard can help players interpret data and change their in-game strategies?

Yes, but not that much information.

6. Do you think the design learning dashboard can potentially promote players' sense-making on their in-game behavior and update their game strategies? Please elaborate on the reasons.

I think yes. I try something different when I see something else that might be the reason. But it might be yes, but it might be no.

When I looked at more information, I focused on the read information.

They are a different—totally different experience.

Impact:

7. To what extent can players benefit from decision-making in scenario two from critically thinking on the current learning dashboard?

It was personal. The 1st time I did my best. The second time, I intended to do better. Then it does not matter.

8. Do you think the design learning dashboard can enhance players' decision-making by triggering their awareness, reflection, and sense-making? Please specify with reasons.

Yes, the suggestions and specific data. I reflected, and I did or tried something.

Overall, what do you think of this research's design learning dashboard in promoting players' critical thinking? Do you have any suggestions for improvement?

This one is 8/10, and the previous one is 6/10. The design learning dashboard made me curious. When it makes me curious, it is easy to trigger thinking.

Suggestions: only use small improvements. Do not make too much change.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.

Appendix F2: Questionnaire 2 Answered by Participant H

This research uses a learning analytics model, including awareness, reflection, sense-making, and impact (Verbert et al., 2013), to evaluate The Dilemma Games' learning dashboard. Please answer the following questions to evaluate this research's design learning dashboard outlines.

Awareness:

1. What do you think of the dashboard's information presentation of the original learning dashboard? Do you think it is well-designed to present players' data?

It is a lot of information. I cannot read what I did. I find it was hard to figure personalized performance—lots of numbers. I have to look carefully. That is the wrong way. The dashboard needs to be clear and reader-friendly. There was no trigger critical reflection for me.

2. Do you think the design learning dashboard can help players be better aware of their data? Please justify with reasons.

Yes, it is useful. It helped me see what I was doing and how I could do better. It can trigger critical feedback.

Maybe "an instructor+dashboard" can be better? An instructor can help understand the data and advise on how to understand the games.

I think it is important not to ignore the feedback in the dashboard.

Reflection:

3. To what extent can the original learning dashboard trigger players' self-reflection on their in-game behavior or decision-making?

No. It does not trigger me to have self-reflection. What did I do? It does not

Scenarios are more prominent than decision-making, in my opinion.

4. Do you think the design learning dashboard can potentially trigger players' reflection on their in-game behavior? Please justify with reasons.

Yes, because it is more clear about what I do compare to others.

Still, further information, add good, bad, and neutral. This could trigger decision-making.

Sense-making:

5. To what extent do you think the original dashboard can help players interpret data and change their in-game strategies?

No. Same as the old one.

6. Do you think the design learning dashboard can potentially promote players' sense-making on their in-game behavior and update their game strategies? Please elaborate on the reasons.

Yes. With the explanation. The dashboard needs some explanation to create critical feedback.

The scenario is too much, but not the competence of the mayor.

For example, providing it could provide the worst or the best scenario.

How many times real case scenario. Measure real-case scenarios.

Within a half-hour, team together. A decision makes in an hour. You have to create a worst-case scenario and make decisions based on that.

Also provide that how many times have the worst scenario lasted?

We look in history, what already happened in the Netherlands. (reference crisis). It is very important in decision-making.

It should be closer to real-life cases.

Impact:

7. To what extent can players benefit from decision-making in scenario two from critically thinking on the current learning dashboard?

No.

8. Do you think the design learning dashboard can enhance players' decision-making by triggering their awareness, reflection, and sense-making? Please specify with reasons.

There are straightforward suggestions it can help. I will focus on the tips.

Overall, what do you think of this research's design learning dashboard in promoting players' critical thinking? Do you have any suggestions for improvement?

Overall, it is interesting. I believe in a serious game approach, and I suggest focusing on competence rather than scenarios. But maybe it should create a new game: dashboard and instructor. Help understand the data and real-life skill transfer.

Time for reflection is not enough—the feedback part of the game. People are not taking reflections seriously. Finish with your feedback part. Push players to think about that. Create something where self-reflection is mandatory. Do you need to reflect on that immediately? Maybe I will have more critical feedback later? The second part, next time you play. Start with reflection. Make it a part of a portfolio. Transition it to real life.

Thank you for your time and valuable suggestions! Your personal information will remain confidential. Your response will only be used for this research analysis.