Serious simulation game development for energy transition education using integrated framework game design

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Abstract. Due to the advantages that serious simulation game offered, many areas of studies, including energy, have used serious simulation games as their instruments. However, serious simulation games in the field of energy transition still have few attentions. In this study, serious simulation game is developed and tested as the activity of public education about energy transition which is a conversion from oil to natural gas program. The aim of the game development is to create understanding and awareness about the importance of energy transition for society in accelerating the process of energy transition in Indonesia since 1987 the energy transition program has not achieved the conversion target yet due to the lack of education about energy transition for society. Developed as a digital serious simulation game following the framework of integrated game design, the Transergy game has been tested to 15 users and then analysed. The result of verification and validation of the game shows that Transergy gives significance to the users for understanding and triggering the needs of oil to natural gas conversion.

1. Introduction

Energy consumption in Indonesia tends to increase constantly on an average of 3.99% increase annually [1]. The transportation sector is the greatest energy consumer which specifically land transportation had the highest portion among other transportation modes. The increase of energy consumption in Indonesia is also led by the increase of vehicles volume. Annually, motorcycle volume is increased by 11%, 9% increase of passenger cars volume, and 8% increase of trucks and buses. This also happens especially in the capital city of Indonesia, Jakarta.

As the capital city of Indonesia, Jakarta has a total vehicles volume of 17,523,967 units by a proportion of 74.66% motorcycle and 18.64% passenger cars [2]. However, most of the vehicles are using oil as the fuel compared to natural gas and biodiesel. That the oil consumption is increasing annually yet the domestic production of oil decrease by 4.41% per year, lead Indonesia as the net importer of oil since 2013. The increase of oil import volumes created unpleasant impact for the economic sector and household consumption.

Thus, the government releases a conversion program from oil to natural gas for public transport and private cars. This program is related to the transition theory that transition could happen in every system scale in socio-technical point of view start from an atom, cell, individual, organization, sector, national even worldwide. Moreover, energy transition is one of transition type in scale system of sector [3].

Nevertheless, the implementation of conversion program has not achieved the desired target yet. The program that has been started since 1987 only gain 0.03% adoption rate of natural gas vehicles. The study from Bureau of Oil and Gas represents that one of the key factors that determines the success of conversion is socialization and education to the society [4]. The lack of socialization and education about energy transition to society hampers the implementation of conversion.
As the time being, the method of socialization and education is conducted in a more interesting way considering the needs of society. Thus, serious simulation game is a suitable approach as an instrument for energy transition education since it has been proven as an effective instrument [5]. The serious game has been widely used in any field of training, socialization, and education with significant impact [6]. There have been considerable studies about the serious game in term of energy education. However, only a few attentions have been paid for serious simulation game in energy transition, especially about conversion from oil to natural gas.

2. Literature Review

2.1. Energy transition
The word transition is defined by Shove and Walker (2007) as a substantial change and movement from one state to another state [7]. Chappin (2011) states that transition could happen in every system scale and energy transition is a transition on a scale of a sector. Transition often occurs in a complex system, thus, simulation is really helpful to give insight for accelerating transition process before intervening the real system itself. In his book entitled “Simulating Energy Transition”, Chappin mentioned that to conduct a simulation about transition energy, the simulation needs to represent the physical and social components of energy transition system. Physical components of the system, including infrastructure and equipment, whereas social component including the related actors of transition system like government, society, company and so on. One of the examples of energy transition is the conversion from oil to natural gas. Means that the use of oil as fuel in vehicles is substituted with natural gas to reduce the consumption of oil. This kind of energy transition happened in Indonesia since 1987 but has not met the desired target yet.

2.2. Conversion from oil to natural gas
Before doing the conversion from oil to natural gas, knowing about the type of natural gas used in the vehicle is important. Compressed Natural Gas or CNG is a type of natural gas that is stored in a state of gas by a compression of 200-250 bar pressure [8]. Moreover, in the Natural Gas Vehicle Module published by GTZ, there are two types of oil to natural gas conversion. The first type is a bi-fuel conversion that has a mechanism of using natural gas as the main fuel yet if the gas is running out the fuel system will be automatically changed to petroleum. On the other hand, the second type is dual fuel conversion. When the machine is idle, the petroleum is used until the machine warming up and inject the natural gas to the machine with the proportion of 80% natural gas and 20% petroleum.

Additionally, a converter kit is needed to do the conversion. It consists of CNG cylinder valve as the place to store CNG, injection valve, pressure regulator and ECU for CNG. In Indonesia, converter kit price ranged from 12-18 million Rupiahs. After doing the conversion, ones can refill the CNG in Gas Refueling Station or Mobile Refueling Unit.

2.3. Serious simulation games
Has begun to be known since 2002 along the launching of American Army games, serious simulation game nowadays has been implemented in many training, research education and other fields [6]. Serious simulation game itself is designed for transferring knowledge and strengthen skill, and changing social or individual behavior through persuasive technique and content [9]. Moreover, serious simulation game is not merely about entertainment purpose but more to delivering a learning purpose.

EnerCities, Energy Chicken, and ECOPET are the example of research about using serious simulation game for energy education. EnerCities concept is to encourage the player creating a sustainable city for a better energy management [10]. While Energy Chicken game is a real-time daily energy consumption of one’s device in office environment through the performance of animated chickens [11]. The aim of this game is to reduce the energy consumption at office environment. Slightly similar with Energy Chicken, ECOPET is a game that use pet avatar to encourage energy conservation at home and to engage the players in adoption appropriate energy conservation measures [5].

Serious simulation game application is increasing significantly due to the reason that it uses more action rather than the explanation that trigger the player motivation. On one hand, it also accommodates
many learning style and ability. Moreover, it could enhance the decision making and problem-solving skill [12].

2.4. Triadic game design
One of the approaches to creating a serious simulation, “Triadic Game Design” was introduced by Harteveld [13]. The idea of Triadic Game Design is to balance the element of reality, meaning and play in game. Through the element of reality, the game represents the condition of the real world. The game also addresses the problem that occurred to be simulated in the game environment. Furthermore, the element of meaning is pointing out about the purpose of the game.

Thus, this element is assuring that the game could contribute benefit and knowledge transfer to the player. Lastly, the element of play is that the game require to have the ‘playing’ sense itself. Although considered to be a serious game, interesting and attractive aspect should not be left behind.

3. Methodology
The methodology used to design the game is integrated framework game design [14]. Integrated framework game design is the fusion of action research and design research that consists of 4 stages:

- Stage 1: the problem formulation that addresses the research problem, theory or model conceptualization and game design concept.
- Stage 2: development and evaluation of the game including game activity structure, game activity synthesis, scenario design/mapping, visual construction, first phase game review and evaluation and the new game design.
- Stage 3: Reflection and Learning including simulation game, debriefing and participant’s evaluation.
- Stage 4: Formalization of Learning is the outcome generalization from the developed game.

![Figure 1. Integrated framework game design (Klapztein, 2016)](image_url)

This study covers all stages of integrated framework game design to ensure that the game meets all the requirement for energy transition education. Each step of the framework is conducted consecutively. The first until third stage of the game will be explained in methodology section and the fourth stage which mainly about the result of this study will be presented in the section of result and discussion.

3.1. Stage 1 – Problem Formulation
In the first stage, the research problem that has been pointed out in the introduction chapter is shaped as the background for game design. Prior to the designing the game, the purpose of the game should be defined first. Considering the module of Natural Gas Vehicle from MVV InoTec GmbH (2005) [8], the regulation from the government and the current condition of oil and gas in Indonesia, the learning purposes of the game are:

- To trigger the awareness about oil to natural gas conversion
- To know the elements of conducting conversion
- To consider the condition that can affect the decision of doing the conversion
- To understand the effect of fuel consumption to economic, social, health and environmental indicator

3.1.1. Game conceptualization and learning model. To address the need of game design about energy transition, a game concept is created. The game concept represents the big picture of game flow. It also represents the condition or state of using oil until doing the conversion and finally using gas as primary energy source. In addition, in game conceptualization there is explanation about oil to natural gas conversion that consists of the mechanism of doing the conversion, the component and the infrastructure. That later can be considered by the player to decide the desired condition of doing conversion.

Learning model of the game is designed based on the game model by Garris as shown in figure 3 [15]. According to Garris, there are three steps of learning model that are input, process, and output. The inputs from the game are the learning points that have been stated previously. Then, the process is a game cycle that consists of understanding the condition, deciding the options, and using the performance as reflection.

The process of the game is determined to be cyclic because each of the components is related to each other. The condition is becoming the consideration for the player to make a decision. Then, the decisions that have been made, will affect the indicator of economic, health, social and environment as the performance of the player. The output from the process is called the learning outcome. After doing the simulation process, the player is expected to have an awareness about oil to natural gas conversion. The player also expected to know and understand the mechanism of doing a conversion. Within consideration of condition and performance, the player is expected to configure a decision about doing the conversion. Besides, the player will be expected to develop his analysis and decision making skill from the performance to predict the next condition and think about what next decision to take.

3.1.2. Game development specification. The make sure that the content of the game is playable, the triadic game design is used as the guideline to make the game specification. The game specification is referred to the existence and balance of element reality, meaning and play [13]. For each element, there are some requirements that are listed. In the element of reality, the game requires representing the real condition using the real data about oil to natural gas conversion in Indonesia. In one hand, the element of meaning presents the existence of game purpose, game advantages, and motivation of playing the game. Then, to make the game playable, the element of play is addressing the game interface, challenge, and technology used to create the game.
3.2. Stage 2 – Development and Evaluation

3.2.1. Game activity structure. The make the game concept more detailed and as the base for developing the game, game activity structure is made. There are 11 activities in the game design and for each activity, there will be player performance as the result of the decision made for each activity.

Table 1. Game Activity Structure

| Activity | Description |
|----------|-------------|
| 1        | Selecting vehicles |
|          | There are some options of vehicles (including new and used car) along with the detail of price and car specification. The player needs to decide what vehicles they want to drive for further activities. |
| 2        | Simulation of weekdays mobility |
|          | The player will input their regular mobility in weekdays including the starting point, destination, distance, and frequency. The input from a player will be calculated for annual mobility of player. |
| 3        | Analyzing the effect of fuel subsidy to performance |
|          | Fuel subsidy is one of the momentum that occurs in fuel regulation in Indonesia. Through this activity, the player will analyze how the fuel subsidy will affect the player performance. |
| 4        | Simulation of mobility in vacation period – distant journey |
|          | There will be some options of destination to choose while having a vacation. Each of the destination needs to display the cost, distance, and traffic level. In this activity, the player can understand how traffic level will affect the performance. |
| 5        | Government target and background of oil to natural gas conversion |
|          | Explanation about government target due to the energy management and the background of releasing oil to natural gas conversion program is displayed. |
| 6        | Component, infrastructure, and mechanism of oil to natural gas conversion |
|          | Explanation about CNG, gas infrastructure, mechanism and benefit of oil to natural gas conversion |
| 7-10     | Offering 1: Conversion of oil to natural gas with the current condition, when fuel subsidy is cut, when more infrastructures are available, and when payment method is changed. |
| 11       | Analyzing the performance of before and after conversion |
|          | Analyzing the performance of each indicator to see the benefit of doing oil to natural gas conversion. |

3.2.2. Visual construction. The developing of the digital game use Netbeans IDE 8.2 software with Java programming language. The interface of the plot of the game will be made with an appealing design. Transergy is the name of the digital serious simulation game. Through the visual construction, the interface of the game is made to ease the player understand about energy transition. The sample of the game interface is shown below.

Then, the explanation from the component and mechanism of oil to natural gas conversion is explained.
Other interfaces regarding the players in game performance which covers indicators are shown below.

3.3. Stage 3 – Reflection and Learning

After the game is made, the simulation of the game to the user is conducted. There are 15 users to test the game and know the significance of the game for energy transition education, that the game is beneficial to improve their knowledge of oil to natural gas conversion. Before playing the game, the users need to fill the pre-test form. The pre-test form is needed to know the condition of player comprehension about energy transition before playing the game. After doing a pre-test, the game rules and instructions are briefed to the users.

When the users are playing the game, the game facilitator is observing the player and preparing the post-test form to be filled by the users. The post-test form has same questions like pre-test form. Thus, using the pre-test and post-test results the significance of the game to the users about the comprehension of energy transition could be known. Besides, the users also fill the game evaluation form as the tools for verification the game content based on triadic game design.

4. Results and Discussion

After the game is made, there will be verification and validation from the game. Verification will be done alone by checking whether the game has fulfilled the game plan specification and not having an error source code logic. While validation will be done by testing the game to 15 players to know whether the game able to transfer the aim and learning points through pre-test and post-test forms with same questions. Validation is also done to know whether the reality, meaning, and play elements in the game is already balanced by giving an evaluation form concerning the game to the players.

From the verification results, it can be concluded that the game has cover all the design specification requirement which are learning purposes, learning points, and logical code. Results from validation
Based on the pre-test and post-test form show that before playing the game, the average of the pre-test result is 42, and the post-test result is 103.3.

Besides comparing the result of each player, comparing the results from each question to know how the comprehension from the learning points in the game is conducted. The comparing of the pre-test and post-test results for each question is shown in figure 8. From the graphic, it can be interpreted that the topic that the players totally do not know before playing the game are the gas price, converter kit price, gas infrastructure and waiting time of queueing in the gas filling station. However, after playing the game, the players have known about that topic, and the score of other topics are also increasing.

![Figure 8. Result of each question topic](image)

From the result of pre-test and post-test, a non-parametric Wilcoxon statistic test will be conducted to know whether there is a significance between before and after playing the Transergy game.

The non-parametric Wilcoxon statistical test is done by SPSS software. From the test using the software will be obtained the value from p-value and if p-value (\( p\text{-value} \)) >0.05, H0 will be accepted. Meanwhile if p-value (\( p\text{-value} \)) <0.05, H0 will be declines. The result of the Wilcoxon test is p-value 0.000. This means that H0 is declined and H1 is accepted. It can be interpreted that playing the game gives a significant difference to the player.

Next validation that will be made is doing a validation to the reality, meaning, and play element based on the user testing player feedbacks. From the validation results, can be seen whether those three elements are already balanced. The results of the reality, meaning, and play elements validation is shown in table 2. The Likert scale of 1-5 is used where 1 shows the players do not agree that the game contains those elements, while 5 shows the players agree that the game contains those elements.

| Elements          | Score |
|-------------------|-------|
| Reality           | 4.52  |
| Meaning           | 4.32  |
| Play              | 4.23  |

From the element validation result, can be seen that those three elements stand between the value 4.2 to 4.5 which shows that the reality, meaning, and play elements are already balanced. However, the play aspect is need of improvement to keep players motivated for playing the game until finished.

5. Conclusion
From the verification and validation result made to the game, it can be concluded that:

1. This research produces a digital serious game about energy transition named Transergy that is made by considering the reality, meaning, and play elements. The game development is using the
framework of integrated game design framework. The game has four learning aims and contains learning points about oil to natural gas conversion.

2. To know the impact of the game as education media about energy transition, verification and validation are done from the game test. From the result analysis, it can be concluded that digital serious energy game - Transergy can be used as education media about energy transition, especially oil to natural gas conversion and ready enough to use in worldwide education about introduction of energy transition concept.

For the further research about developing games of energy transition, especially for oil to gas conversion, the suggestions are:

1. Conduct more game test with more player to derived more generalized result
2. Developing more advanced interface to make the game more interesting

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