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Master's Dissertation 2012

Design of an Eco Factory Game

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Graduate school of system design and management, Keio University

Major in System Design and Management

Summary of Master's Dissertation

Student Identification Number	81133382	Name	Sun, Han-Yi 孫恆義

Title: Design of an Eco Factory Game

Abstract:

The ongoing discussion of being ecofriendly has been a hot topic since a few decades ago. Industrial factories are the current major causes of our global warming issue, producing eighty five percent of all carbon dioxide in the world. Developing countries are a long distance behind world standard in terms of eco. The main cause of this difference is thinking process and education provided to people living in those countries. Numerous studies have shown that due to the rapid economic growth of the developing countries, government and companies in those countries opt for strategies that will bring as much profit as possible; and because ecofriendly procedures require large economic investments during the initial stages, they are ignored.

In order to solve that problem, we identified college students' education as the more effective method to improve the situation. We chose to design a business games to be used as an education tool to increase students' awareness of the global warming issues. Business games are proven as an excellent way to present key concepts in a simulated environment with group interactions. They are especially useful in situations where "learn by doing" behavior exists. They are also much more cost effective when compared to experiments and fieldworks.

The major mechanism in the competitive game we designed was decision making. The students were required to maximize profit while dealing with penalty constraints accompanied by new game rules as the game progressed. The three major environmental measurements we chose to present in the game were waste, emission, and energy. Each eco investment the students chose to implement came with monetary and environmental gains and loses. Students had to form strategies by themselves in order increase their customer base by lowering environmental burden, and make profit so they do not go bankrupt.

The resulted showed that students were able understand the basic concept of ecofriendly measurements, which were tradeoffs. They understood that initial investment would be replaced by increased company reputation and customer base, and that resulted in increased demand and profit. As for the eco methods themselves, students were able to understand the prioritization of reuse, reduce, and recycle applications. Finally, with the introduction of government incentive, consumers are more willing to perform eco activities, which in turn will result in the factories to pursue eco procedures as well. This cycle had the potential to effectively change the eco system in developing countries from the inside out.

Keywords:

Eco awareness, Business game, Eco factory, Tradeoff decisions, Government incentive

Table of contents

1 Introduction

1.1 Research background

1.1.1 Increasing environmental issues, especially in developing countries

Environment issues have been a big topic since a few decades ago. In the aftermath of the industrial revolution, people had come to realize the harm and danger of factory production related pollutions. One of the biggest problems, carbon dioxide emission, has become a worldwide problem now; and not just countries which are responsible for their share of emission (Matsuoka, 1999). The COP3 conference held in 1997 in Kyoto proposed that every country in the world to be allocated a portion of carbon dioxide that it is supposed to reduce. Meaning that solving global warming is not the sole responsibility of a handful of countries, but everyone in the world has to be active in order for the situation to improve. One would think that after all these years, some measures would have been taken, and the situation would have been controlled somewhat. However, that is not the case as of 2012. Increasing average global temperature, bizarre weather patterns, shortage of food supply etc. are continuing to happen as a result of global warming. According to the 2012 Global Carbon Dioxide emission report published by the PBL Netherlands Environmental Assessment agency, global carbon dioxide emission reached an all-time high in the year 2011, at thirty four billion tons (Jos, 2012). Figure 1 and 2 below shows the major countries in the world and their corresponding carbon dioxide emission. Figure 1 contains developed countries, and figure 2 contains developing countries. By a simple glance of comparison, one can see that the developing countries reflected efforts to reduce CO2 emission over the past decade. On the other hand, not only did developing countries showed very little

effort to try to solve the emission problem, half of them actually produced two to three times more on a yearly basis.

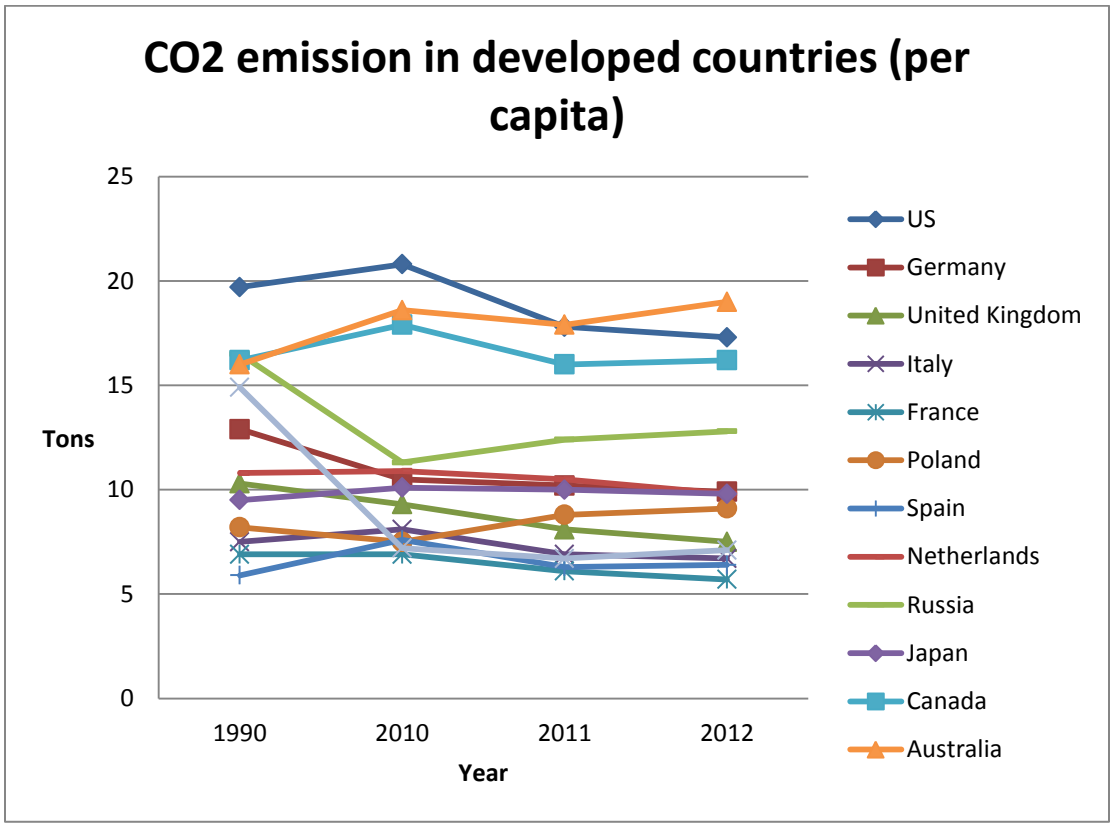


Fig. 1: CO2 emission in developed countries (Source: Trends in Global CO2 emissions, 2012 report)

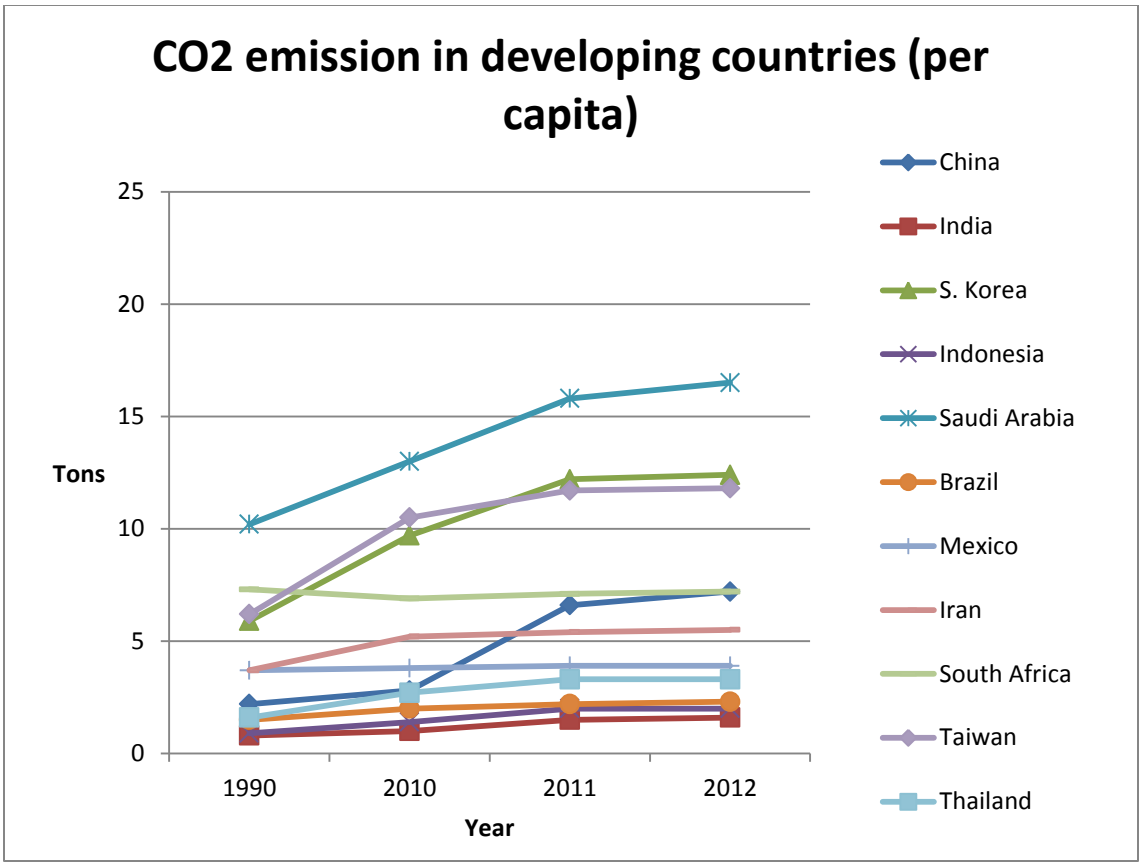


Fig. 2: CO2 emission in developing countries (Source: Source: Trends in Global CO2 emissions, 2012 report)

Not only were there no improvements or solutions carried out, but in reality the emission continues to go up as if nothing is wrong with it. Some scientists proposed that it was already too late for mankind to "solve or prevent" the problem, but instead it is better to think of ways to "deal" with the problem; for example altering the structure of earth's atmosphere by launching chemical missiles, or creating better structures to house agricultural products.

1.1.2 Material shortages and environmental related problems

Decreasing availability of raw materials is another problem. Mankind is depleting earth's resource, from "renewable" forests and water supply, to metals and oil that took thousands of years to form. The result is the steadily increasing price and limitation of use by countries or

companies. Figure 3 below shows some of the primary materials used in industries nowadays and their steady increase in price over a span of fifteen years.

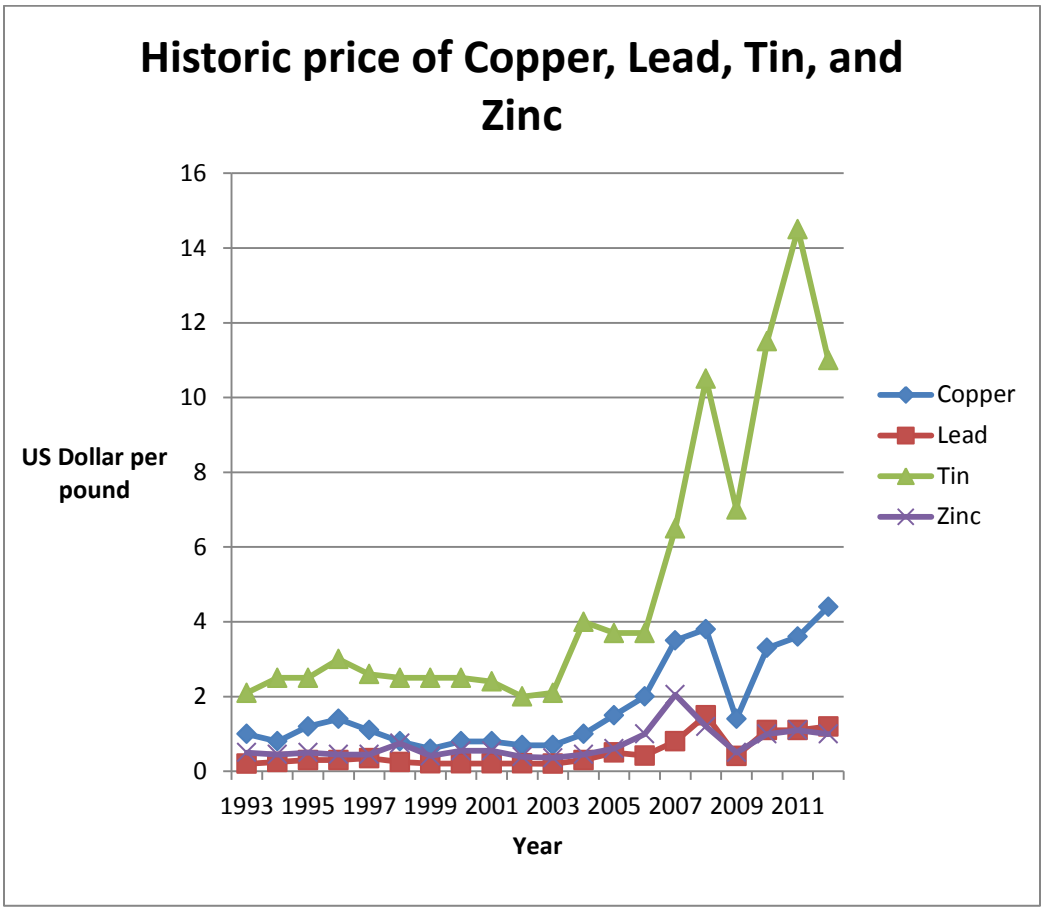


Fig. 3: Prices of base materials (Source: http://www.infomine.com/investment/)

There were certainly bounce backs due to a lot of reasons like recession, currency exchange rate, and political negotiations and so on. However, the general trend of the price is increasing for all of them, and it is difficult to think that the situation will change in the future as we cope with increasing technology and population.

To counter the problems caused by increasing price of raw materials and limited availability of raw materials (due to political, economic, or environmental reasons), industries

often have tendencies to seek solutions through technology. Throughout history, innovations had been applied quite a few times whenever there were shortages or unavailability. In the 1800's, pyrites were discovered when there was a shortage of sulfur. In the 1900's, wood pulp and esparto were introduced to counter the lack of rags for paper making. During the mid-1900's, synthetic process was created in the textile and chemical industry when the war caused a worldwide shortage of primary materials (Ray, 1975). Continuing to today, tires composed of orange oil, plastic bottles largely composed of plants were all innovations made not only aimed to solve shortage problems, but also environmental problems as well.

1.1.3 Increasing awareness of ecofriendly products and services

The idea of eco friendliness is not a new term. The concept of minimizing waste and pollution created through process of production was used extensively in the late nineteen eighties (de Bruijin, Hofman, 2000; Bass, 1998). The environmental laws before that were mostly aimed to solve the problems at the end of a process. For example the water quality needed to be achieved before it can be released into the river; or gas has to be purified before it can be discharged into the atmosphere. With the introduction of pollution prevention policies however, companies started to look at solutions that can be used at the source or middle of a process. The idea of material reduction and waste reuse were all brought up along with the new policies.

Eco label	Country	Area of effect	Year issued
American Grassfed	United States of America	Food and Agricultural	2003
Basta	Sweden	Construction and buildings	
Better Cotton Initiative	Africa	Cotton farming	2010
Blue Angel	Germany	Health, Climate, Water, Resources	1978
China Environmental labeling	China	Standard setting for all kinds of industries	1993

Fig. 4: Examples of eco labels around the world

With the increasing availability of information regarding degradation of environment, ecofriendly awareness of the general public has increased significantly in recent years. Consumers nowadays are starting to look for specially labeled eco food and products (examples of global eco labels are shown above in figure 4). According to ISO, 1999, an eco-labeling scheme consists of three steps: selection of product category, development of criteria, and certification and licensing. The idea of eco labeling started about thirty years ago in Germany, the German Blue Angel. Today, most of the EU members have introduced national labeling programs. Developing countries are also looking into this trend recently. In Vietnam, the government aims to eco label one hundred percent of exported goods, and at least fifty percent of domestic goods by the year 2020 (Morioka et al., 2010; Ministry of National Resources and Environment, 2003). The functions of eco labeling can be viewed from three perspectives:

producer, consumer, and policy maker. For producers, it is a way of showing the social and environmental performance of the products. Eco labeling also paves the road and slowly transfers awareness of consumers toward the eco market. For consumers, eco labeling is a sign of quality and source assurance; though at a higher price than normal products, it enables consumers to understand the social and environmental attributes of the products, which normally cannot be understood. For policy makers, eco labeling is used as an incentive for innovation, technology breakthrough, and responsibility (Bratt et al., 2011).

1.1.4 Increasing government regulations and penalties

As environment issues become more serious exponentially, stricter regulations are also being imposed periodically. In Germany, consumers need to pay more to operate a conventional car that uses diesel fuel because the penalty involved in the use of diesel makes it a more expensive option compared to high tech electric or hybrid cars. European countries like Austria, Denmark, Germany, and Sweden have been leading the world in terms of ecofriendly procedures. Their yearly CO2 emission reflected low emission; and especially taking into consideration that most of the CO2 emission reports categorize Western European countries as EU, meaning that their already low CO2 emission was produced by twenty seven countries and not just one (EU 27). A growing number of SME's globally have already recognized the necessity of track records in quality and environmental management in the near future in order to satisfy consumers and government requirements (Zorpas, 2009). Figure 5 below shows the number of sites with active eco management in Europe in 2006.

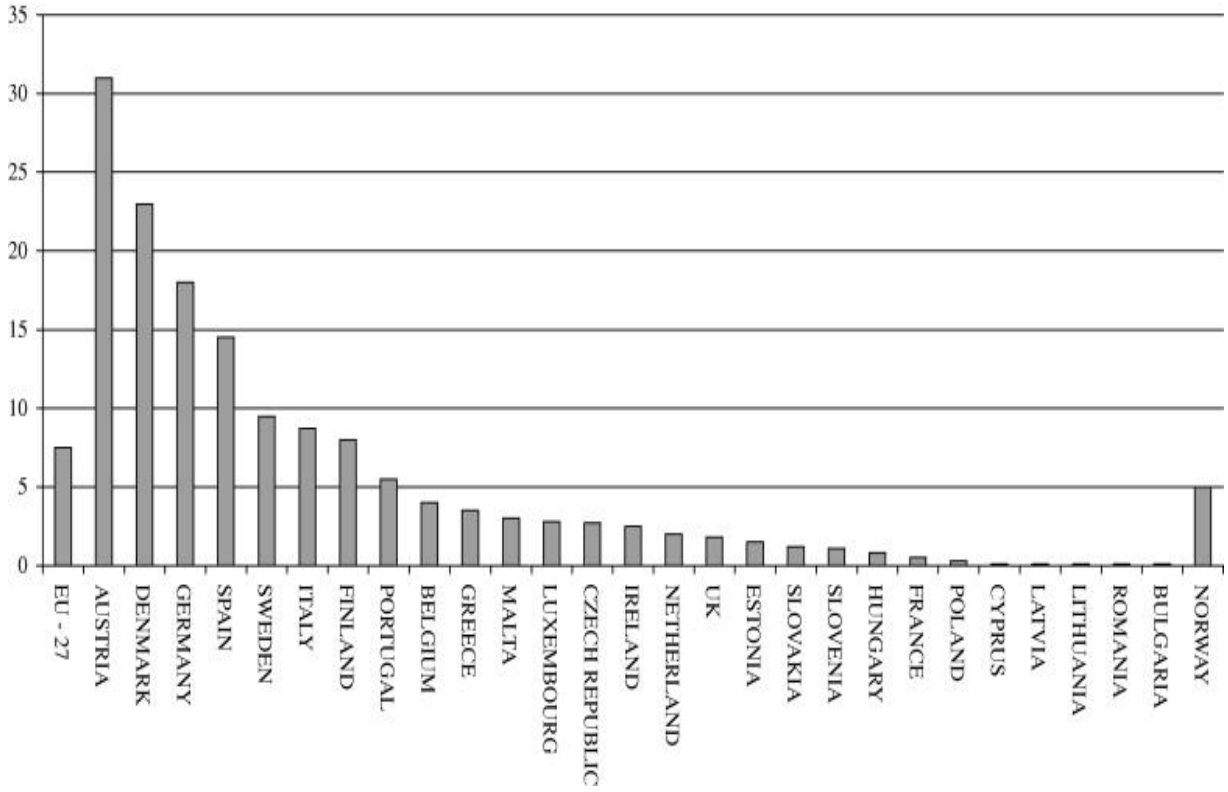


Fig. 5: Number of sites having implemented an eco-management and audit scheme, or ISO 14001 certification in 2006 (per million habitants) (source: Zorpas, 2011; Eurostat 2008)

1.2 Research problem

1.2.1 Developing countries lose reputation; labeled as "trouble making countries"

Companies in most of the advanced countries in the world have to abide by their government's environmental laws. However in the cases of developing countries, that is not always the norm. The reasons can be many: corruption, ignorance, refusal of taking the responsibility etc. Take China, the world's most populous and developing country at the moment, for example. In 2011, China's per average per capita carbon dioxide emission was at 7.2 tons. That amount was almost equal to all the emissions done by the whole European Union in the same year, at 7.5 tons (Jos, 2012). The main reason was of course the rapid development that

China is undergoing. The increase in building construction and expansions in infrastructure demanded increasing fuel consumption (as indicated by the cement and steel production shown in figure 6 below).

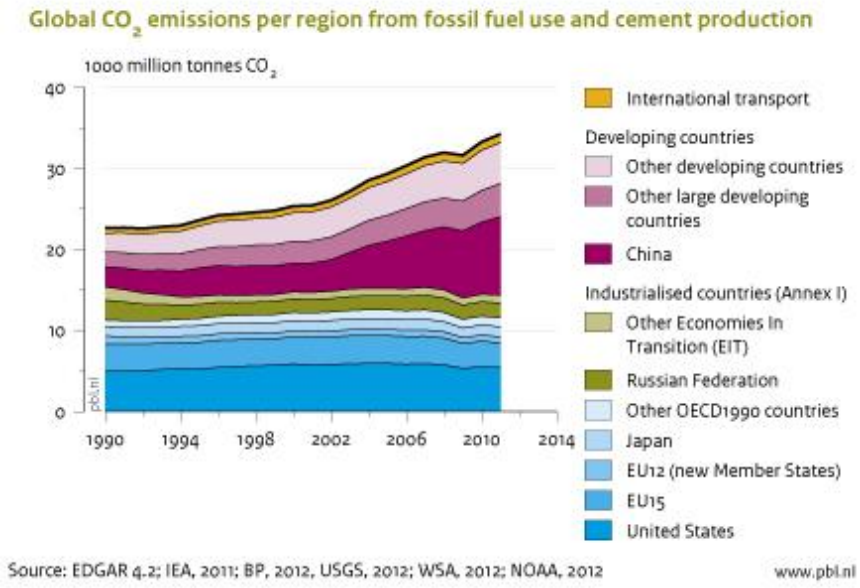


Fig. 6: (source: Trends of global CO2 emissions, 2012 report)

China has an existing environmental regulating system, and even an eco-labeling system (shown in above section); but sadly when looking at the results of such systems, we can assume that the system exists for the sole purpose of showing something to the public and the world, instead of changing and improving the environment. Corruption is a very serious problem not only in China, but a lot of developing countries. Anyone can be bought off quite easily with the right sum of money. If there is a mutual benefit for both of the parties involved (for example a polluting factory and the environmental agency), it is very easy and common that both parties cover each other's wrong doings and proceed as if nothing is wrong. As the internet and public communication improve in developing countries, and also between developing countries and the

world, we see on a daily basis that all sorts of corruptions occur. In China, an increasing number of individuals or local communities are rebelling against this situation. They are collecting videos, environmental measurements, and proofs of pollution to try and publicize the problems. However, the result is slow, if not totally useless due to cover ups and ignorance.

Another way of losing reputation is simply "not doing enough". A lot of smaller companies are just performing tiny steps toward greening the environment. Actions like switching off unused computer screens and decreasing use of air condition are all ecofriendly methods, but effect resulted just by those actions are often too small to make an impact. Small and medium companies are less aggressive in taking eco measurements due to unwanted risk and stability of business. Eco measurements require a somewhat large investment in the initial stages; this produces a lot of instability and becomes an unknown future that most of the small and medium companies are not willing to gamble on. Although small actions are very effective methods in increasing employee awareness and act as an initiative in transforming into eco (Lee K., 2011), the results are limited.

1.2.2 The lack of eco mindset in developing countries

As said in the above section, the mentality of "develop first, green later" is still very strong among industries and government in developing countries. This mentality has caused a lot of heated arguments during international conferences as well. In the case of Southeast Asian countries, pollution prevention and greener production of the western development process are ignored unless the benefits of doing it can be clearly seen or justified (Bowonder, 1981). It is difficult for developing countries to accept the initial effort and investment needed to transform to a greener system. Most of the ecofriendly efforts made in developing countries were initiated

by advanced countries, for example Germany or Japan. Those efforts could be factories built, inter-company relationships formed, or concepts introduced. Examples are the Mark and Spencer factory in Hong Kong, and the Hitachi factory in China. They were some of the first eco factories to be implemented in Asia, and with foreign origins. In other words, developing countries are doing what the advanced countries are instructing them to do. This could be a bad mentality especially in the long run because that means Asian countries will always be learning from others, instead of being innovative themselves.

When looking at some of the reasons European companies adopted ecofriendly technologies, we saw very different mindset and motivation from developing countries. According to figure 7 below, the top five reasons European companies choose to practice ecofriendly procedures are all related to personal good will and company benefits. The top reason, which states "personal view" and "economic benefits", is totally opposite from developing countries' views. Apparently there are concepts and logics not yet fully understood by developing countries regarding eco products or services and their benefits.

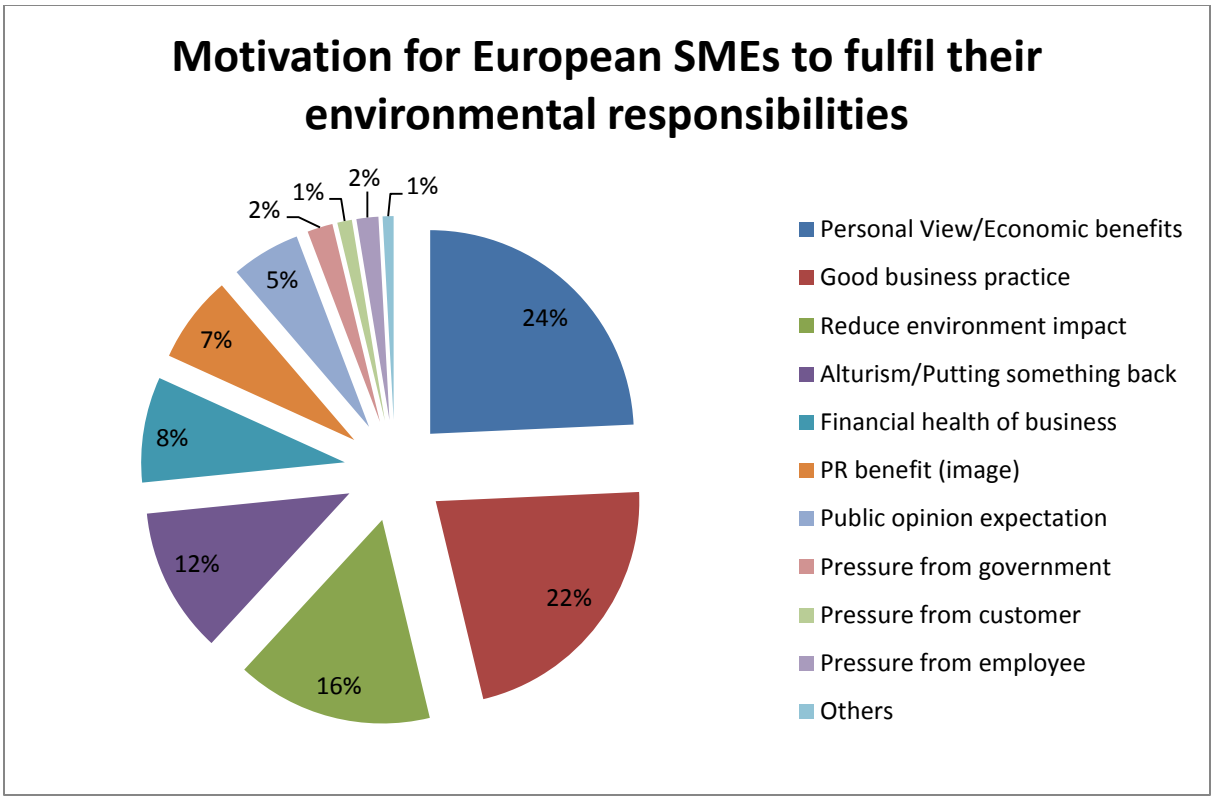


Fig. 7: Motivation for European SMEs for going eco (Source: Zorpas, 2011)

1.2.3 Lack of acknowledgments from the people

From the differences shown in the above sections between results and mindsets of people in developing countries and developed countries, we can conclude that the fundamental reason in which developing countries are not pursuing eco friendliness as much as developed countries cannot be money. In other words, there is no reason that choosing to be ecofriendly results in bad economic performance, or else developed countries will not pursue it too. In fact, the reality is the total opposite. There are numerous studies done both in developing and developed countries, and the results all clearly showed that implementing eco friendliness, particularly in production industries, lead to increase in profit gained. We will give two examples of such kind of studies.

The first one was done in India, a major developing country in the world at the moment. The target of the study was one big garment producer in the western part of the country (Barari et al., 2012). The study used a game theory, where two groups in the company with different strategies compete to see which strategy yielded the most profit. Group one applied eco procedures during production. Group two did not choose to do that. The results of the study are shown below. Figure 8 shows the result of the two groups in terms of market advantage.

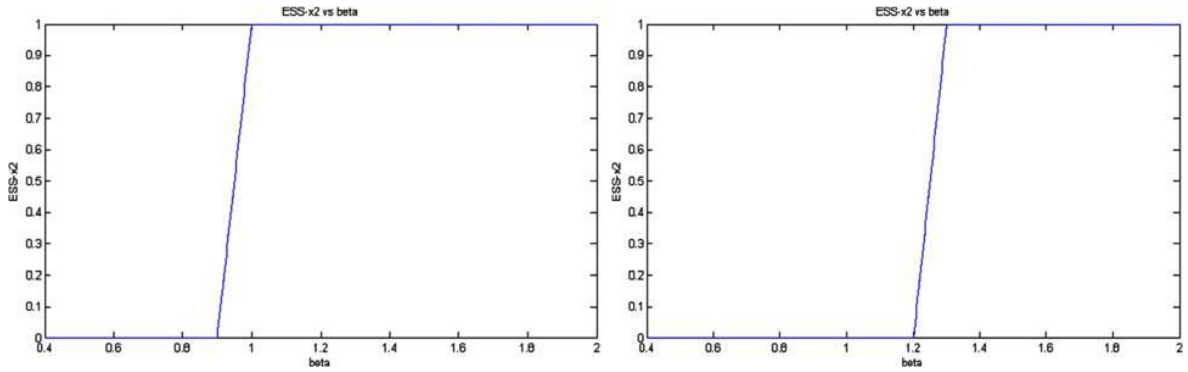


Fig. 8: Market advantage achieving speed (eco production result is shown on the left side, and normal production result is shown on the right side) (Source: Barari et al., 2012)

With the x axis representing the time (same span on both graphs), the graphs show the point in time when consumer reaction was triggered. Group 1's result was shown by the graph on the left side. When compared with the graph on the right side, which represented group 2's result, one can clearly see that the triggering point of consumer's reaction of group 1 happened earlier than group 2. The result suggested that group 1 was able to achieve a market advantage due to the green impetus their green product brought into the market. Figure 9 shows the result of the two groups in terms of revenue earned.

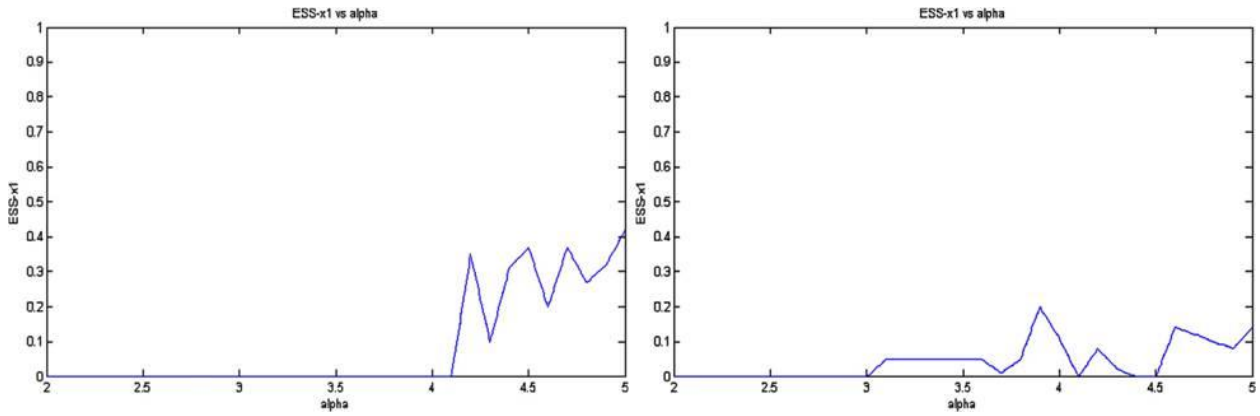


Fig. 9: Amount of revenue (eco production result is shown on the left side, and normal production result is shown on the right side) (Source: Barari et al., 2012)

With the X axis representing the time and the Y axis representing the revenue, the two graphs showed the revenue earned by the two groups earned over a same period of time. Normal production started to bring in revenue at an earlier point of time, as shown by the graph on the right side. The reason included price, product familiarity, information provided to the consumers and etc. When compared to the graph on the left, however, one could conclude that the total revenue earned was quite different. The conclusion is applying green production yielded a better result in terms of business strategy and revenue. However in the case of revenue, time is required for the system to start rolling before good return on investment can be realized.

The second example was done in Taiwan, another developing country state in Asia (Chang, 2012). The targets were fishermen. In this study, fishermen were separated into two groups: with group one's products carrying eco label issued by the government. Group two's product did not carry such a certification. The result of the study is shown below in figure 10.

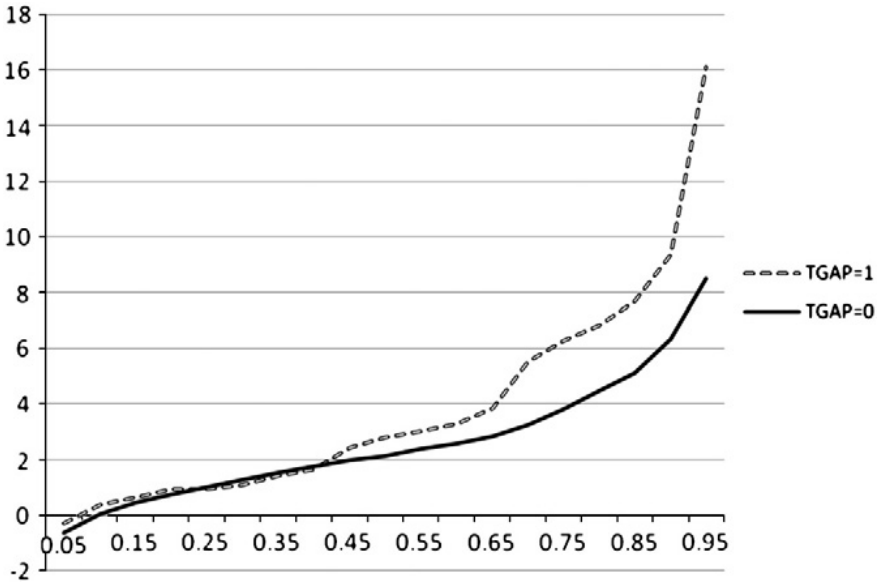


Fig. 10: Result of eco label users and non eco label users in fishery in Taiwan (source: Chang, 2012)

The dotted line represented eco labeling using fishermen, while the solid line represented fishermen who did not use eco labels on their products. The result was that with an increase in the usage of eco labels, the income increased at the same time. In fact, the average income of label users was 17,200 US dollars higher than non-label users annually. An additional survey regarding eco label usage was also done during the study. One interesting note revealed that for the young generation who received higher educations, they understood the effect of greening the products and services. They were much more aware of the power of green products and how they could gain an advantage in the market by understanding the consumers. Thus an increase of the usage of eco procedures happened for young people who received higher educations.

The two examples of studies done have shown that consumers in developing countries are somewhat supportive of eco systems. However, that did not represent the behavior of the general public. The eco performances of developing countries were still very low, and the general acknowledgments of eco systems and products are still very insufficient.

1.3 Solving the research problem

From the information and problem identified in the above sections, we proceed to form our proposed solution in this research. European countries and numerous studies around the world already showed that providers who implemented eco procedures during production will gain higher profits compared to those excluded eco procedures. However, the situation in most of the developing countries is still very clear: denial of the facts. For this research, we focused on three stakeholders: the government, the companies, and the public. In the casual loop diagram shown below, we present the three stakeholders, and their relationship between each other and environmental problems.

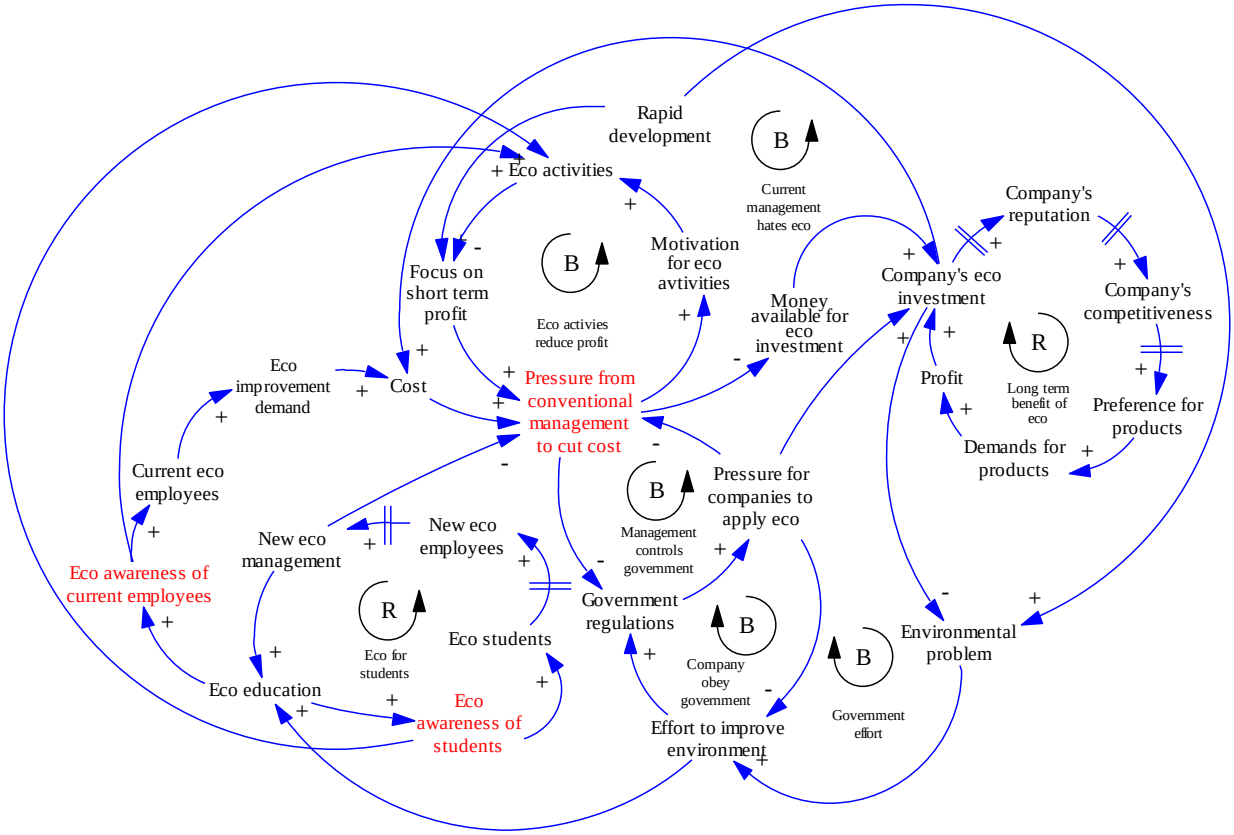


Fig. 11: Causal Loop Diagram of the government, companies, and public in developing countries

In the upper portion of the diagram, we showed the consequences of rapid economic development in terms of environmental impact. Rapid economic development results in companies placing their focus on immediate monetary gains. Eco measurements require an investment right from the starting point, meaning that companies will see substantial decrease in profits at the first stages of the eco plan. This phenomenon is of very little interest especially to industries that are undergoing a rapid growth, and also small and medium companies which opt for stable income and low risk operations. In the lower right portion of the diagram, we showed the efforts made by the government, by means of regulations and penalties. In the cases of developing countries, that effort is shadowed heavily by corruptions and lack of commitment. The governments understood the importance of country growth, and they will most likely avoid actions that will hinder such growths. From the government related balancing loops shown in the diagram, we argued that governments and companies shared the same interest: maximizing country and economic growth, therefore it is inefficient to propose solutions that utilize more regulations and laws, as they will yield minimal results.

To maximize the result of a solution for this problem, we proposed an education system aimed at students. Students do not have the same social pressure induced like which the current workforce has. They will understand the benefits and consequences of taking eco measurements from the beginning, and can take precautions or plan ahead for the system to start working. On the other hand, they can create eco demands, which will result in increase in eco awareness and productivity by industries in the country. In other words, we suggested that an education targeted at students will yield a better result in the long run in transforming how the management and government think.

As for the education itself, we chose the format of a business game. The business game will not act as a stand-alone education method, but as an add-on to the current lecturing system. We assumed that students under normal circumstances attend lectures as basic education. On top of that, a supplementary education should be added to act as self-checking and applying tool. Due to the content of this research being related to environmental actions, we proposed an education tool with the function of enabling the students to apply what they already learned from lectures, and to compare the results with their expectations. Business games are excellent education tools for subjects that require the method of "learning by doing" (Bourgonjon J. et el., 2010; Tao et al., 2009; Connolly T. et al., 2012; Mahboubian M., 2010). Environmental concepts not only involve laws and methods, methods, but also the correct combination in order for the effects to be maximized. Business games enable students to apply existing experience or knowledge on a specific topic, and acquire improvements or new knowledge according to the result of the games. They are also considerably cheaper and less time consuming compared to other effective "learning by doing" methods such as experiments and fieldworks. In figure 12 below, we showed the Pugh selection table that we used to decide business game as the format of our game in this research. The criteria and weight were decided by questionnaires done by current students. According to the students, the application of existing knowledge is one of the most important factors when judging the effectiveness of an education. Motivation was also very important as it determines the mental state of studying students.

Criteria	Weight	Lecture only	Lecture + Field trip	Lecture + Workshop (business games)	Lecture + Case study	Lecture + Speech
Time needed for completion	4	DATUM	S	S	S	S
Cost to implement	3		S	S	S	S
Motivation for attending	6		+	+	S	+
Time of operation	2		S	S	S	S
Discussion opportunity	5		+	+	+	S
Application of existing knowledge	7		S	+	S	S
Availability to students	1		S	S	S	S
	Total score		11	18	5	6

Fig. 12: Pugh selection of education methods

For the content of the business game, we decided to use the setting of a manufacturing factory. The reason was the significant affect manufacturing industries have on the environment and society of developing countries. One of the most serious outcomes of increasing manufacturing factories is pollution, whether it is the pollution of water, land, or air. Industrial waste is a definite byproduct of the process of manufacturing. Therefore it will be one of the major factors included in our game. On top of that, we have chosen other two factors that would be presented in the game: carbon dioxide emission, and energy consumption.

Emission is one of the main causes of global warming. Some of the main sources of emission are machines, transportation, buildings and so on. As countries develop, the number of sources of emission also increases. In this research, we divided carbon dioxide emission into two main categories: energy related, and economic activities related. Energy related emission is defined as emission created by the process of generating energy. In developing countries, the

major source energy still comes from coal and fuel burning. Those two processes produce extremely high amount of carbon dioxide, and is one of the main of air pollution. However, the solution to energy related carbon dioxide emission is not in our scope, due to the fact of the difficulty and complexity of the system needed to change the existing situation. When we looked at advanced countries, we saw a lower amount of carbon dioxide emissions; but not because of less energy used, but of the technology applied to obtain energy (nuclear, wind, solar etc.). The planning and effort needed to change exiting energy producing system in developing countries to that of advanced countries is not a simple task. Not to mention that after changing the plants, cities infrastructures have to be changed too. Therefore we concluded that in this research, we will not target energy related emission, and target economic activities related emission instead. Under the economic activities related emission, we saw a high percentage of emission resulting from manufacturing industries. According to an IEA report published in 2007, thirty six percent of the world's carbon dioxide emission came from manufacturing industries. As most of the manufacturing took place in developing countries due to economic reasons, we could conclude with a decrease of emission in developing countries, a huge improvement would occur.

Energy was included as another factor because it has a very close relationship with emission. As we have mentioned in the above paragraph, emission also happens as a result of generating energy. In the game, we defined energy as electricity. With the increase of factories and machines, electricity used to power them also increased. In the graph below, we can see the importance of reducing both emission and energy due to the weight they carry in the whole eco system scheme.

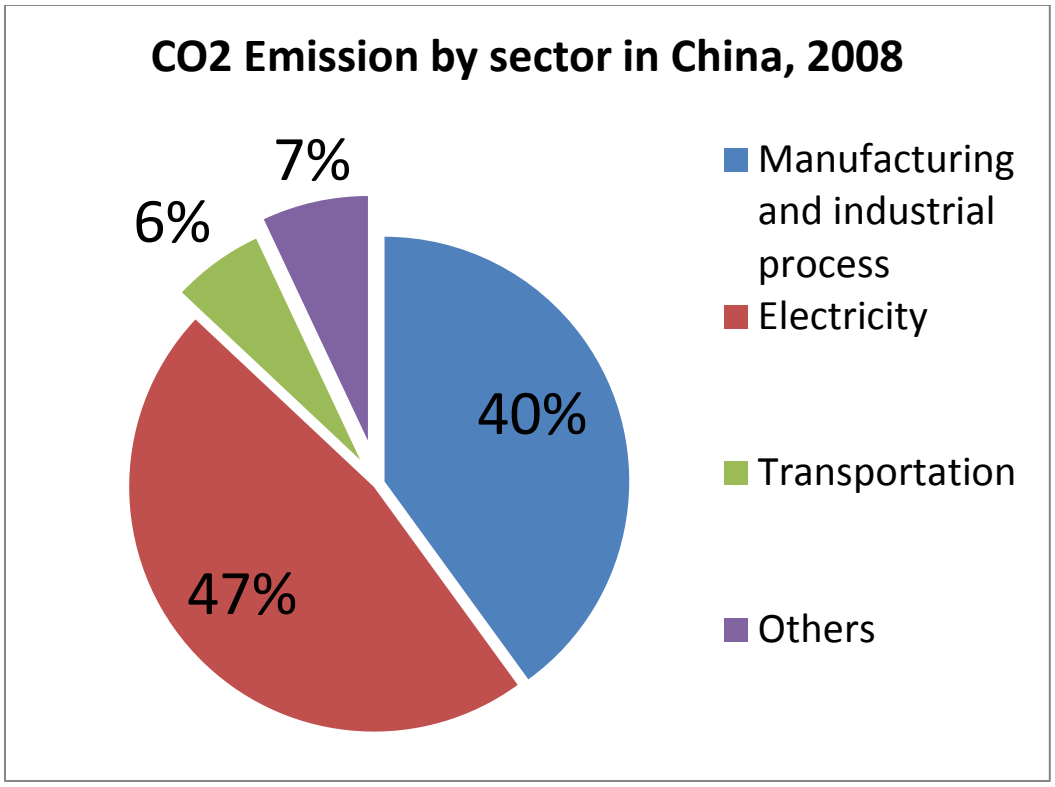


Fig. 13: Emission by sector in China, 2008 (source: World Resources Institute)

1.4 Research motivation

I have played business games in multiple occasions during my university years in the United States and Japan. Those sessions allowed us students to apply our knowledge in a simulated environment. Some games were visualizations of real concepts in the business world. It shocked us to realize that although we already knew about potential problems and errors that that human would make, and even some solutions to the problems, we were still not able to avoid those errors completely at the beginning of playing the games. Other games were created based on simple business theories, and it was interesting to walk through those theories step by step and apply improvements by ourselves. To me those were the main functions of business games.

They are tools that can be used for students to physically explore lessons learned in classrooms or textbooks, and to find out the real reasons behind those theories and effects.

As a Taiwanese having studied in countries with advanced environment friendly technology and strict government policies regarding wastes and pollutants, I could feel the difference of mindsets of people between those countries and developing countries. It is true that all the major industrial countries in the world have some kind of environmental restrictions in place. However, especially in Asia, those regulations are not strictly obeyed by most of the manufacturers. The idea of "develop first, green later" is still very much the trend that industries and government take. Postponing new eco technology and concept will put Asian countries in the downstream for the foreseeable future. We will always be importing, buying, learning from advanced countries. If we take efforts to make changes by ourselves, we can increase our knowledge and even take some initiative to help improve the environment.

1.5 Research purpose

To conclude this chapter, we proceed to state our purpose and objective of the research, and we give a brief overview of what this research paper contains in each chapter.

1.5.1 Purpose of research

The purpose of this research is to increase the eco awareness of students, especially the ones in developing countries. We wanted to enhance the understanding of some of the main concepts used in eco systems in the real world providing them with a tool with which classroom concepts can be connected with real world application. By using this tool, students will be able to experience the logics behind eco factory management and understand how situations around

them can be changed easily to deploy eco techniques. Through this experiencing, understanding, and thinking process, they will be able to participate more actively when it comes to taking initiative in strategies creation and people interactions when it comes to designing eco management.

1.5.2 Objective of research

The objective of this research is to design a business game with elements of eco management. Transforming business (in this case eco management) concepts into a game involves making mere ideas into something that people can perform, act, and physically experience. In this research, our objective is to make an eco-business game in which players will be able to physically perform acts like reusing and recycling materials. They will also be able to physically experience the impact of gas emission from vehicles and electricity used by machines in a simulated environment.

1.6 Structure of thesis

In chapter one, we have given a general background of this research. We have identified the critical problems that are happening today, and the concern we have if the problems continue to exist. We also stated the general purpose of this research, and the physical results we were expecting to build in order to complete this research. In chapter two, we introduce the concept of business games. We will define and explain some of the common terms related to business games. We will then go over some current examples of popular business games to give an idea of what they are like and what they can accomplish. After that we will discuss literatures that serve as aid and information during this research. Finally, we will state our originality compared to

other researches, and what different methods we took and results we accomplished. In chapter three, we will list the methods that we used during this research. We will list them in a timely order to show the process we took from forming idea, creating prototypes, and finally testing them. In chapter four, we will present the two prototypes created for this research, the test results of those prototypes. In chapter five, test results of the two prototypes will be discussed. We will show the testing procedures and feedbacks we received from participants. Lastly in chapter six, we will recap the results of this research once again. We will state potential uses for the games created for this research, and some of the limitations and difficulties we faced while researching and designing the business game.

2 Business games

2.1 Definition of business games

2.1.1 Definition of key words

Business games (also called business simulation games) are educational tools used to enhance or visualize concepts in the business world. The content of business games can range from management (time, product, human resource etc.), finance, and company behaviors and so on. Below are some of the key terms often used in the building of business games.

Gamification: the use of features and concepts from games in non-game environemnts, such as websites and applications, in order to attract users to engage with the product (Macmillan dictionary). It is the process of making something into a game. A very simple example is football. One person kicking a ball around with his feet is called "kicking a ball". The process of gamification used here is to gather twenty two persons, separate them into two teams, assign each team a goal, and compete to see which team kicks the ball into the other team's goal more. The process of "gamification of a person kicking a ball" was done.

Serious game: serious games are games that designed for purposes other than pure entertainment (Wikipedia). Usually serious games are primarily used in classrooms, companies, social studies, or researches. They provide players of the game to learn without real, physical consequences. Schools of medical and engineering use serious game to avoid damage done to real humans or machines. Business schools and companies use serious game to simulate business related activities without the involvement of real money.

2.1.2 Current business game examples

There are many business games available as of today. The formats are also many, with a majority of them being operated by computers in forms of simulator. While a lot of the computer business games are ultra-realistic and based on real world numbers, a big percentage of them cost a lot of money. That results in a lower accessibility especially for students and individuals. For board type business games, the cost is much lower, and usually much higher group interaction and participation is required.

The beer game developed by a group of MIT professors in the 1960's is one of the most famous and most played board type business games in the world. Today it is one of the most played business games in colleges, especially in the department of business administration and management. It allows students to experience the "bullwhip effect", which happens when companies in one supply chain try to manage their inventories based on predictions and past experiences. Almost every company involved will show some degree of backlog and overstock situations throughout the game. One very interesting phenomenon is that the more experienced the players, whether work experience or game experience, the worse the backlogs and overstocks become. Thus, beer game is a very successful designed game in which not only new players learn new knowledge and concept, old players also benefit from it by understanding and outlining the flaws in their mindset and experience. Another example of a board type business game is the logistic game developed by ETH Zurich. The game setup is a production line in a factory. Players learn the importance of quality of product, cost of materials and inventories, and time of deliveries. The concepts are simple and easy to understand; however, through physical activities and cooperation done by players, they can see the differences easier, and thus understand the mechanism more compared to receiving lectures.

Fig. 14: Beer game developed by MIT (source: http://logisticsbureau.com/Beer-Game-Simulation.htm)

For computer based business games, due to the nature of their professionalism and availability, they are utilized in lesser occurrences, and often in specialized classes or company workshops. Public online business games usually contain a much lesser degree of professionalism, and the purposes are more for fun than education. Green my place is an international eco game with players around the world. The main purpose of the game is to provide suggestion and reminder of how tiny everyday eco actions can result in big energy savings when a lot of people do them. The game features mini games on a weekly basis where teams of players compete with other teams for the most saved energies. Capstone business game is a corporate designed game aimed for players who would like to experience the management of a company. It is one of the business games where numbers and statistics involved are based on real world figures, and players are required to have a substantial knowledge beforehand in order to understand and operate the game.

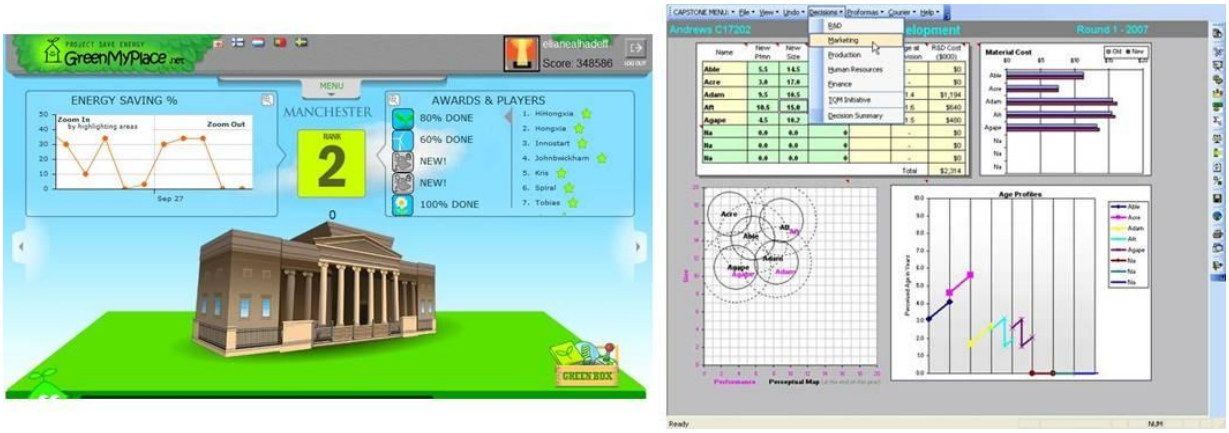


Fig. 15: Examples of computer business games (Left: Green my place, Right: Capstone business game) (source: http://www.businessweek.com/stories/2008-01-30/virtual-workplaces-in-the-classroombusinessweek-business-news-stock-market-and-financial-advice)

2.2 Literature review

There are numerous examples of researches done to aid in increasing awareness and understanding of students. Most of the games created in the researches were used use teaching tools to help players experience and visualize business concepts, strategy makings, and problems solving. As the environmental problems gained more and more attention, efforts were made to create eco games to satisfy the new needs for understanding eco management and decision making. We divided literature reviews for this research into two categories: factory games, and eco games.

2.2.1 Factory games

Research based factory business games were done mainly to observe and increase awareness of business concepts. One of the biggest usages of factory business games is to educate current employees on new manufacturing concepts, factory layout changes, or efficiency of production. Another big usage of factory business game is during workshops or interviews in

companies. Due to the nature of businesses, however, the above types of factory business games are seldom played by people who are not part of the companies. Public factory business games that are available to anyone are usually more general in concept, and aims to present the basic rules of production or business.

One of the most famous production business games created was the beer game. It was invented in the 1960's by Jay Forrester, a professor at MIT Sloan School of management. The beer game was designed to simulate ordering and stock management mechanism in a supply and demand setting. The purpose of the game was to teach students the importance of information sharing, supply chain management, and collaboration. However in today's world, the issue of environment slowly became a serious problem that all companies have to think about. A lot of new attempts to design eco games that will teach people the importance of sustainability have once again proved the importance of business games in terms of education. In the next section, we will give some examples of researches done in the past to tackle the issue of eco awareness.

2.2.2 Eco games

(Pacheco et al., 2006) Discussion and summarization of the paper is as followed: Second chance game was created as an environmental education sustainability awareness game aimed to increase eco awareness of young students (primary school). The game utilized simulated environments of earth, in which students have to construct miniature houses with limited resources. The objective of the game is to provide decision making procedures as the students try to use the resources they have as efficient as possible. In the case of shortage of materials, students are allowed to trade with other teams. However, trading increases pollution produced. The lesson to be taught to the students is that every single action will leave an ecology footprint.

They have to make tradeoff decisions and try to execute actions that will benefit everyone as a whole. The research successfully carried out the purpose of increasing eco awareness of the target students. It served the purposes of altering students' mindsets and actions after participating in the game. Due to the fact that the game was designed for very young students, the depths of the decisions to be made were not complicated. The tradeoff factors were obvious to notice, and could not be used to educate students enrolling in higher education. Also the game did not tackle the one of the most serious environmental problems today: CO2 and waste generated from industries.

(Pak et al., 2010) Discussion and summarization of the paper is as followed: Landscape transformation (pasture game) was a research done in Colombia with eco management of frontier grasslands. It used a role playing game in which players acted as parties with individual interests in utilizing the lands. Due to the decreasing jungle and increasing farming, usable grasslands continue to decrease in the Colombian frontier. In order to efficiently use the grasslands, management and cooperation must be carried between all the parties with interests or else no one will benefit. This game enabled all parties to present their concern and strategy to everyone else, thus encouraged communication and decision makings. The content of the game was carefully designed based on real world data and measurements. Without the risk of real loses, simulated usage could be seen by playing the game, and all parties could understand the consequences of their own actions. This game provided decision making for the players,

(Cowley et al., 2011) Discussion and summarization of the paper is as followed: "Green my place" was a research and game developed to increase awareness of daily actions that contributes to eco lifestyle. It is an online computer game with players all over the globe participating. Players were divided into five cities according to their own preferences. The game

utilized a series of mini games related to household electricity usage. The mini games would refresh every day, and the players would earn points by engaging in eco actions, for example switching off monitors, changing light bulbs and etc. in the end of a week, the scores of each of the cities would be compared, and a winner would be announced. This research was intended to remind the public of the small actions that could result in changes in energy usage. The research did not provide a way for the players to think about improvements and innovations. It simply provided a checklist of available activities.

(Barari, 2012) Discussion and summarization of the paper is as followed: In this research, two sales teams from an apparel manufacturer were competing against each other for profit in a game setting. The purpose of this research was to understand the mindset of consumers in terms eco friendliness. They concluded that with the implementation for eco procedures, the overall profit of a company will increase due to customer reputation increase. Eco friendliness will provide market advantage for the company as a result of an increasing eco awareness of consumers. However, profit will happen at a later stage during the business compared to non eco procedures. The main reason was the initial investment required to transform a conventional production line into an eco one. In the long run, eco companies will outlast conventional companies, and achieve a higher overall profit. This research provided an insight for us regarding consumers' perspective. In today's society, consumers are changing their requirement from products. eco market will slowly outgrow conventional market. However, in developing countries, this is not the case. Consumers in developing countries are still leaning more towards conventional products due to lower price and easier access. Therefore in our research, we had to implement a way to motivate the customers toward eco actions.

(Long, 2009) Discussion and summarization of the paper is as followed: This research provided a Nash equilibrium strategy for the government and enterprise in terms of energy saving and emission reduction activities in a game. They concluded that in order for effective energy saving and emission reduction to happen, the enthusiasm of the enterprise must be of a high level. Also the relationship between the government and the enterprise is the key. A good set of law must provide the best interest for the two parties. At the end of the research, a few suggestions of laws and installment of institutions were made for the government and enterprise to cooperate. In developing countries, this is very hard to happen because the government and enterprise are basically on the same side. The government will not agree with actions that limits the activities of the enterprises due to economic reasons. Therefore in our research, we have to consider the relationship between the consumer and the enterprise and consumer and the government.

(Zhao et al., 2012) Discussion and summarization of the paper is as followed: This research was very similar to Long's research in terms of finding the balancing point between the government and the enterprise. However, issues of waste were added as one more consideration for the two parties on top of energy and emission. Another different approach that Zhao took was that he did not propose policies and institutes; instead he used gaming software ("gambit") to simulate the measurements. He concluded that the government should be the dominant force in implementing eco laws. As soon as enterprises started to adapt to the laws, the government can then ease off the pressure put on the enterprise because by that time the enterprise will be promoting eco friendliness due to the green market. Again with Long's research, the relationship between government and the enterprise is slightly different in developing countries. We cannot expect them to regulate each other; instead we need a new entity to provide the motivation.

(Chew et al., 2009) Discussion and summarization of the paper is as followed: This research simulated different methods of application, and provided information on how to successfully implement multiple water plants in an eco-park, by using a game theory. The simulation was run with profit, cost, and water resource as the factors of measurement. Basically, a Nash equilibrium solution was required for all the water plants participating due to everyone having their own self-interest in this scheme. Instead of using a role playing game where everyone tried to find out the best solution, computer simulation was run, and a sensitive analysis was also used to check on the fluctuation of the models. This research provided us with the insight of how multiple similar roles with slightly different interest is to find a best solution for the bigger eco scheme. In our research though, we will have similar roles (factories) competing against each other for the eco market. A balancing solution was not necessarily needed due to the competitive nature of similar enterprises.

(Zhang, 2008) Discussion and summarization of the paper is as followed: Zhang proposed a good mix of policies from the central government, with full supporting systems from the lower levels of the government was a good way to enforce eco activities. He promoted the use of eco labeling, green government procurement, and involvement of financial institutes to help promote green market to increase the effectiveness of eco friendliness. We thought that the government alone cannot achieve eco friendliness, as we are seeing from situations in developing countries. A political system alone does not have enough power to motivate the industries and public to transform into a green society. There were many more researches which suggested different strategies from the government; however, we concluded that those strategies were of minimal effectiveness, as reflected by the current state of developing countries.

(Tanimoto, 2005) Discussion and summarization of the paper is as followed: Tanimoto tackled the eco awareness issue from a more social perspective. He used four scores to measure behaviors of groups of companies. A shift of ego oriented value system to the frustration-free system is required for the society to move towards sustainability. The dilemma faced by companies when choosing to become eco is one huge factor. This is the exact same situation companies in developing countries are facing. The letting go of profit to pursue eco concept does not fit their ego oriented value system, therefore changes cannot be made. In this research, we implemented a government and consumer relationship as the source for pushing companies towards a more frustration-free value system.

(Magombeyi et al., 2008, Le Bars et al., 2007, Rajabu, 2007) Discussion and summarization of the paper is as followed: These three researches targeted the eco awareness in terms of water management. In Magombeyi and Rajabu's research, a board game called the "river basin game" was designed to increase water resource management awareness specifically in Africa. Players tool the roles of different farmers located along a river. Each of them regarded the water as a resource for their own interest, and cooperation and communication was needed to maximize the efficiency of water usage. In this game, the roles of consumers were presented and they had to solve the problem by themselves through negotiation and information sharing. The approach they took on having consumers as the main driving force of solving environmental problems provided useful insights for us because the integration of this role into the society was the important process.

(Dong et al., 2011) Discussion and summarization of the paper is as followed: Fang proposed the "bad money drives out the good money" phenomenon the society in terms of eco markets and products. He pointed out that the three main aspects that were hindering the society

towards an eco-transformation were market failure, government failure, and the social system itself. We saw a very similar phenomenon in developing countries, where the public is lacking information and action regarding eco products and eco activities. The government does not enforce eco policies enough due to the pressure and priorities installed by enterprises. This resulted in the "abnormal operation and paralysis of the entire eco-product market." However in the end Fang proposed three suggestions which emphasized on the importance of improving the eco market and the eco products. We suggested that those changes alone were not enough to change the current situation, and on top of that there were already many similar proposals presented by many researches. We thought that the most effective way to actually motivate the consumers is to provide some sort of direct incentive. In other words, instead of making the products more appealing to the consumers, make the process of buying the products more appealing.

(Mallidis et al., 2012) Discussion and summarization of the paper is as followed: Mallidis simulated strategies for companies in terms of transportation cost and emission reduction. He concluded that efforts made to decrease carbon dioxide emission by optimizing the supply chain network did not require a substantial cost because the strategy to decrease emission was often aligned to the strategy to optimize the supply chain. From his research, we realized that at times, optimizing of the transportation, inventory management also results in the minimizing of environmental burdens. In the game, we will try to recreate this phenomenon for students to understand and experience.

From the literatures we read, we could conclude that almost all of the researches tried to solve the environmental problems from the perspectives of policy makers, or the enterprises themselves. However, those implementations will only work well in situations where the

government and the enterprises both understand the importance of eco friendliness. In developing countries, that is often not the case, and instead from solving the problems from the government and enterprises' perspectives, we suggested that there is also a need for a strategy to motivate the consumers. In the table below, we showed a comparison of the positions of previous researches and this research. We took parts of what previous researches had proven, and add onto that the perspectives of the government/enterprise working with the consumers to achieve an ecofriendly social system.

Researchers	Govn't	Manufacturer	Consumer	Resource/ Waste	Energy	Emission
Pacheco et al., 2006		O		O		
Cowley B. et al., 2011			O	O	O	O
Pak M. and Brieva D., 2010			O	O		
Barari S. et al., 2012		O	O			
Long R. et al., 2009					O	O
Zhao R. et al., 2012	O	O		O	O	O
Chew I. et al., 2009	O	O		O		
Zhang Z., 2008	O				O	
Tanimoto J., 2005				O	O	O
Magombeyi M. et al., 2008			O	O		
Dong F. et al., 2011	O	O	O			
Bars M., 2007	O	O	O	O		
Mallidis I., 2012	O	O				
This research	O	O	O	O	O	O

Fig. 16: Comparing literatures

2.3 Originality of research

Our originality of this research is involving the three main players in the manufacturing industry: government, manufacturers, and the consumers. In advanced countries, most of the companies, and also the public possess high eco awareness. When companies and the public understand and accept the importance of being eco, little conflict will happen between them and the government eco policies. In the unique situation of developing countries however, a mutual agreement cannot be reached regarding eco policies and activities. As we mentioned in the background section, government in developing countries has a tendency to agree with the growths and policies of the companies due to the economic gain. This results in a stand-off between the government and companies, and the public. The needs and requirements of the public are often ignored or lightly treated. In a lot of cases, government will provide cover up for the companies.

Therefore in this research, we included all the three players in a game situation to show students that how the three of them can work together to reach a common agreement, especially in developing countries. The solution we proposed was based more on the social aspects of this problem, instead of focusing on the economic area. Most of the previous research tended to provide understanding and solutions from the government and companies' perspectives only. Those researches will be a better fit in advanced countries, where most of the possible problems are the negotiation between policy makers and companies. In developing countries, we see a unique situation of the public disagreeing with the government and the companies; therefore we added the role of consumers in our research.

As for the content of the game, we decided to include the three basic factors experienced by all manufacturers: waste, emission, and energy consumption. Due to the social scheme we

selected for our research, we did not target a specific type of manufacturing industry. We wanted to show the relationship of the government, manufacturer, and the consumer in terms of the actions the three of them can take to influence another. By only selecting three basic contents for our game, we could clearly show the effects of different actions taken by the three roles on the manufacturing process. Previous researchers focused on specific aspects of the manufacturing processes because they intended to understand the relationships on those specified subjects on a deeper scale. Since we targeted the whole social effect and change, we had to include more manufacturing subjects, but on a slightly shallower scale so that we do not over confuse the cause and effects (shown in the figure below).

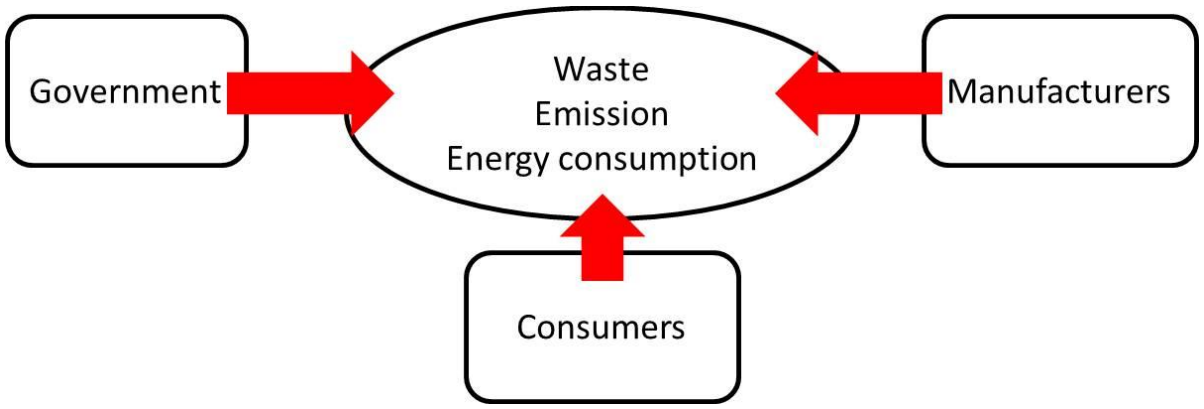


Fig. 17: Including of three players to affect eco issues

3 Research methods

3.1 Research process

This research started with the identification of the research problem. We took a look at the current eco situation around the world, and we noticed that there was a significant lag of understanding of the purposes and merits of factories adopting green production, especially in developing countries.

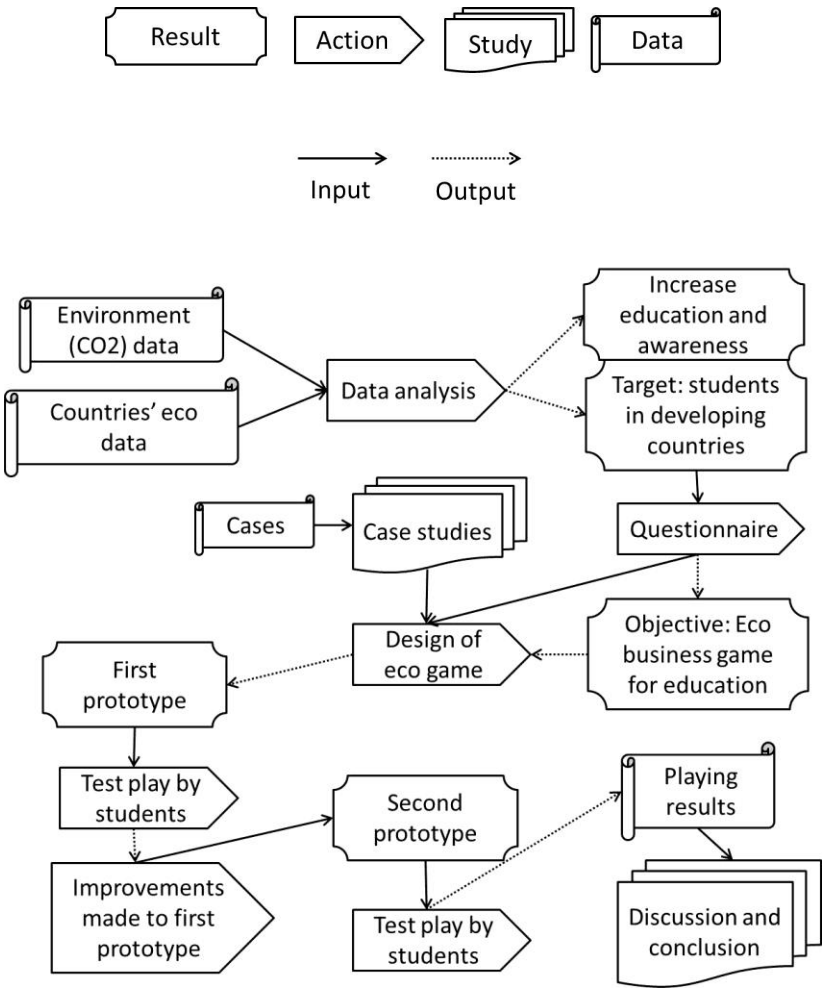


Fig. 18: Research process

3.2 Methods used for this research

3.2.1 Causal loop diagram

A casual loop diagram is a tool useful for presenting variables and their relationships with each other visually. We used the two causal loop diagrams to highlight our focuses for this research. The first diagram focuses on the society aspect of this research. We made a comparison between students and current factory employees in terms of how they can be affected by eco education, and how the knowledge gained will be applied. The second graph focuses on the basic concepts of eco management in a factory setting. We used the graph to understand the requirements and consequences of eco options available in factories.

3.2.1.1 Requirements from casual loop diagram

In the first graph, we showed that the initial effects of eco education for students and current employees can be very similar. Both of the groups will gain eco awareness and understanding, and both of the groups will want to take actions to improve the environment. However, in the current employees' situation, they will face the final decision makers along the process of trying to make a change. The final decision makers will be the obstacle that the employees cannot overcome, especially in today's developing country. Eco demand in current developing countries is simply too low compared to the developed countries. Companies will have a very difficult time sustaining their business if emphases are put on implementing eco procedures. On top of that, the focus on keeping the profit as high as possible from managements in developing countries will disagree with employees who wants see a change towards a greener output, which means less profit due to more investment. In the students' case, improvements and applications can be carried out easier for many reasons. One reason is that the students will be

the next wave of employees. They will not only be bringing the awareness and knowledge into companies, but also they will become the new decision makers. Even before that process takes place, they will become the new customers that will increase demands of green products and green procedures. By affecting current students, the transformation from conventional mindset to eco mindset will be much easier and smoother than trying to affecting the current generation.

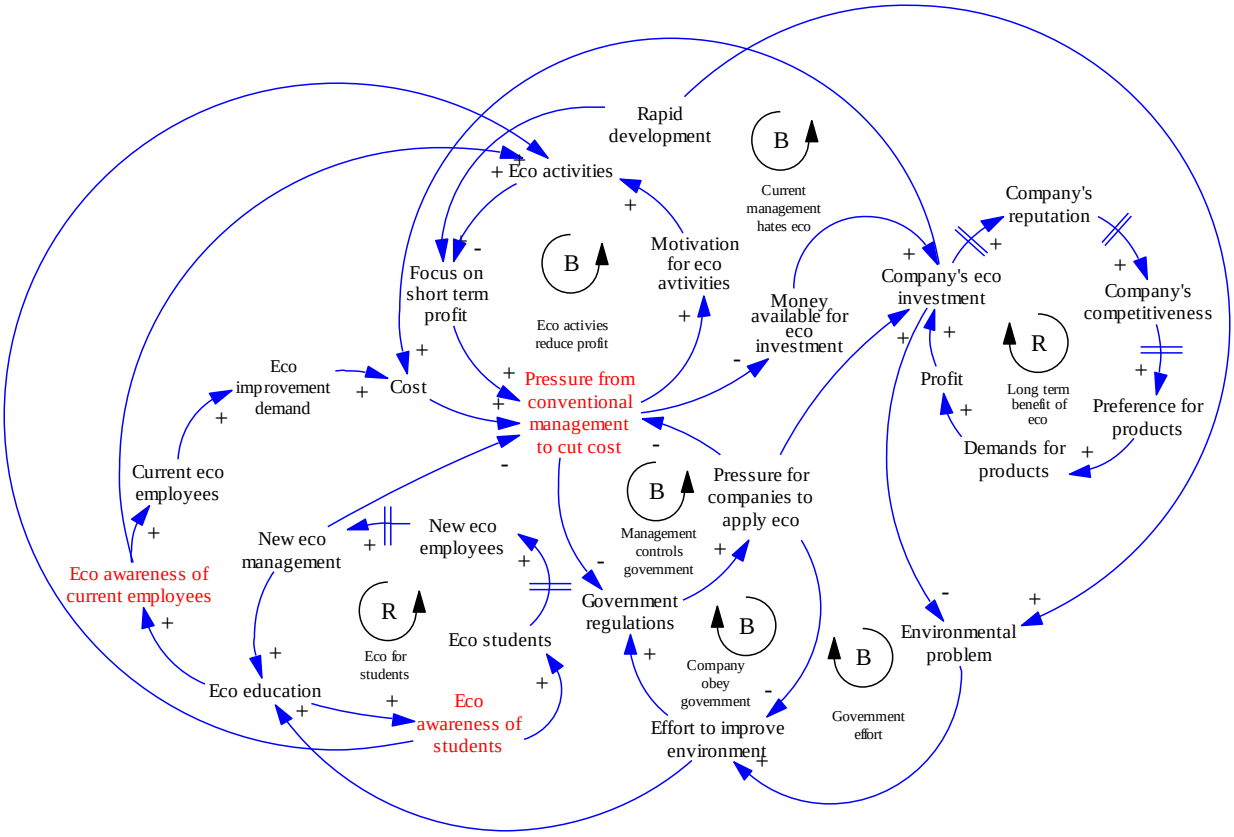


Fig. 19: First causal loop diagram in this research

The second graph shows the basic measurements affecting companies we chose to focus on in this research: waste, emission, and energy consumption. A large portion of eco management is about making tradeoff decisions. Usually the decisions involve two major variables: money required, and eco effectiveness. It sounds like a very simple calculation, similar

to a seesaw. However, when all actions involved have an effect on money and eco effectiveness, the relationship can become more complicated. This is why we used the causal loop diagram to help us identify the tradeoff relationships involved, and implement them in the eco game that we designed.

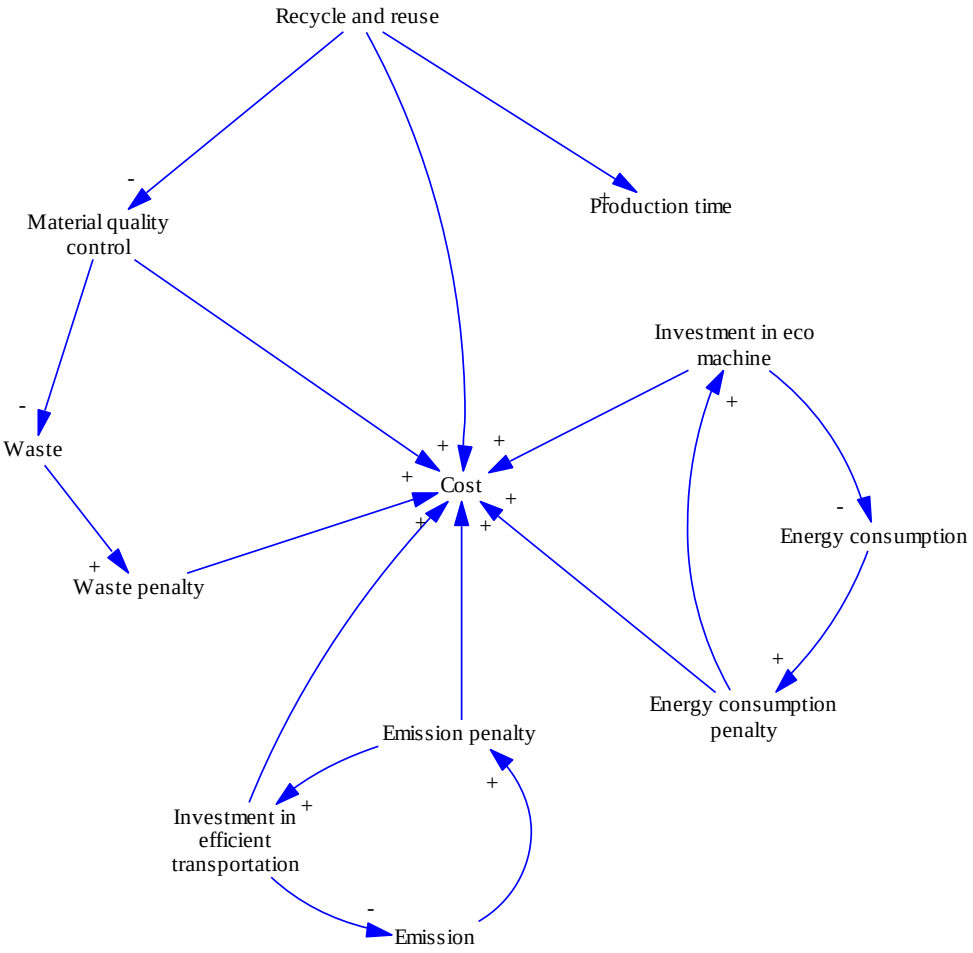


Fig. 20: Causal loop diagram of the factory concept used in this research

3.2.2 Stakeholder analysis

We used stakeholder analysis to identify all possible stakeholders that will be involved in this research, and the relationship between them. Due to this research being a design of an educational tool, most of the stakeholders will be the ones receiving the education (students in our case), and the ones who will be administrating the education (teachers in this case). In the table below, we listed the stakeholders and brief explanation of their interest and positions.

Stakeholders	Roles	Activities	Potential benefit
Teachers	Education provider	• Deploys the business game to educate • Evaluates the effectiveness of the business game	• Additional effective way of teaching
Students (from university freshmen – master second year)	Education receiver	• Uses the business game to learn	• Increased understanding of subjects taught • Increased motivation for learning
Educational institutes	Location provider	• Provides rooms/hall for students and teachers to play the business game	N/A
Factories	Cases/examples provider	• Provides facts/numbers/insights for the game developer to be used in the business game	N/A
Society	Personnel provider	N/A	• Social changes due to education
NGO	Service provider	• Provides a platform for the business to be implemented in more locations	• Money

Fig. 21: Stakeholder identification and description for this research

After we listed potential stakeholders and briefly described their involvement and activities, we used a power vs. interest grid to further present the level of involvement of each stakeholder in this research.

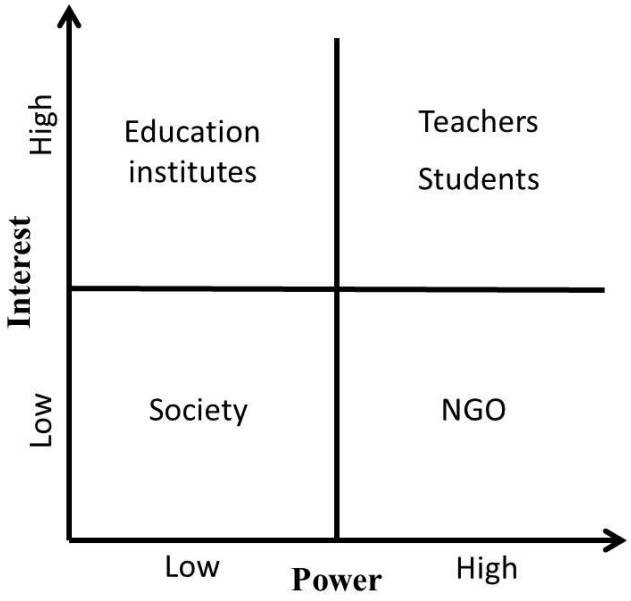


Fig. 22: Power vs. Interest grid of stakeholders for this research

The grid showed that in this research, the teachers hold high power and high interest because they are the decision makers when it comes to the usage of the game we designed. They decide when and how the game is to be used to teach students, and also if the contents of the game needs alteration to suit their needs. The students have high interest in this business game, which we concluded by conducting a questionnaire. They also have high power over the game in terms of feedback and results. Educational institutes have high interest on the potential education effects brought in by the game, but their power over the game itself is limited. From the grid, we concluded that the opinions and suggestions of teachers and students need to be taken into account in order to address the issue at hands.

3.2.3 Questionnaire

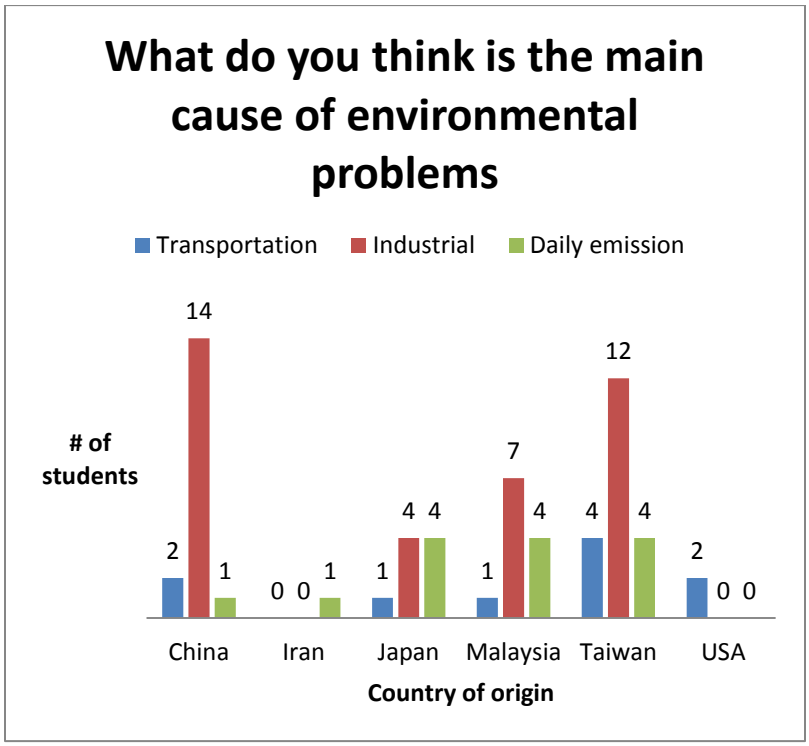
Questionnaires are used to gather statistical information directly from respondents. We used questionnaire in this research to collect information from students regarding business game involvement experience, and the level of understanding of eco issues. Also we were able to acquire requirements from the students as the input for the game. A total of eighty students took the questionnaire, and we were able to derive useful information for our game designing process.

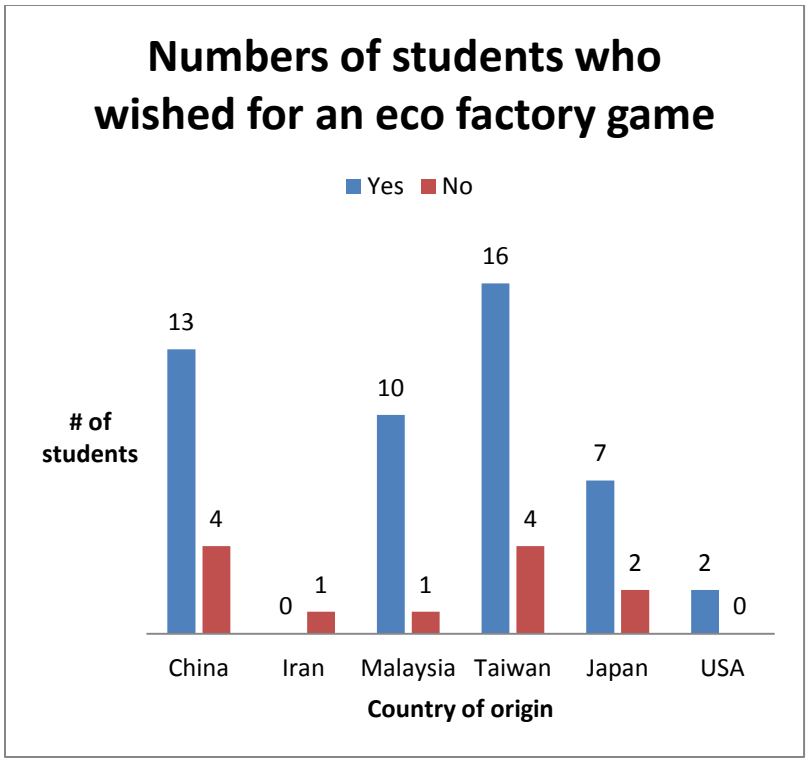
3.2.3.1 Requirements from questionnaires

All the eighty respondents are active students ranging from first year university students to doctorate students. Nineteen percent of the respondents have a background of developed countries, and the remaining respondents are from developing countries. The questionnaire we created served two purposes: the first purpose was to find out background information and opinion regarding business game involving experience, and also preference regarding the business game formats and purposes. Of the respondents who have experienced business games, sixty two percent of them did it in schools, while the others having done it in workshops and individually. The average rating of the effectiveness and enjoyment of business games as an educational tool (based on a 1 to 5 scale) was a 4.31 and 4.50 respectively. According to the respondents, the most important factors of a good business game are the fun element of the game itself, and then ability to encourage thinking and judgments. To our surprise, the one of the least important factor is the realism of the game. Regarding to the format of the business game, fifty five percent of the respondents revealed that they prefer board/block type of business game similar to the beer game. Another thirty eight percent thought that physical games, where

participants are required to move around, are preferred. The final eight percent of students prefer computer simulated type of business game.

The second purpose was to find out current students' mindsets and understanding regarding eco issues and methods. We wanted to provide an educational tool that will attack the areas in which current students think that most improvements and aids are required. This way we can make sure that this tool will be as straight forward and effective as possible. Regarding the cause of environmental issues, sixty one percent of the students considered industrial activities created the biggest source of pollution and problems, followed by twenty four percent of students saying that daily energy consumption contributed the most. Finally, in order to understand the basic concepts of eco management, eighty percent of the students suggested that they would be interested to participate in a business game simulating factory production with eco management and decisions.





Based on the above information and requirements we collected from current students through questionnaire, we proceeded to designing a business game that would include all the major factors preferred by the highest percentage of students. Our business game would be a board type game with a factory setting, and decision making mechanism based on the "3R" concept.

3.2.4 Case studies

In order include realism in this business game, we first took a look at what are some procedures, methods, and strategies that companies are currently using in the real world. We chose some main concepts used in real world that we thought would be important for students to understand, simplified where necessary, and applied it into the game. We used examples that are not totally unknown to target students because we wanted to students to have some basic

understanding of the issues at hand, and perform according to what they already knew during the game. Once they finished doing what they thought was enough, we would then show them consequences or extra considerations that they did not notice beforehand. For students with complete understandings of the topics presented in the game, it would be a good chance for them to take on leadership, and physically experience the concepts.

Case studies were the main sources of idea we used when designing the game. Most cases studied took place in Asia, and the industries involved ranged from farmers, food processing to cars, metal and chemical. We studied a wide range of industries in order to extract the core concept of eco management. We did not want to specify an industry because the environment and common practices of that industry would make the content of the game too narrow for our target students.

3.2.4.1 Requirements from case studies

We derived two main concepts from our case studies. The first concept was the waste management hierarchy of the "3R" concept. In normal circumstances, reducing waste is the best method in managing waste, followed by reusing, and finally recycling. Due to the extra investments and pollutant as a result of implementing reusing and recycling, those two methods will be less effective and less eco compared to plain reducing the waste generated. We wanted to make sure that the decisions that the students make in the game will reflect this reality. The second concept was "factory clustering". Basically that means multiple factories gather around and share resources and wastes. In reality, there are numerous occasions where one factory's waste can be used by another factory as material. However, in order for that to happen, extra costs, extra transportation, negotiations between companies might be required. Therefore that

adds another layer of strategy available for students to utilize when they try to manage the production during the game. (Shi et al., 2010, Panyathanakun et al., 2012, Anh et al., 2011, Vachon et al., 2008, Zhu et al., 2007, Eltayeb et al., 2011, Lee, 2011, Koplin et al., 2007, Zhu et al., 2004, Hsu et al., 2012)

3.2.5 Prototyping

We applied the prototyping process similar to computer game developers to design our game. First, a prototype was created based on initial requirements. Then we invited students to play it to find out the "bugs" of this game, and then we made improvements to create the next version of prototype. We repeated this process a few times until the game flow became smooth, and the measurements and calculations reflected the concept that we wanted to teach to the students.

3.2.5.1 First prototype (conventional factory game, based on ETH Zurich's logistic game)

The first prototype was based on the basic concept of ETH Zurich's logistic game. ETH's logistic game simulates a production line in a factory. We tried to recreate the game flow to understand the main operations in a production line, and the importance of quality, cost, and time in a conventional factory.

3.2.5.2 Second prototype (eco factory game)

After testing the first prototype and making sure that the operation flow was smooth, we proceed to making the eco factory game. We took the core concept of the flow of a material supplier, a product manufacturer, and a customer, and transformed that into our eco game. We

added measurements of waste, emission, and energy consumption on top of the original quality, cost, and time measurements.

4 Development and results of the games

4.1 Conventional factory game

Before we started designing a game, we had to decide on the theme, or setting of the game. As mentioned in above sections, we chose to create an education tool focusing on the environmental issues. As countries industrialized, pollution in many forms were created and released into the atmosphere. Today, industrial CO2 accounts for 85% of the cause of global warming, the top cause. The second and third causes are then transportation emission and methane emission. With this fact, we decided to design our business game with a factory setting in order to address the most serious issue at hand. To start off our design, we first tried to recreate a factory game based on ETH Zurich's logistic game. ETH Zurich's game highlights the production process inside a single factory. We took the base model of the game and created our own version of a factory business game. The purpose of doing this was to see for ourselves the essence of a factory production. The eco factory game that we wanted to design would include a lot of core manufacturing concepts based on current factory manufacturing processes.

The conventional factory game simulated the production process from material supplier, to manufacturing stations, quality checks and reworks, and back for the customers. It consisted of simple operations carried out by all the players involved: for example parts assembling, transportation, quality checking, and shipping for the customers. The game layout of our conventional factory game can be seen below.

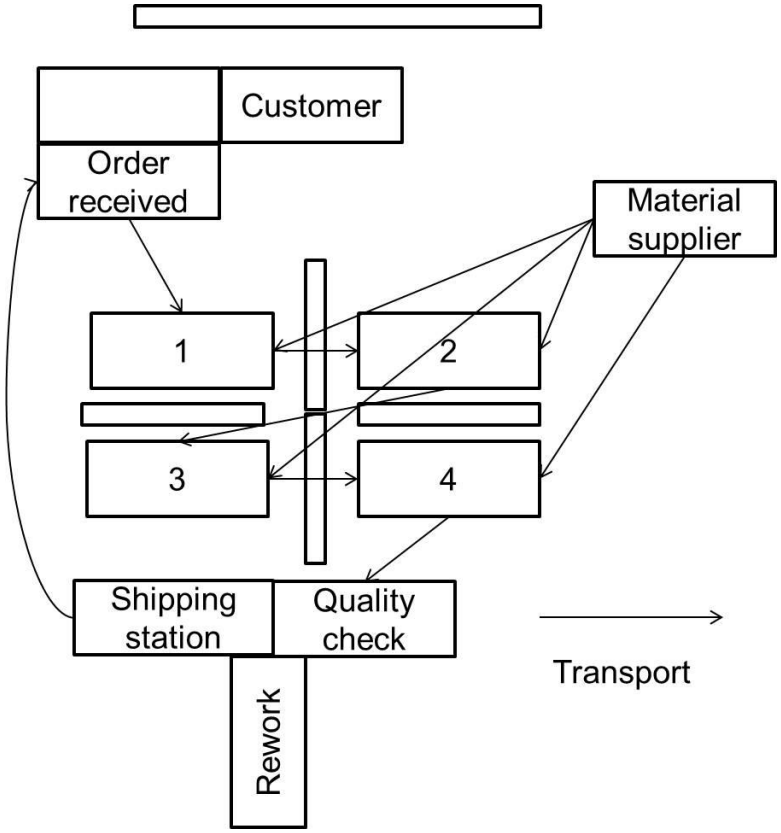


Fig. 23: Layout of the conventional factory game

The game started with working stations far apart from each other. The objective of the game was to minimize the waste of time for transporting, the manufacturing bottlenecks, and to satisfy customer's demand.

4.1.1 Results of the conventional factory game

After playing the game, students were able to understand the importance of the quality of products assembled. With the increase of product defects, a serious bottleneck was created at the quality checking and reworking stations. Every assembling station must first make sure that the products they produced were ready for the next stage in the assembling line. Quality checking and reworking does not add value to the product and the production. It is a correcting and

repeating process, therefore students must make sure that time and cost are not wasted on such a procedure in a production line. Another lesson learned by the students was the importance of bottlenecks at the assembling stations. For this issue, students combined different methods to improve the situation. The reassigning of workers and rearranging of the tables resulted in improvements to the whole production line.

4.1.2 Feedbacks received from the conventional factory game

The lessons we learned from the conventional factory game became the new direction and requirements that we had to reflect for our eco factory game. The first feedback received was the speed of the game. In order to reach the eco stages of this game, improvements of the current production line had to be made first. By including the time needed to perfect the manufacturing stations, the players were confused by the true purpose of the game. Players suggested that production line in a game with eco setting should be set up in a way that eco procedures could be carried out almost immediately. This way the students could focus on the main objective of the game, and the purpose of the eco factory game could be met much easier. The second feedback was about the product assembled. The two versions of products used in the conventional factory game were both too complicated for the players to assemble. Due to the complexity, a large amount of time was required to make changes to the product, even if the change was a very small one. This resulted in most of the focus and time spent during the game was to alter the product, instead of to think about the manufacturing process as a whole.

4.1.3 Additional requirements for the eco factory game

After we made improvements to the conventional factory game according to feedbacks from students, we proceeded to defining and setting the eco concepts that we wanted to use for the eco factory game. We first took a look at the environmental situations in developing countries. The eco factory game will be used to help in educating students in developing countries; therefore we wanted to include issues or methods that affect them the most. We concluded that three major polluting factors would be the most important and appropriate contents to be included in the eco factory game: carbon dioxide emission, energy consumption, and waste. As mentioned in chapter 1, the problems caused by carbon dioxide emission in developing countries have been increasing rapidly in the past twenty years. The result was the worsening of global warming, and serious air pollution, especially in major industrial cities like Beijing, Guangdong, Jakarta and so on. Energy consumption is very closely related to carbon dioxide emission. The more energy is required, the more carbon dioxide emission will result due to coal burning, fossil extracting and so on. It is therefore essential to consider both carbon dioxide and energy at the same time. We defined waste in this research strictly as industrial waste produced from the manufacturing process. Waste is one of the main cause of increasing landfills and soil and water pollution in developing countries. It also affects directly the wild lives in the surrounding area. In figure 22 below, the waste generated and collected by different regions in 2012 was shown. One can see the lower collection rate of generated waste in the African and Asian region. (Japan is also included in the Asia Pacific region, which means that the collection rate of developing Asian countries is actually lower from what is shown in the graph, given that Japan, by itself, has a waste collection rate of approximately 85-90%) The reason could be lack of technology, lack of a supporting government plan, or lack of money.

However, the more important issue we wanted to point out is that with high eco awareness, all of the reasons listed above could have been solved more or less.

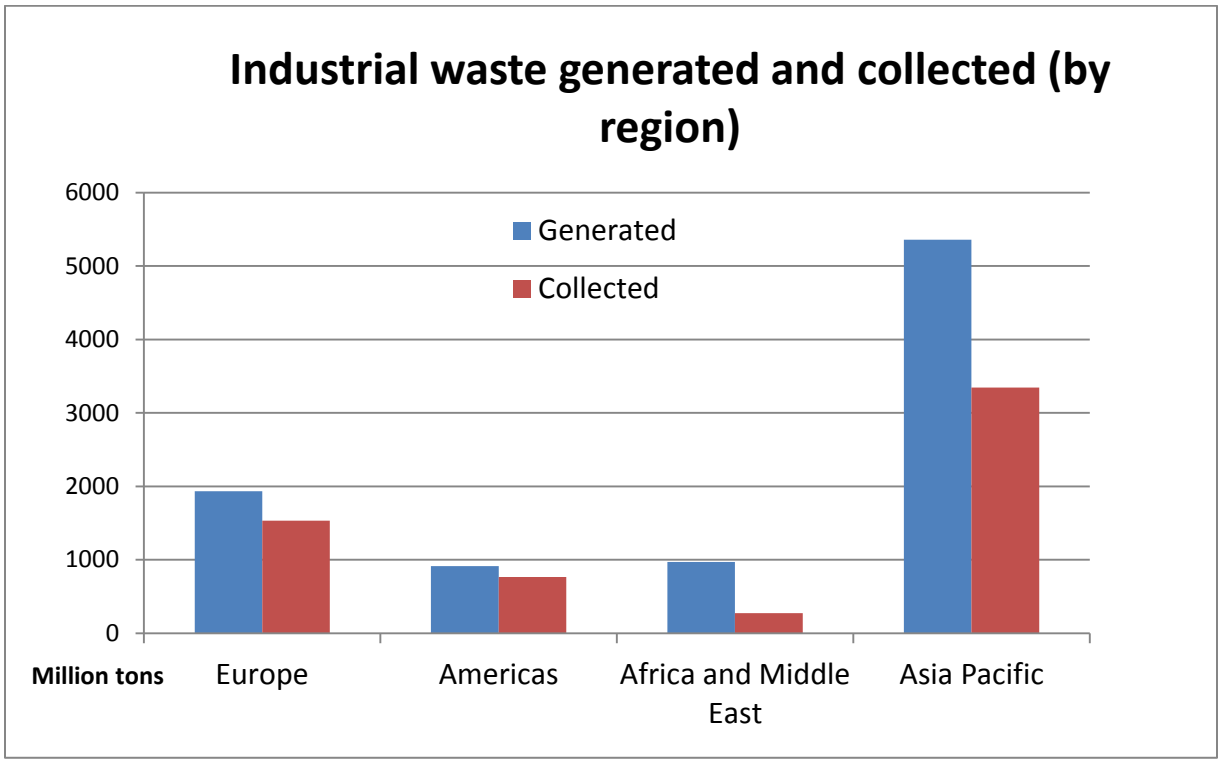


Fig. 24: Industrial waste generated and collected (by region)(source: Frost and Sullivan, 2012)

Another additional requirement for the eco factory game was the involvement of the government in the whole eco system scheme. From figure 7 shown in section 1.2.2, one can clearly see that the most European companies engage in eco activities voluntarily. Unfortunately, that is not the case in developing countries. In order to effectively carry out eco activities, enforcing laws and incentives must be implemented in developing countries.

4.2 Eco factory game

The eco factory game was designed to include improvements made from the convention factory game, and the new requirements discussed in the previous section. As expectations and demands from the society changes, the effects of current factory games became obsolete. Therefore, the need of a new business game aimed to educated students with new information was required. The eco factory simplified the process of production, while keeping the major stakeholders intact. The layout of the game is shown below.

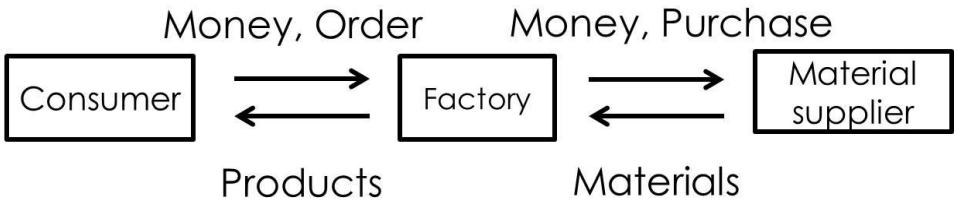


Fig. 25: Layout of the eco factory game

The students will be divided into three different roles. The main objective is to maximize profit. The game will be played three times (we called it three "games"), each game consists of ten rounds, and each round lasts two minutes. The reason for playing the game four times was to simulate increasing regulations from the government. As pollutants' penalties increase, the teams will have to battle against increasing cost to penalties while satisfying customers' demands.

There are three main stakeholders that we simulated in our game, material supplier, factory, and customer. The first stakeholder is material supplier. It is the source of any kind of production, and it plays a very important role in contributing to the production and environmental outcomes due to the fact that the materials supplied will affect the strategies of the

factory. The second stakeholder is the factory itself. The factory is the major decision maker in our game. The basic decisions include materials used and production strategy. However as the game progresses, more and more strategies will be needed to keep the production flow. The third stake holder is the customer. Customer creates demands which the factories will have to fulfill to make profit. Similar to the factories, the customer's demand will change according to the performance of the factories as the game progresses with additional rules.

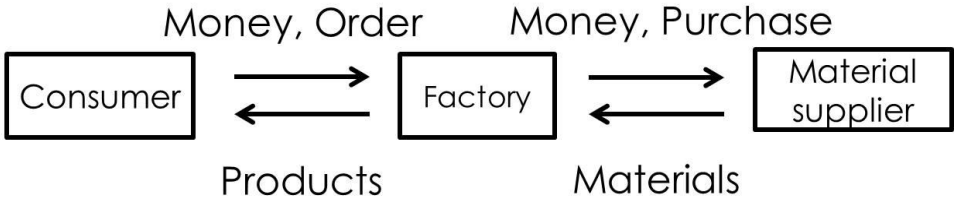
The concept we used when designing the product was based on quality and production strategy differences. There are two versions of the product that the factories can choose to make. The first version simulates a high quality, eco product. It requires high quality materials to make, and the price at which it can be sold is the highest. The second version simulates a normal quality product which only requires fifty percent of the high quality material, and it has a lower selling price. With two different types of products available for the factory to produce, we added the element of decision making for the students. Since material comes in a set and the amount of pieces is fixed, it is up to the factory to decide the usage of the materials.

The material supplier will supply two kinds of material sets: a premium set and a standard set. The premium set costs more, carries more pieces of materials, and contains less waste. The standard set costs less, carries less pieces of materials, and contains more waste. We designed the material suppliers the way they are to simulate changes in material acquiring technology, and waste generation. One example of improved material acquiring technology is changing the cutting pattern of a machine to acquire more useable small pieces of metals from the same piece of metal, or changing the shape of the metal pieces supplied in order to cut them more efficiently in the factory. The waste carried in both of the sets is to simulate that waste is impossible to be eliminated. In the same example discussed above; whether it is changing the

cutting machine, or changing the material piece itself, additional process has to be made somewhere in the material supplying flow, therefore waste cannot be fully eliminated.

The factories are the main focus of the eco factory game. They will be in charge of making production decisions and material strategy. The different production mixtures and material ordering they applied will result in different profit and different expense. As the games goes on, penalties will be incurred on all pollutants. That will result in addition thinking of movements to maximize profit.

For the simulation of the customer, we applied a mix of push and pull system. The customer will order an amount of products every round. The factories will need to satisfy the quantity ordered by the customer. The types of materials used are depended on the strategies taken by the factories. For example, the customer orders three eco products, and two normal products. The factory can deliver the orders using all premium materials, all standard materials, or a mix of both. The reason for this type of order satisfying mechanism used in the eco factory game is to add a decision making element for the players to achieve learning and understanding of their own actions.



Products	Characteristic	Price	Materials	Characteristic	Price
Eco product 	• Recyclable	• 120	Eco set 	• Less waste • More high quality material	• 60
Normal product 	-	• 60	Standard set 	-	• 30

Fig. 26: Operations of the eco factory game

Every round new order will be issued by the customer. The factories will decide on the amount and type of material they will use to manufacture the products. The process is repeated for ten times. After that one game ends, each team's profit is calculated and compared. The teams will have a period of ten minutes for discussion. They can take a look the result of the finished game and make strategic changes. After the discussion period is over, the game will resume with a new game with additional new rules, and this process will repeat for one more time until the whole game finishes.

We will explain the game in terms of CVCA graphs and equations. After every game, the team's profit will be calculated by the simple equation of:

Each game is defined as Gi, where i =1, 2, 3,
Each team in the game is defined as Tc, where c=red, green, yellow
(Gi,Tc)

Main objective of the game:

$$Profit(Gi,Tc)=Sales(Gi,Tc)-(Variable\ Cost(Gi,Tc)+Fixed\ Cost(Gi,Tc))$$

Fig. 27: Basic equation of the game

After game 1, there will be new rules introduced which players had to abide by. The rules served as new constraints of the factory operations. For game 1, students do not have to worry about rules and penalties, as the only measurement taken is the amount of inventory and orders of materials. Therefore, the equation for game 1 is as followed:

Profit(G1,Tc)=Sales(G1,Tc)-(Variable Cost(G1,Tc)+Fixed Cost(G1,Tc))
Sales(G1,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G1,Tc)=Material Cost(G1,Tc)+Inventory Cost(G1,Tc)
where,
Material Cost(G1,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G1,Tc)=15*N(square piece)
Fixed Cost(G1,Tc)=100

Fig. 28: Calculation for game 1

The activities and flow between roles in game 1 is as followed:

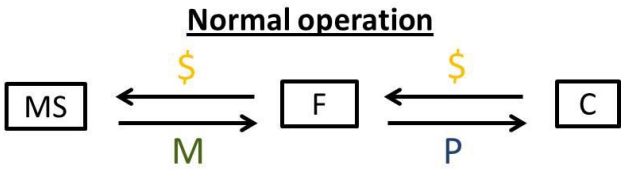


Fig. 29: CVCA for game 1

The three squares represent the three roles in the game. “M” stands for material, and “P” stands for products. For game 2, waste penalty is added as a new constraint in the following equation:

Profit(G2,Tc)=Sales(G2,Tc)-(Variable Cost(G2,Tc)+Fixed Cost(G2,Tc))
Sales(G2,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G2,Tc)=Material Cost(G2,Tc)+Inventory Cost(G2,Tc)+Waste Penalty(G2,Tc)+Recycle Cost(G2,Tc)
where,
Material Cost(G2,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G2,Tc)=15*N(square piece)
Waste Penalty(G2,Tc)=20*N(black piece)
Recycle Cost(G2,Tc)=5*N(products recycled)
Fixed Cost(G2,Tc)=100+Recycle Tech(500 if invested, else 0)+Truck Tech(100 if invested, else 0)

Fig. 30: Calculation for game 2

Included in the fixed cost of game 2 is an option for students to think about. To implement or not to implement is up to the students according to the strategy they choose. The CVCA for game 2 is as followed:

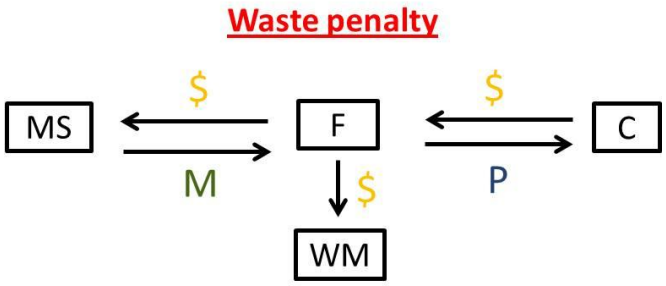


Fig. 31: CVCA for game 2

In game 2, the players will pay additional penalties with every piece of waste generated to "WM", which stands for waste management. What we wanted the students to do during game 2 were to purchase only eco material sets. Due to the reason that eco material sets provide more high quality materials and less waste, it will effectively cut down cost and waste count for students. In the graph below, we presented three pure strategies choosing scenario for maximizing profit during the game. As we can see, starting from game 2, if the students did not apply the strategy of using only eco material sets, they would not be able to achieve the maximum profit that they can receive.

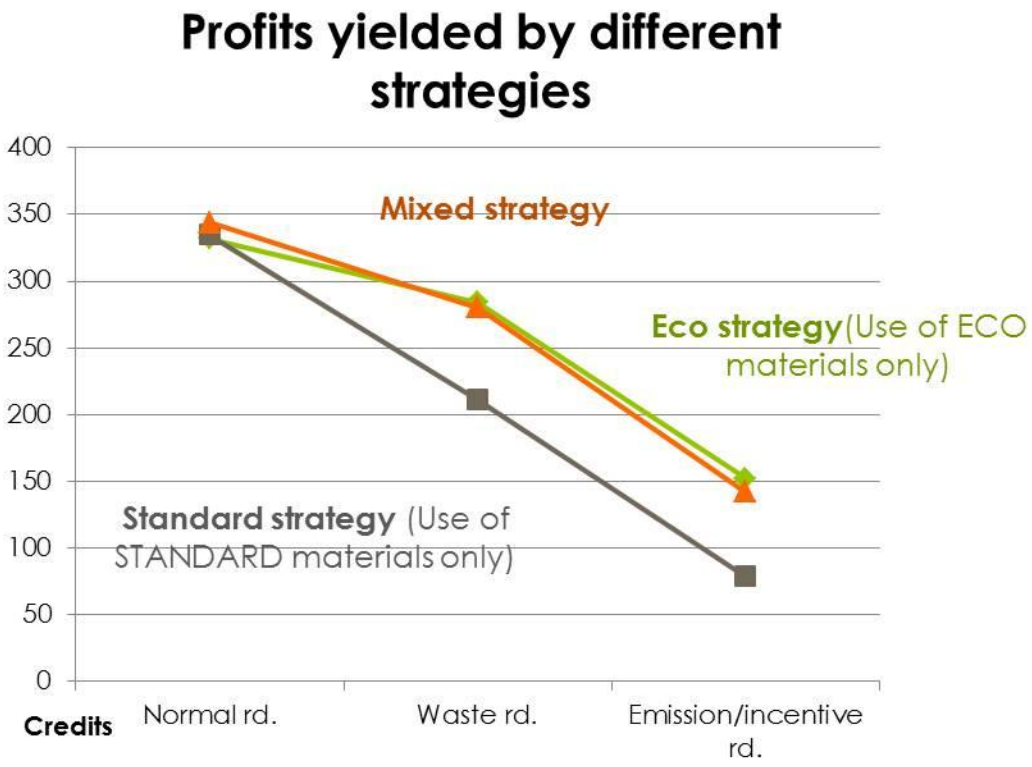


Fig. 32: Maximum profit available to students during each of the game rounds

Finally in game 3, additional rules of emission and energy are added, and the equation is as follows:

Profit(G3,Tc)=Sales(G3,Tc)-(Variable Cost(G3,Tc)+Fixed Cost(G3,Tc))
Sales(G3,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G3,Tc)=Material Cost(G3,Tc)+Inventory Cost(G3,Tc)+Waste Penalty(G3,Tc)+Recycle Cost(G3,Tc)+Emission Penalty(G3,Tc)+Energy Consumption Penalty(G3,Tc)
where,
Material Cost(G3,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G3,Tc)=10*N(square piece)
Waste Penalty(G3,Tc)=20*N(black piece)
Recycle Cost(G3,Tc)=5*N(products recycled)
Emission Penalty(G3,Tc)=60*N(trips by trucks)
Energy Consumption Penalty(G3,Tc)=100*N(number of players in production)
Fixed Cost(G3,Tc)=100+Recycle Tech(500 if invested, else 0)+Truck Tech(100 if invested, else 0)

Fig. 33: Calculation for game 3

The CVCA for game 3 is as follows, with two additional roles:

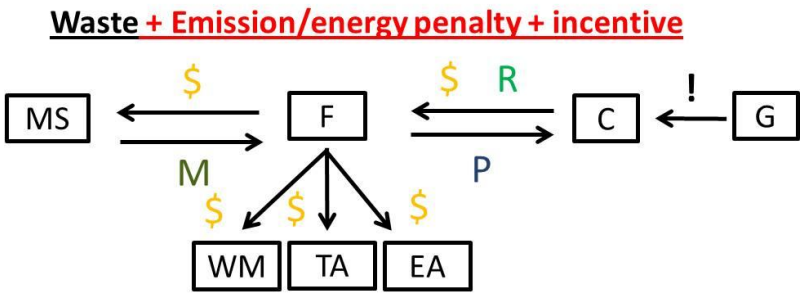


Fig. 34: CVCA for game 3

Two additional roles were added in game 3, "TA" and "EA". "TA" stands for transportation agency, which will collect penalty from the factories for every trip their transportation made. "EA" stands for electricity agency, which collects additional penalty from the factories for the energy consumed. "G" stands for government, which will provide incentive for the consumer to take products back to the factories for recycling. We wanted to see that with the introduction of government incentive, consumers will be more willing to participate in eco activities. The graph below shows the result of full consumer cooperation with the government to achieve a more eco society. Assuming that all eco products are recycled by the consumers with the help of government incentive, we can see that the factory will make a profit higher than the best strategy available to the factory.

Fig. 35: Profit gained by factories without recycling, and with 100% recycling rate by the consumers

4.2.1 Results of the eco factory game, first test

The game was tested three times by three different groups of students. The first test took place over a span of three weeks in December. Eight master students from the English business engineering lab of SDM in Keio University took part in the tests. The game was tested on the

Hiyoshi campus of Keio University. The first tests were intended to run the game in a "closed beta" situation. The test players repeatedly play the game to make sure that the game functioned as it was intended to. The measurements used for strategy performance were tested and changed in order to represent each team's decisions in the best way. Two distinct results can be seen from the first test. The first result was the difference in profit made between two teams who used different strategy. One of the waste management lesson we included in the game was the waste hierarchy of the "3R" (reduce, reuse, recycle) concept. In normal circumstances, the most efficient method in terms of return on invest is reduce, followed by reuse, and the least efficient method is recycle. The team who utilized the reduce strategy more than reuse or recycle have a higher profit then the teams who chose the opposite. The result is shown below in figure 32.

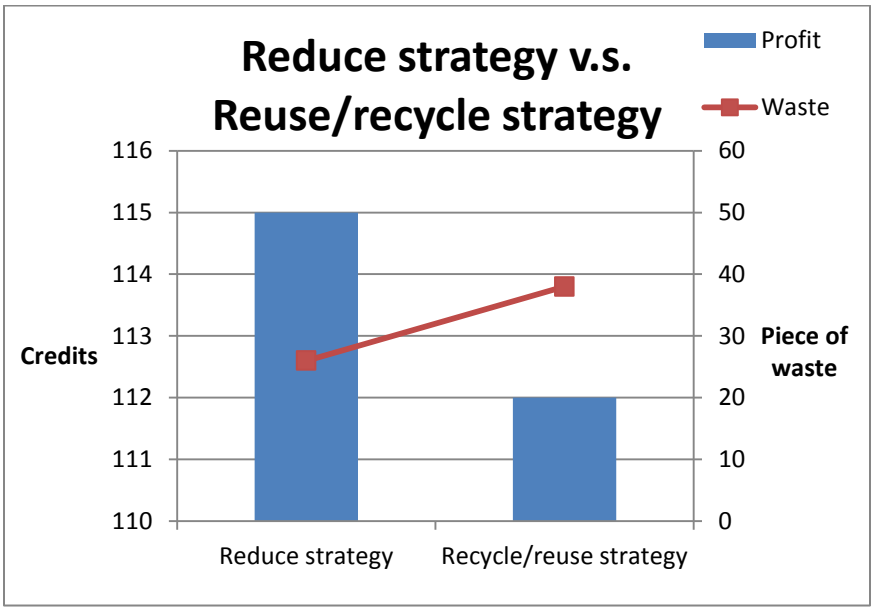


Fig. 36: Reduce vs. Reuse/recycle strategy

The reduce team tried to reduce waste by only using higher quality material sets while the recycle/reuse team used a mix of premium and standard materials. After the game ended, the

reduce team showed a high profit (credit in game) than the recycle/reuse team. The waste generated by the reduce team was also lower. Another distinct result was that as the game progressed, the teams were able to quickly find a way to more efficiently reduce the waste either by ordering better materials, or better managing the material ordering strategy. The result can be seen in figure 33 below.

Fig. 37: Profit and waste at the end of the game

We took the result of one team during the game. The profit decreased constantly till the end of the game, which was normal due to the way we designed the game. However, the significant result was that with everything else remaining constant, the team was able to continue to find ways to reduce the waste. The gap between profit and waste amount became closer and closer as the game went on.

4.2.1.1 Lessons learned from the first test

Due to the nature of the first test not focusing on the education aspect, but on the function of the game itself, we could only acquire limited data on the lessons learned by the students. In the later tests, the students learned the priorities of the "3R" methods. In terms of the efficiency measured by the return on investment, the reduce method is more efficient than the reuse method, which is then more efficient than the recycle method. As mentioned above, one team was intentionally instructed to apply only reducing methods, which means that the team would use only high quality materials. The other team was free to apply whatever strategy they wanted in order to maximize profit. We designed the game in this way to reflect the fact that reducing is the best way when one considers being eco, and the team that utilized the reducing concept the most would end up with the highest profit.

One lesson that we learned from the students after test 1 was the importance of keeping track of one's own eco activity throughout the manufacturing process. Initially we designed the flow of the game so that the students would only know their performance after one game was finished. However, students reflected that they would prefer to know all the consequences of their actions on the fly so that they could plan more accordingly. For the next two tests, we added this element into the game to satisfy the needs from the students.

4.2.2 Results of the eco factory game, second and third test

After the first test, two more tests were done with an intention to test the game as an education tool like we intended. The second test was done on January 19th, 2013. Participants consisted of three students from graduate school of Bunkagakuen Daigaku, and three students from SDM. The third test was done on January 20th, 2013. Five participants from assorted

colleges and universities, and four students from SDM took part in the test. Since there were three manufacturing factors, and three social roles we included, results related to each of those factors and subjects will be shown below.

The first major result shown is related to waste reduction. The red and blue bars represent premium material sets ordered and standard material sets ordered respectively. The orange line represents the waste accumulated at the end of each game. Every material sets come with waste, and the number of waste depends on the set of the materials. Premium materials cost higher for the factory to acquire, but the number of waste is lower, and the quality of the material is also higher. Team red was able to perform very closely to how we expected players should perform. As the game went on, they showed an increase in the ordering of premium material sets, a decrease in the ordering of standard material sets, and a significant decrease in waste. The results of team yellow and team green were similar to that of team red's, however, they showed a little bit of uncertainty regarding material ordering strategy and waste decreasing. In team green's case, they showed a significant decision in game 2, when they almost ordered premium material sets exclusively. However in game 3, they took a step back and increased their standard material set ordering.

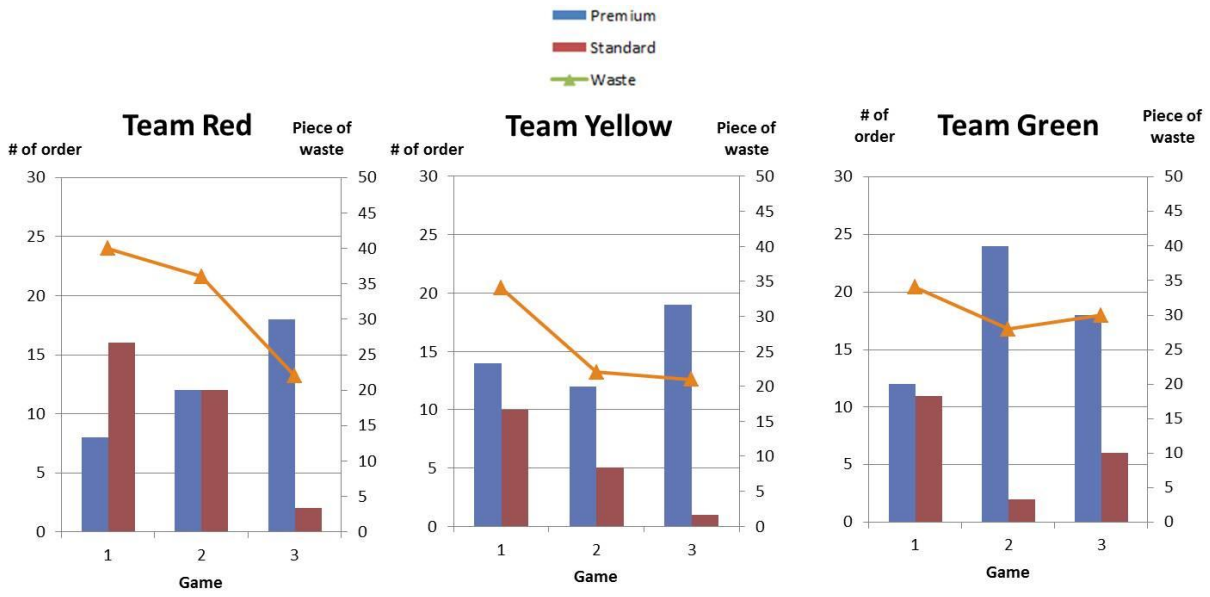


Fig. 38: Results of the three teams in terms of "waste"

The second major result shown below is related to the emission by factories. The blue bars represent the number of times the teams ordered materials. The red lines represent the number of times transportation was requested in order to receive materials, or to deliver the products to the customer. Team red showed a decrease in both times ordered and numbers of trips made by the transportation. Team yellow showed a big improvement in terms of both orders placed and trips made at the end of game two. However in game three, they rebounded a little bit back up. All three teams performed the same at the end of game three, meaning that although that although the approach teach team took was different, they were able to understand the rule of the game and resulted in the same efficient way.

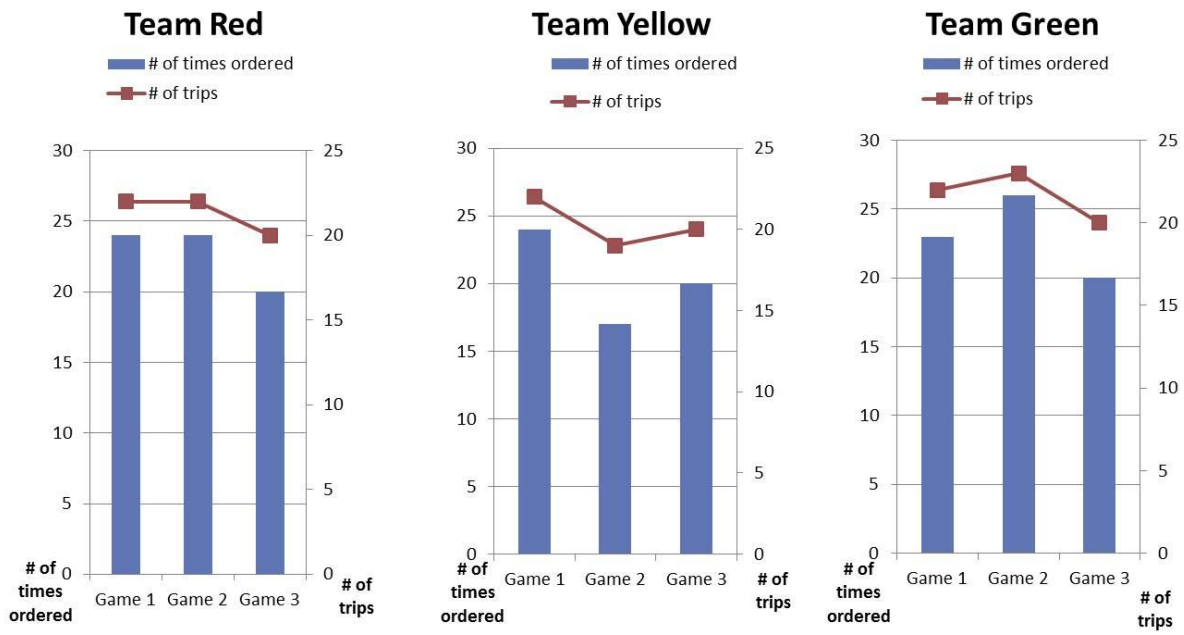


Fig. 39: Results of the three teams in terms of "emission"

The third major result shown below is related to how with the help of the government, the customers can change the manufacturing processes. During the game, government incentive was given to the customers whenever products were brought back to the factories for recycling. We designed this rule to specifically monitor how the customers and factories react to it. The blue and red bars represent the number of premium products and standard products ordered by the factories. The orange line represents the total number of times the factories ordered materials. The results show that in general, the number of premium products ordered increased as the number of standard products ordered decreased. Team red and green showed a decreasing total number of times the factories ordered materials.

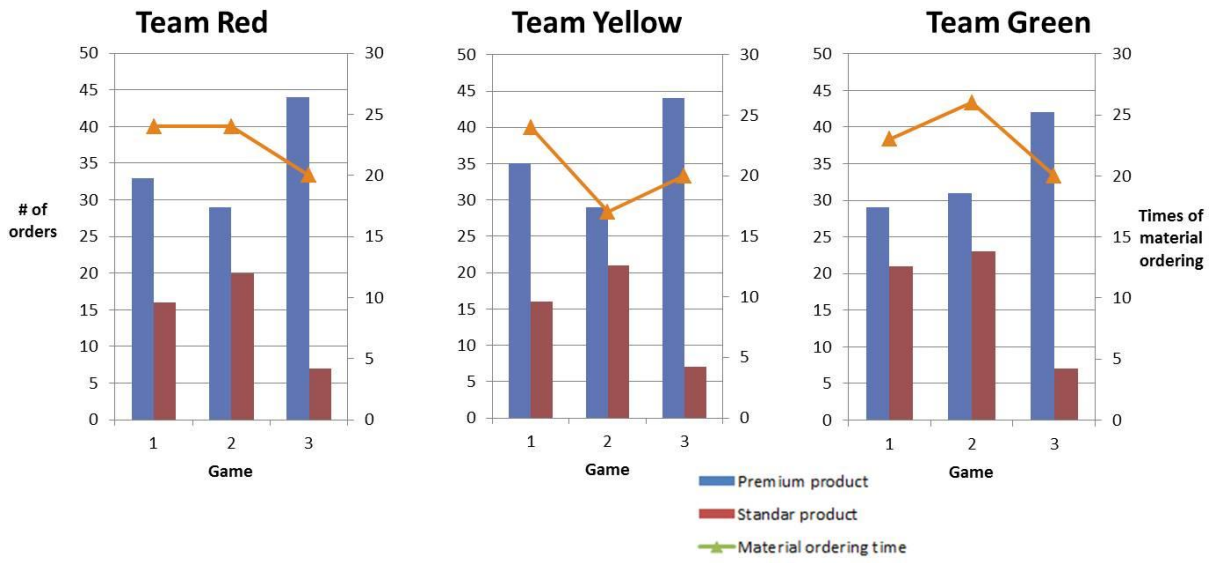


Fig. 40: Results of the three teams in terms of "recycled products"

4.2.2.1 Lessons learned from the second and third test

To validate the game, we first took a look at the averaged students' result and compared it to the optimal result of the game. We wanted the students to produce a result as close to the optimal result as possible. By achieving that, we could conclude that the students were affected by the game rules, and that they understood the eco mechanism we designed for the game. The result regarding waste is as followed.

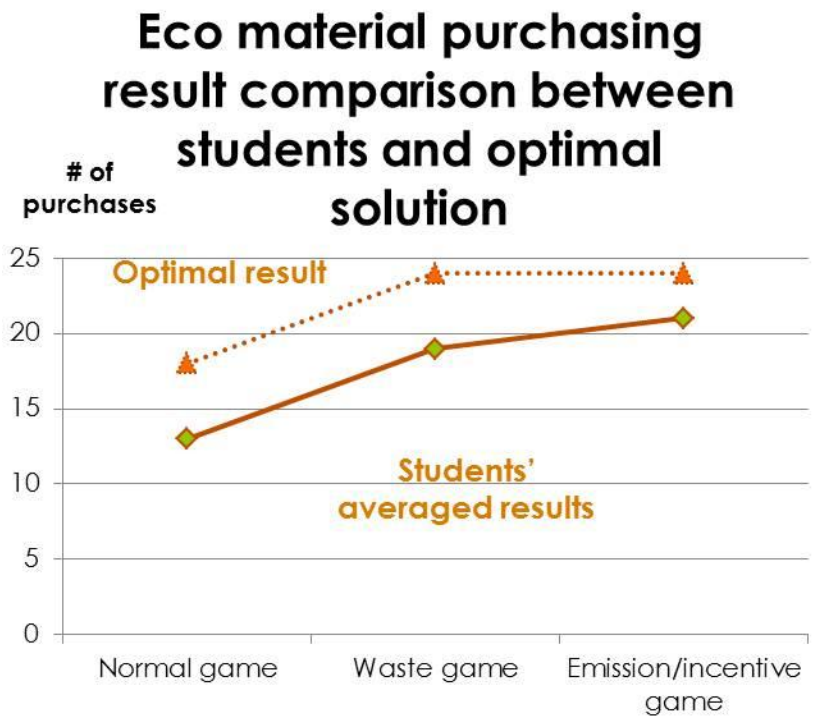


Fig. 41: Student's averaged result compared to the optimal result of the game

Students' trend of behavior was similar to the behavior of the optimal result, although not completely stacking. After the game finished, we used interview and Q&A sessions to get information from students regarding their opinion on the game, before and after differences, and also varies thinking pattern and communication they engaged during the game. Regarding the waste result, students understood the importance of reducing inefficient use of materials. At the beginning of the game, students reflected the use of cheaper materials to achieve higher profit. When the waste penalty was introduced as a new rule, the first thing students thought of was to reduce the waste. Since order was decided by the customer, the only way factories could reduce the waste was to start importing the premium materials. As seen from figure 22, team red students implemented that strategy immediately. They did not switch to all premiums at game 2 because at that time they were still unsure of the consequences of the higher cost. After the end

of game 2 though, they were certain that in order to avoid even more lose, they had to switch to more premium materials. Team green made a more aggressive change in game 2 compared to team red. However in game 3, they tried to cut down the cost by reducing ordering of premium materials again. In reality, team green would endure an overall higher cost and waste due to the abrupt switching of the production line and suppliers. In the end, the teams were able to understand the importance of reducing waste from as soon as possible after our discussion session. After the waste is created by the manufacturing processes, more cost and more effort is needed to deal with them. Therefore, it is of best effect if the waste is reduced or eliminated at the very beginning of the whole process.

We also tested different amount of penalties assigned to the wastes during game two, and how the students behaved to the changes. According to the graph shown below, students did not achieve the optimal number of purchase while the penalty was set at 20. However, once the penalty was raised to 30, students were then forced to purchase eco materials only. Therefore we concluded that the waste penalty should be set at 20 in order for students to change their behaviors, while leaving them enough space to make wrong mistakes and learn.

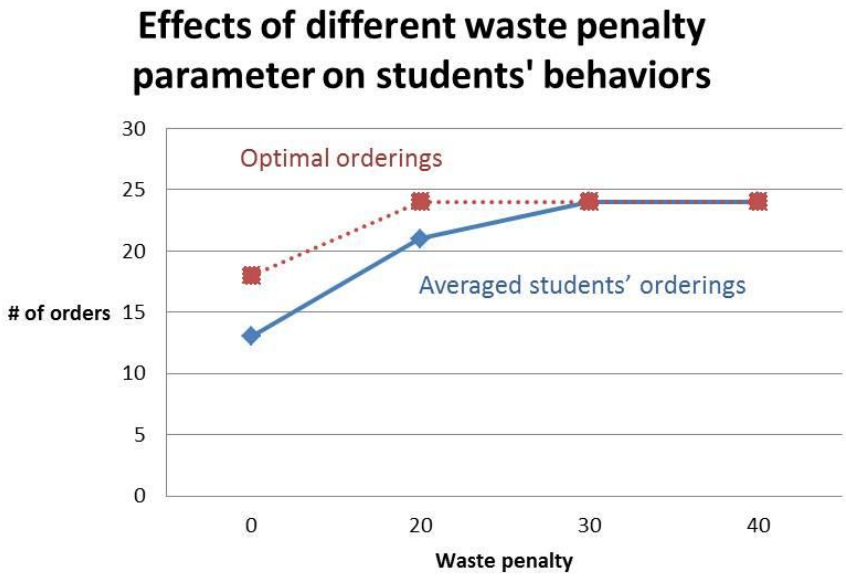


Fig. 42: Students' behaviors with different waste parameters

Regarding the emission result, all teams reported that the maximization of transportation capacity was what their method. That response had us surprised. Initially we thought that the students would already be fully utilizing the transportation capacity from the beginning of the game. We designed in a rules in a way that in order to reduce emission, better fit of materials were required at the time of ordering so that no extra corrections would be made. However, the test gave us new insight to the students. To them, maximization of the transportation was not considered before the penalties. It was only after the introduction of the penalties that the teams started to think about material ordering strategy more seriously as they only had one chance to make the delivery. Team red took a more conserved approach again regarding emission. They kept their ordering strategy the same for two games before making changes. The reason was they did not think that reducing one or two trips would make a big difference. Team yellow made the most improvement in game 2 among the three teams. Team green focused on reducing the waste by mostly ordering premium materials. However, their strategy resulted in them having to make

more orders and trips due to satisfying customer orders. The key to reducing emission in the game was to make sure to use more premium materials as they provide more manufacturing potentials, and to come up with a good material ordering strategy so that each trip made by the transportation is fully utilized with the correct amount of materials.

The next lesson discussion is about the main focus of this research, the relationship between government, manufacturer, and the customer. To put it in simple words, with government incentive, customers were more willing to bring products back to the factories for recycling. That in turn resulted in factories perform more eco procedures, and thus the whole system became more ecofriendly. In developing countries, the eco awareness of the general public is still lacking compared to advanced countries. In order to increase product recycling and decrease garbage disposal, incentive must be implemented. Factories must then make alterations in order to meet the recycling demand. In return, the factories can make use of the recycled products, and decrease the materials they need. That will result in a decrease of waste, emission, and energy consumption. In other words, if the eco awareness and actions of the public can be increased, the whole system will slowly transform in a green supply and demand cycle. During the game, we saw an increase in the ordering of premium products over standard products as soon as the incentive from the government was introduced. We set the rule that only premium products can be recycled, thus they were considered to be "eco products". With incentives, customers increased the orders of premium products, and gladly returned them back to the factories as recyclable products. Factories on the other hand, used materials extracted from the recyclable products on their production line. The result of increased materials from the recyclable products was the decrease in need of new materials. Since for every premium products made, almost the same amount of materials could be reused, the need for new material

ordering went down significantly. Material ordering decrease resulted in waste decreased, and also the emission decreased due to less amount of transport was needed. With the customers being a new demand of eco products, the factories slowly took more eco procedures, and this resulted in the whole environment being more ecofriendly.

There were other lessons learned by the students. Communication was one of the key during strategy making process. Team red showed a less rapidly changing strategy due to disagreement between the team members. One member was more conservative, while another member was more aggressive. The result was that they each had to compensate for each other, and thus resulted in less and smaller changes to the strategies. Eco awareness was also another key while playing the game. Different students had different level of understanding of eco; therefore the reasons for taking different actions were many. The game's main goal was to make as much profit as possible under any given circumstances. Some students placed a smaller emphasis on eco while others understood immediately that in order to be eco, sacrifices must be made. This resulted in interesting strategy changing and discussions among the students during the game.

5 Discussions

5.1 Discussion

By designing the two games, we were able to achieve the purpose of this research, which is to help students understand more in the area of being ecofriendly and being cost effective. We first designed the conventional factory game based on ETH Zurich's logistic game so we could identify some of the key contents of a good production line game. After that, we proceeded to designing the eco factory game, which served as our tool to educate students in developing countries on the topics of eco friendliness.

5.1.1 Conventional factory game discussion

The conventional factory game we designed helped us in understanding the core concepts of a production line. The results highlighted the main points which decide if a production is smooth or not. It also helped us define the main roles in our eco factory game. By playing the game, students were able to understand the importance of making good quality products, and minimizing the time needed for transportation. In the end, if all products made were of acceptable quality to the customers, and the time needed between each work station was either minimized or eliminated, the production line would be able to reduce cost to the lowest possible.

During the game, students constantly tried to find out the flaw of their set up. The first discussion session usually ended up with discussion on the product defects. Due to the nature of the design of products, wrong assemblies will always occur at the beginning stage of the game. Therefore students were required to identify the problems first and make sure that from that point on all products will be qualified for delivery to the customer. The next step is identifying the

bottlenecks of the assembling line. Each student has different assembling capability in terms of speed, material planning and so on. Without everyone being of the same pace, there will definitely be bottlenecks. That was when students started to think about the location of work stations and workers. Players with higher assembling abilities would often take up more task as they were more efficient. Once that was combined with moving of the work stations closer to each other to simulate an automated production line, the students were able to reduce cost to a much lower amount compared to when they first started out.

5.1.2 Eco factory game discussion

The eco factory game helped students understand the importance methods to take when considering eco friendliness. To solve waste problems, the first thing that one should do is to use materials with higher efficiency. Reducing waste is the most efficient method in almost all circumstances. Once the waste is reduced, emissions and energy consumption would decrease as well. Regarding society, incentive must be provided to raise the eco awareness and activities of the consumers, especially in developing countries. Once the consumers are willing to bring back used products for recycling, environment garbage and pollution will decrease. To response to the brought back products, the factories will have to implement eco procedures and planning. Essentially, new waste can be avoided, and the old waste will be used again to make products. In terms of cost, it will definitely be higher than non eco activities; however, when considering in the long term, the benefits of having less environmental problem always weights the most.

At the beginning of the game due to lower understanding of the game mechanism, students often ordered materials randomly just to satisfy customer orders. As the game progressed, they slowly get more used to the pace and flow and the manufacturing process and

the customer orders, and thus were able to think more strategically in terms of materials ordering and deliveries made. When the waste penalty was introduced, players started to regard standard material set ordering as a worse strategic choice, and therefore the ordering of premium materials increased. If they have not yet make alterations or improvements to their transportation, they would go ahead to do that when the emission penalty was introduced. Due to the way we designed the game, the players would soon realize that more premium material ordering would naturally result in less transportation needed; which was the whole point of how to become more efficient. The government incentive introduced in the last game served as a motivation for the customers to be involved in helping the manufacturing industry in becoming more ecofriendly. The three parties did not communicate directly with each other in terms of strategy. So when the customers started to order more premium products, factories would produce more eco products, and that made the manufacturing line more ecofriendly. That cause and effect mechanism is what we hoped to achieve by increasing eco awareness of the young generation in developing countries.

6 Conclusion

6.1 Summary

6.1.1 Run through from problem to solution to result

In this research, we first identified the problem in developing countries. There is a lag in technology application, and also mindset regarding environmental issues between developing countries and developed countries. The result of our problem analysis was that the government and industries in developing countries insist on putting all their focuses on short term profit making. Despite the fact that numerous examples in European countries and Japan, and eco studies done in Asia pointed out that adopting eco measurement would lead to better performance, not enough emphasis was put into that area. On the other hand, the consumers in developing countries also play an important role in stopping eco development. With no eco demand, there will naturally be no eco supply. From statistics, reports, and questionnaires conducted by a number of environment agencies and ourselves, we found out that although most of the public are aware of the environment problems, they choose to do nothing. The reasons are lack of support network, lack of a good eco system network, and most importantly, ignorance.

The solution for the problem we identified can be many. However, most of the solutions are not very effective. For example, eco marketing campaigns, government aid for eco products and projects, television programs and so on exist in most of the developing countries. Judging from the current environment situation, we can assume that the current solutions failed to fully serve their purposes. As a result, we approached the problem from another perspective, education. Education can be provided to anyone who wishes to receive it, and it is an excellent way to stimulate thinking and application once it is processed by the receiver. We chose current students

as our target in which the environmental can be solved. For current industrial employees, the effect of education might become lower, if not none; due to the fact that even if employees are willing to make improvements, there will be pressure and disagreement between them and the current upper management. Students on the other hand, have a larger potential of change. They are not pressured like the employees are, they can become the next generation of consumers who demands eco products and services, and they will become the new management themselves. It will take time for this whole process to starting running, but the effect will be larger than just trying to make immediate changes.

After we narrowed our purpose and target, we proceed to designing a business game with the purpose to increase the eco awareness and understanding of students. Since industrial pollutions contribute the most to global warming (eight five percent), we decided to incorporate factory procedures as the setting of our game. The main measurements we used to evaluate performance were waste, emission, and energy consumption. Students are required to maximize profit by satisfying customers' demands, while minimizing the lost to regulation penalties throughout the game.

After playing the game, students were able to understand the basic tradeoff decisions required in order to become eco. The immediate effect was the lost in profit as a result of investments and penalties. As time goes on, the reputation and environmental sustainability will increase, and result in profit increase. With the change in mindset and demand, industries will be forced to satisfy that new need. The effect is much more effective than governments setting regulation and penalties. On the operational level, the method with the highest return on investment is "reduce". As shown from the game results, students who prioritized the reduce strategy resulted in higher profit than the ones not doing that. The reduction method also requires

the least effort in implementing. The usual case is the increase of monetary investment. Reusing and recycling process will require much more effort. Other than the technology and monetary investment, a complete plan to deal with the byproducts and aftermaths of reusing and recycling is also needed. This results in a much more complicated network and business strategy. For medium to small companies in developing countries that do not have the money to invest in such a complicated network, or do not have the access to high technology machineries, reducing methods are the most efficient and effective methods that can resulting in immediate change in the outcome of their productions.

6.1.2 Contribution to the society

Through this research, we hope to achieve an increase in awareness of the young generation when it comes to going green. We want to change the mindset of "develop first, green later", starting from students. By enabling them to understand the big pictures behind eco management and the importance and benefits of it, we hope they will be able to see every little opportunity to decrease damage done to the environment. We also hope that more and more people in developing countries take initiative in becoming green and contributing to the control of global warming, be it strategies, technologies, or interactions.

6.1.3 Contribution for academic use

By designing an eco-business game, we have added one more education tool available for students to use. This game can be a great tool for students to visualize the big strategies and interactions taken place between companies to pursue a greener outcome. This game can be used as a teaching tool for students who have partial understanding of inter-company eco relationships,

and show them the trade-offs that must be made to achieve a balance between eco actions and economic profits. This game can also be used for students with a more complete understanding of the consequences of eco actions. These students can take on leadership roles during the game to experience the process of leading people by uniting ideas and actions achieve eco production.

6.2 Limitations and future work

There were a few limitations we faced in this research. The first limitation is the contents included in the game. For this research, we only chose three measurements to focus on: waste, emission by transportation, and electricity consumption. There are many more factors that need to be considered in order for a whole eco system to work; however, as more measurements are added to the game, the complexity and fine tuning of the system increases exponentially. We designed the game specifically to emphasize the more physically factors of eco systems; therefore we excluded other factors that might also affect the system. If there is a need, one can add or change factors according to his or her purpose of the game, and use it to teach students as well.

The second limitation is the availability of the game. Due to the specific design of this game, it can only be played at a specific location designated by the developer. Students who wish to participate must come to a same location. This will limit opportunities for some groups of students, for example smaller less organized groups or groups with members at different locations but wish to participate in this game.

For future work, there is a potential to computerize this game if students' demands exist. By converting it into a colorful and interesting software type of game that allows individuals to play by themselves, but able to compare scores with students around the world, it would become

a very useful tool for students in different countries to see the different mindset and actions chosen by people with different background.

Also there is a need to test the game in more countries as well. Students from different countries will bring with them different culture, different values, and different system of thinking. By expanding the test to more countries, the data and results collected will be very useful in targeting specific behaviors of students in different regions. Those information can be used to fine tune to game if necessary to provide the targeted students with even more accuracy of education.

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Reference

Anh P., Dieu T., Mol A., Kroeze C., Bush S., 2011. *Towards eco-agro industrial clusters in aquatic production: the case of shrimp processing industry in Vietnam.* Journal of Cleaner Production 19, 2107-2118.

Barari S., Agarwal G., Zhang WJ, Mahanty B., Tiwari MK, 2012. *A decision framework for the analysis of green supply chain contracts: An evolutionary game approach.* Expert systems with applications, 2012.

Bass L., 1998. *Cleaner production and industrial ecosystems, a Dutch experience.* Journal of cleaner production, 1998.

Bourgonjon J., Valcke M., Soetaert R., Schellens T., 2009. *Students' perceptions about the use of video games in classroom.* Computers and education 54, 2010, 1145-1156.

Bowonder B., 1981. *Environmental risk assessment issues in the third world.* Technological forecasting and social change, 1981.

Bratt C., Hallstedt S., Robert K H, Broman G., Oldmark J., 2011. *Assessment of eco labeling criteria development from a strategic sustainability perspective.* Journal of cleaner production, 2011.

de Bruijin T., Hofman Peter S., 2000. *Pollution prevention and industrial transformation. Evoking structural changed in companies.* Journal of cleaner production, 2000.

Chang H., 2012. *Does the use of eco labels affect income distribution and income inequality of aquaculture producers in Taiwan?* Ecological Economics, 2012.

Chew I., Tan R., Foo D., Chiu A., 2009. *Game theory approach to the analysis of inter-plant water integration in an eco-industrial park.* Journal of Cleaner Production 17, 1611-1619.

Connolly T., Boyle E., MacArthur E., Hainey T., Boyle J., 2012. *A systematic literature review of empirical evidence on computer games and serious games.* Computers and education 59, 2012, 661-686.

Cowley B., Moutinho J., Bateman C., Oliveira A., 2011. *Learning principles and interaction design for 'Green My Place': A massively multiplayer serious game*. Entertainment Computing 2, 103-113.

Dolgen D., Alpaslan M., Delen N., *Agricultural recycling of treatment-plant sludge: A case study for a vegetable-processing factory.* Journal of Environmental Management 84, 274-281.

Dong F., Zhou J., 2011. *Game Analysis and Design of Eco-economy Mechanism.* Energy Procedia 5, 1993-1997.

Eltayeb T., Zailani S., Ramayah T., 2011. *Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes.* Resources, Conservation, and Recycling 55, 495-506.

Ferretti I., Zanoni S., Zavanella L., Diana A., *Greening the aluminium supply chain.* International of Production Economics 108, 236-245.

Hsu M., Lin F., 2012. *The Developing Strategy of Green Energy Industry Cluster -A Case Study of the Solar Photoelectric Industry in Taiwan.* Procedia-Social and Behavioral Sciences 40, 165-173.

Jos O., 2012. *Trends in Global CO2 emissions, 2012 report.* (PBL Netherlands Environmental assessment agency)

Koplin J., Seuring S., Mesterharm M., 2007. *Incorporating sustainability into supply management in the automotive industry e the case of the Volkswagen AG.* Journal of Cleaner Production 15, 1053-1062.

Long R., Lan Y., 2009. *Study on regulation design about energy-saving and emission-reduction based on game theory.* Procedia Earth and Planetary Science 1, 1641-1646.

Le Bars M., Le Grusse Ph., 2008. *Use of a decision support system and a simulation game to help collective decision-making in water management.* Computers and Electronics in Agriculture 62, 182-189.

Lee K., 2011. *Integrating carbon footprint into supply chain management: the case of Hyundai Motor Company (HMC) in the automobile industry.* Journal of cleaner production 19, 2011

Magombeyi M., Rollin D., Lankford B., 2008. *The river basin game as a tool for collective water management at community level in South Africa.* Physics and Chemistry of the Earth 33, 873-880.

Mahboubian M., 2010. *Educational aspects of business simulation softwares.* Procedia social and behavioral sciences 2, 2010, 5403-5407.

Matsuoka H., 1999. *Global environmental issues and space solar power generation: promoting the SPS 2000 project in Japan.* Technology in society, 1999.

Morioka T., Tokai A., Yamamoto Y., Matsui T., Thai V., 2010. *Selection of product categories for a national eco labeling scheme in developing countries: a case study of Vietnamese manufacturing sub-sectors.* Journal of cleaner production, 2010.

Pacheco P., Motloch J., Vann J., 2006. *Second Chance game.* Journal of cleaner production 14, 848-854.

Pak M., Brieva D., 2010. *Designing and implementing a Role-Playing Game: A tool to explain factors, decision making and landscape transformation.* Environmental modeling and software 25, 1322-1333

Panyathanakun V., Tantayanon S., Tingsabhat C., Charmondusit K., 2012. *Development of eco-industrial estates in Thailand: initiatives in the northern region community-based eco-industrial estate.* Journal of Cleaner Production, 2012.

Rajabu K., 2007. *Use and impacts of the river basin game in implementing integrated water resources management in Mkoji sub-catchment in Tanzania.* Agricultural Water Management 94, 63-72.

Ray, G.F., 1975. *Raw materials, shortages, and producer power*. National institute of economic and social research, London.

Shi H., Chertow M., Song Y., 2010. *Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China.* Journal of Cleaner Production 18, 191-199.

Smith L., Ball P., 2012. *Steps towards sustainable manufacturing through modelling material, energy and waste flows.* International Journal of Production Economics 140, 227-238.

Strozzi F., Bosch J., Zaldivar J.M., 2007. *Beer game order policy optimization under changing customer demand.* Decision Support Systems 42, 2153-2163.

Tanimoto J., 2005. *Environmental dilemma game to establish a sustainable society dealing with an emergent value system.* Physica D 200, 1-24.

Tao Y., Cheng C., Sun S., 2009. *What influences college students to continue using business simulation games? The Taiwan experience.* Computers and Education 53, 2009.

Vachon S., Klassen R., 2008. *Environmental management and manufacturing performance: The role of collaboration in the supply chain.* International Journal Production Economics 111, 299-315.

Zhang Z., 2008. *Asian energy and environmental policy: Promoting growth while preserving the environment.* Energy Policy 36, 3905-3924.

Zhao R., Neighbour G., McGuire M., Deutz P., 2012. *A Software Based Simulation for Cleaner Production: A Game between Manufacturers and Government. Journal of Loss Prevention in the Process Industries* (2012), doi: 10.1016/j.jlp.2012.09.006.

Zhu Q., Cote R., 2004. *Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group.* Journal of Cleaner Production 12, 1025-1035.

Zhu Q., Sarkis J., Lai K., 2007. *Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers.* Journal of Environmental Management 85, 179-189.

Zorpas A., 2009. *Environmental management systems as sustainable tools in the way of life for the SMEs and VSMEs.* Bioresource technology, 2010.

http://www.icf.at/en/6043/raw_materials_price_trends.html (December, 2012) Internationl Cablemakers Federation

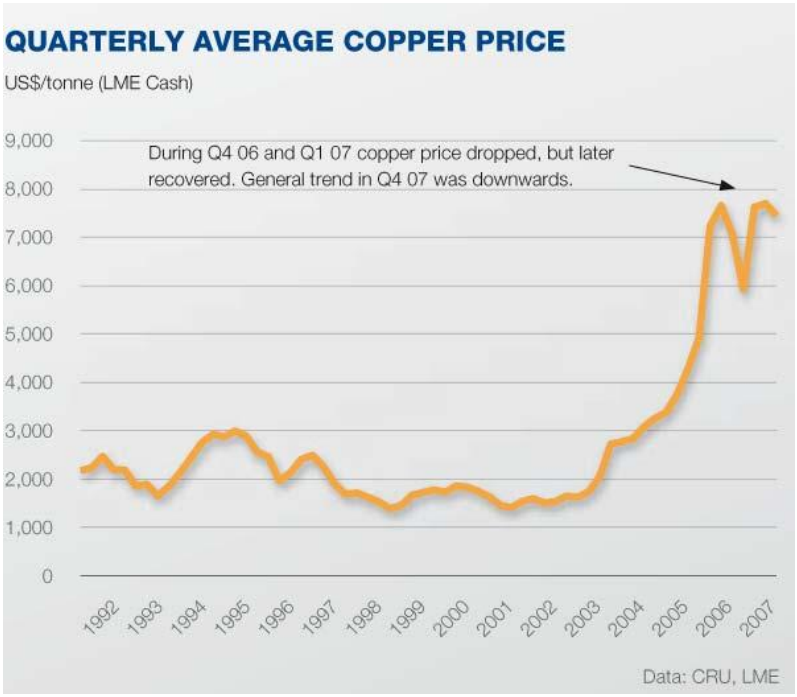
http://www.treehugger.com/green-architecture/the-green-workplace-looks-at-eco-labels.html (Devember, 2012) Treehugger

http://www.infomine.com/investment/, (December, 2012) Investmentmine

http://www.beergame.org/the-game (January 30, 2013)

"Criminal Penalties in EU Member States' environmental law", Final Report, 15-09-03

Appendix (Data)



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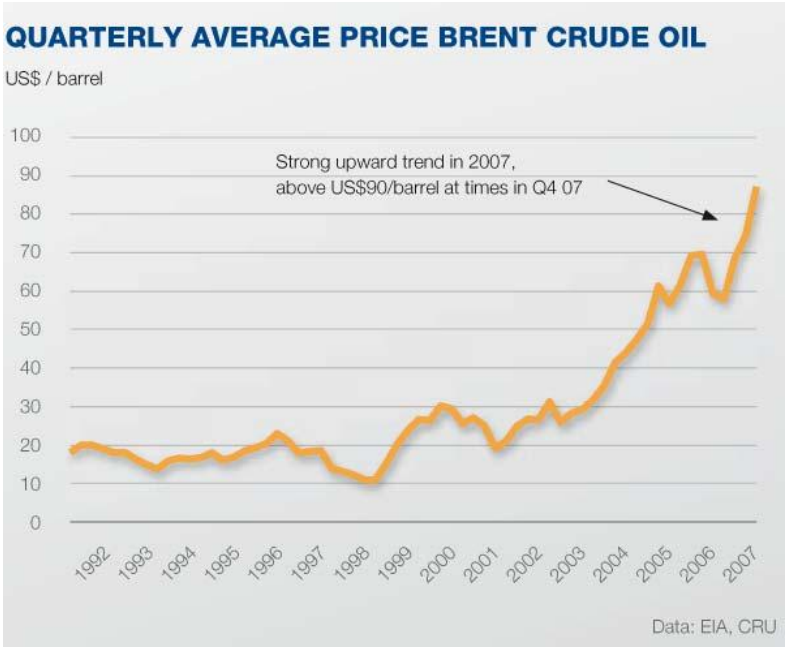

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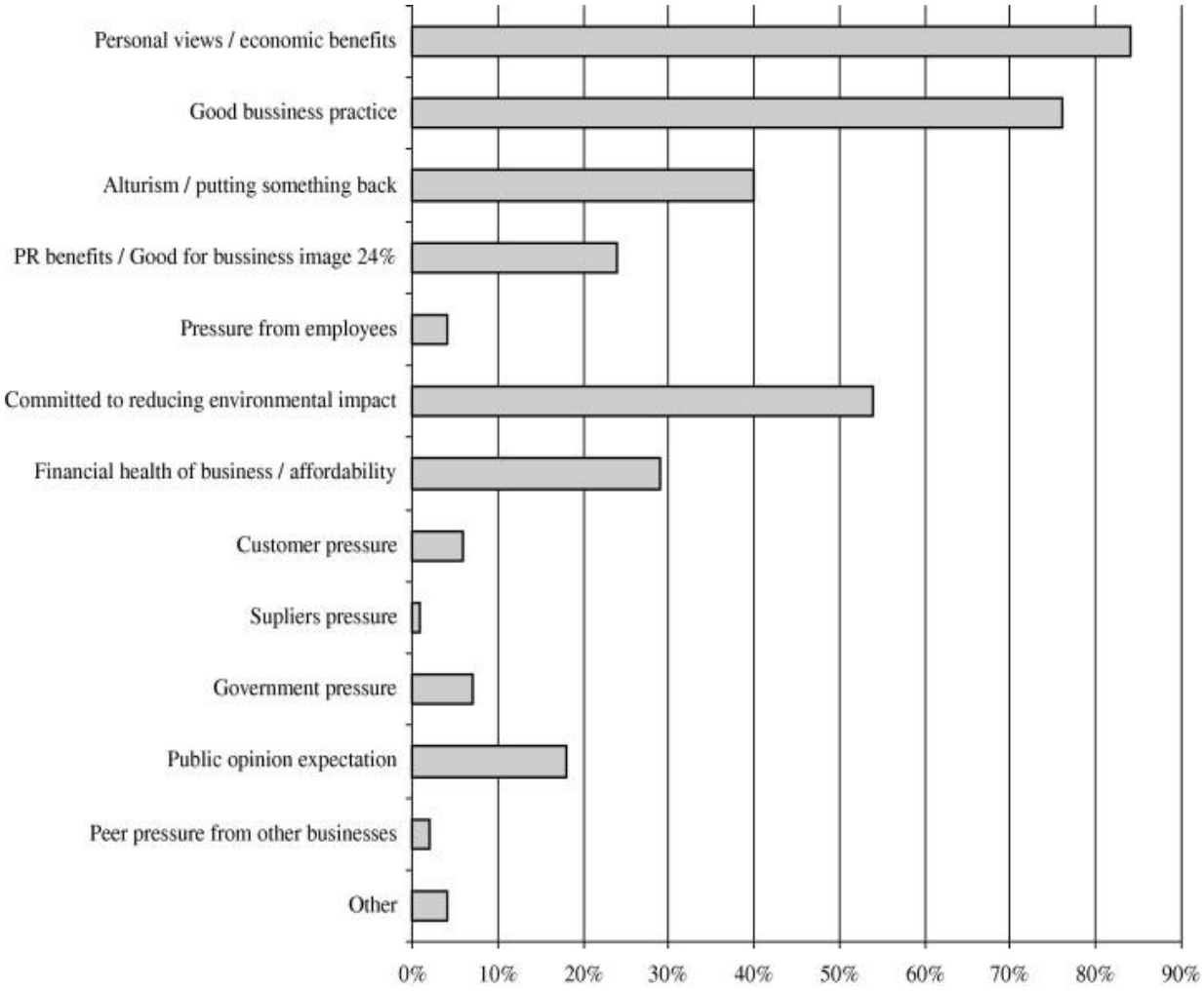


source: Zorpas, 2011

Name	Type	Cost (US dollar)	General purpose
The airplane game	Board	425	Cellular redesign with the idea of pull system and team workload and resource sharing
The cups game	Board	0	Push system vs. pull system. Small lot manufacturing and just in time system
Distribution game 1	Computer	0	Cost effectively manage the flow of goods to supply random customer demand at multiple locations
Distributor game	Computer	Sponsor needed	Understand the need in modern business "to know earlier", to scan the horizon, and to increasingly master the complexity of balancing a portfolio of product and management risks as a senior supply chain executive.

Examples of games

In class manufacturing game	Computer	0	Aggregate planning, inventory theory, lot sizing, productions scheduling and materials requirement planning
The job shop game	Board	0	Drum-Buffer-Rope (DBR)
Inventory control at Spiegel Grove	Board	0	simulates the inventory management process for a single product in a serial supply chain. Safety vs overstock
MIT beer game	Board or computer	0	Supply chain management
Manufacturing game	Board	Sponsor needed	Production, strategy, planning, inventories, manufacturing, effectiveness, maintenance, and the allocation of scarce resources

Examples of games

Manufacturing simulation game	Board	500	Why and how MRP/ERP create "high-cost" shop floor chaos, How to eliminate shop floor chaos and "end-of-the-month" stress, The power of sequential production and point-of-use logistics, How to move from "firefighting" to proactive problem solving
Transportation game	Computer	0	cost effectively manage the routing and scheduling of a fleet of trucks to satisfy customer demand
Wood supply game	Computer	0	simulates the operations in the forest product supply chain in order to demonstrate the dynamics at work in the value creation network and show the importance of information sharing between enterprises
Poker chip game	Board	0	demonstrate the detrimental impact of using traditional single-item, single-firm inventory theory, production/distribution system for a multi-item, multi-echelon production/ distribution environment using theory of constraints (TOC) and just-in-time (JIT)

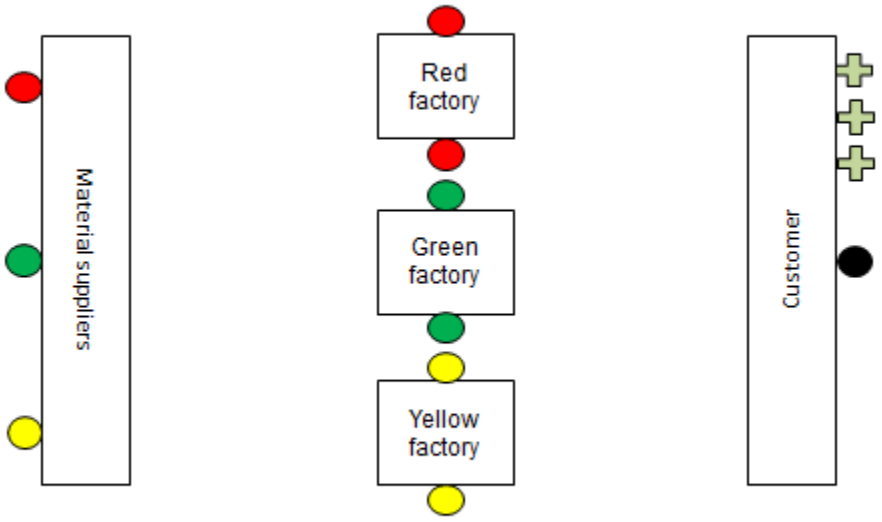
Examples of games

Appendix (Game manual)

Game overall

- Perform production operations in 3 competing groups(factories)
- Each factory will start with 500 credits
- Team objectives:
  - **Maximize profit**
- If credits become less than **zero**, team loses
- Play 4 games in total
  - Each game has 10 rounds
    - Each round is 2 minutes

Game table setting

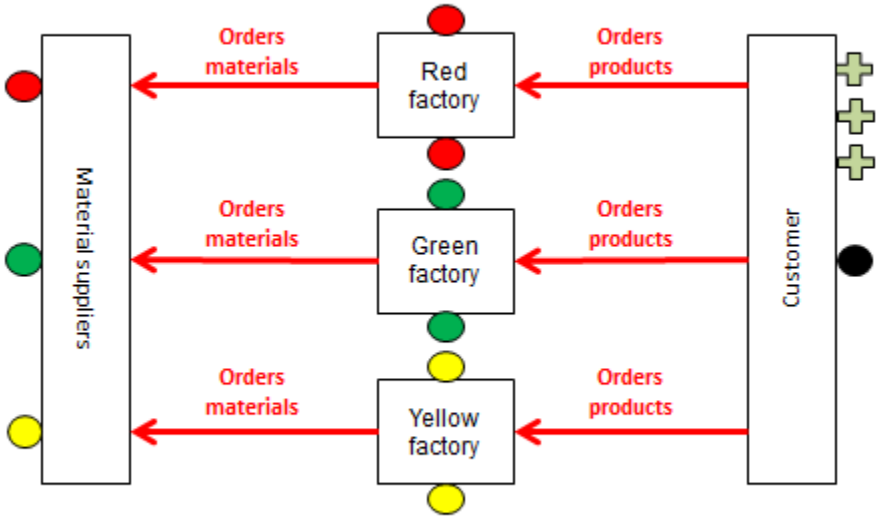


Products

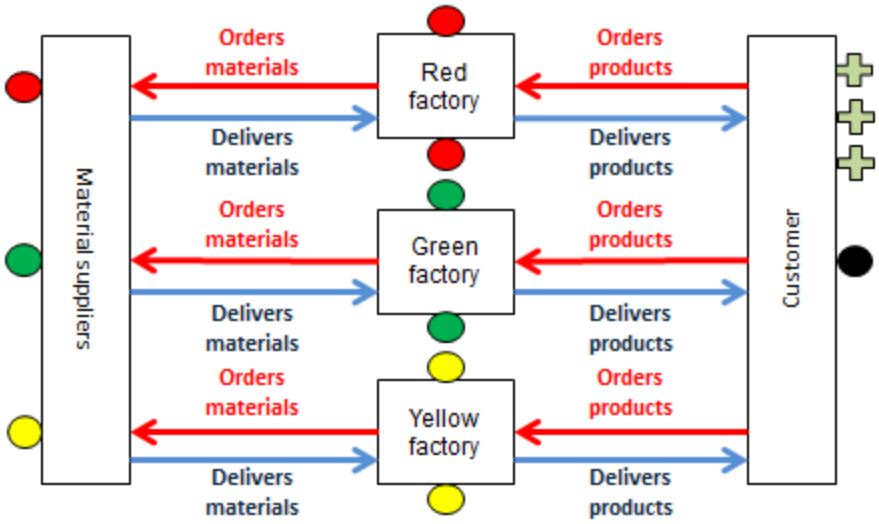
Red Yellow Green

- Each product consists of:
  - **4 pieces of squares**
  - **3 pieces of joints**

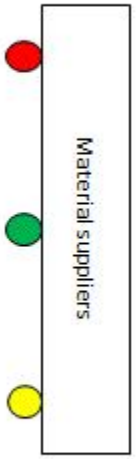
Game table setting



Game table setting



Operation of material suppliers



- Prepares materials in paper cups (to simulate boxes of materials)
- 1 paper cup = 1 box of material
- Space capacity:
  - **Maximum of 4 paper cups** can be held by each of the material supplier at any given time

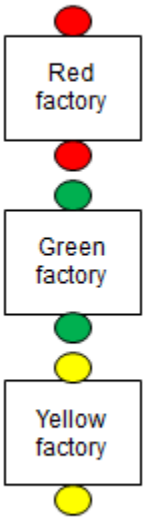
"Material box"

Operation of material suppliers (case of red supplier)

- **Standard set:**
- 10 pieces of squares
  - 60%: pure squares
  - 20%: impure square
  - 20%: waste

- **Premium set:**
- 10 pieces of squares
  - 80%: pure squares
  - 10%: impure square
  - 10%: waste

Operation of factories

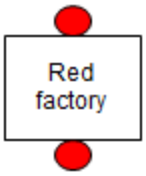


- **Factory producer:**
  - Sorts incoming materials
  - Assembles products
- **Transporter:**
  - Trip count: recorded using the "truck log"
  - Truck capacity:
    - **Maximum of 2 cups** of materials can be carried at any given time
    - Capacity for products is unlimited

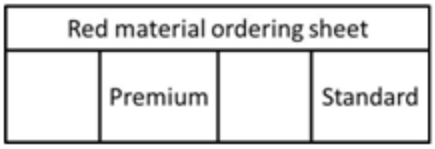
"Truck"

"Truck log"

Operation of factories (case of red factory)

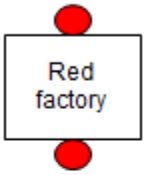


- **Material ordering:**
- Factory decides which sets of materials to order
- Ordering is done by the "material order sheet"
  - **Standard set: 30 credits**
  - **Premium set: 60 credits**



Material ordering sheet

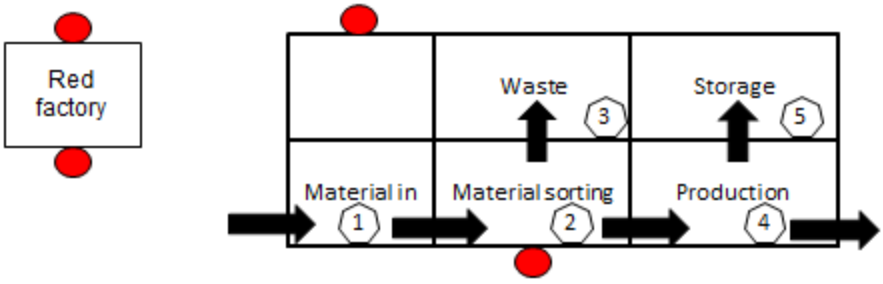
Operation of factories (case of red factory)



- **Product assembling**
  - Normal product (sales price: **60 credits**):
    - 2 pure squares
    - 2 impure squares

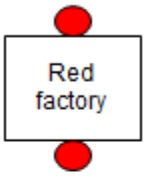
  - Premium product (sales price: **120 credits**):
    - 4 pure squares

Operation of factories (case of red factory)

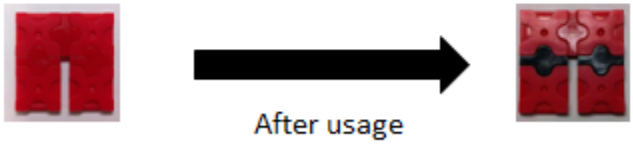


1. Material is supplied
2. Useable material is separated from unwanted material
3. Unused material is moved to inventory storage
4. Material is assembled into product
5. Extra products are stored for later use

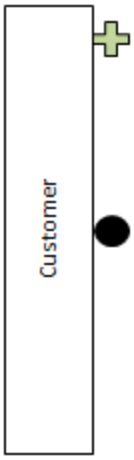
Operation of factories (case of red factory)



- **Product recycling/reusing**
  - Transporter receives used product from customer, takes back to the factory
  - Breakdown cost: **5 credits** per piece used
  - Used products contains:
    - 4 pure squares
    - 2 pieces of wastes



Operation of customer (case of red product)

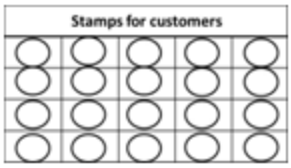


- Place orders every 2 minute
- Order: 3-6 products **(combination of premium and normal products is up to the customer)**

Customer check sheet

- Prepare used products for recycling
  - Incentive: Every **5** recycled products brought back to the factory, customer will receive a prize

Recyclable product



Game rules – eco aspect

- Additional new government policies will be added after game 1, per game
  - Game 1: normal operation
  - Game 2: **waste** penalty law
  - Game 3: waste + **emission** penalty laws
  - Game 4: waste + emission + **energy** penalty laws

Game 1

- Truck capacity:
  - **2 cups** of material per trip
- Material supplier capacity:
  - **4 cups** maximum allowed in the material preparing area
- Inventory costs:
  - Square piece in inventory: **15 credits**/piece
- Fixed costs
  - 1 player: **100 credits**

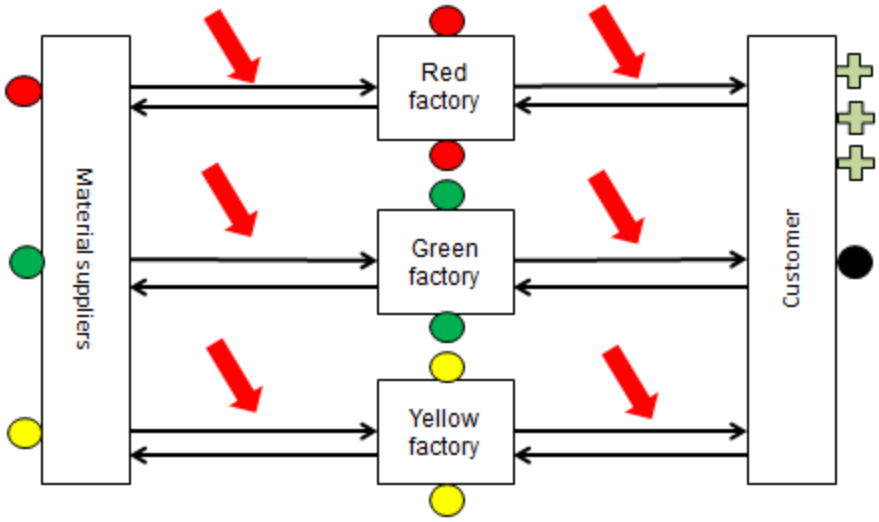
Game 2 new rule: waste penalty

- Waste: all the **black** pieces
- Government involvement
  - Team with corrupted government: each piece of waste costs the factory **20** credits

  - Team with strict government: each piece of waste costs the factory **30** credits

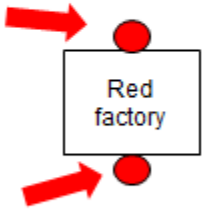
Game 3 new rule: emission penalty

- Emission: **trips** made by the transporter
  - each emission of trip cost: **60 credits**



Game 4 new rule: energy consumption penalty

- Energy consumption: **1 player = 1 machine**
  - each machine cost: **100 credits**



Game rules – company reputation

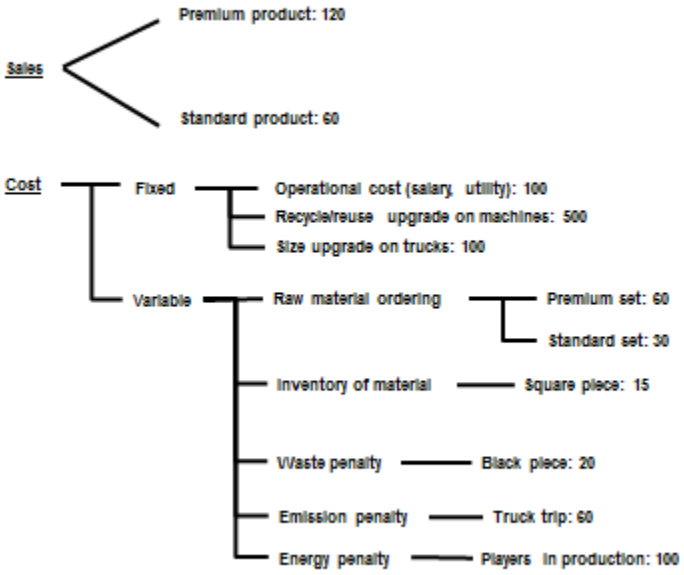
- Company reputation
  - Team with the **lowest amount** of waste calculated at the end of any game: increase in sales price of the team's products.

1 win	2 wins	3 wins	4 wins
+2 credit/product	+4 credit/product	+6 credit/product	+10 credit/product

  - Team with the **highest amount** of waste calculated at the end of any game: decrease in sales price of the team's product.

1 lose	2 loses	3 loses	4 loses
-2 credit/product	-4 credit/product	-6 credit/product	-10 credit/product

Calculation for the measurements



Calculation for the measurements

Each game is defined as Gi, where i =1, 2, 3,
Each team in the game is defined as Tc, where c=red, green, yellow
(Gi,Tc)

Main objective of the game:

Profit(Gi,Tc)=Sales(Gi,Tc)-(Variable Cost(Gi,Tc)+Fixed Cost(Gi,Tc))

Team competes for highest profit

Calculation for the measurements – Game 1

Profit(G1,Tc)=Sales(G1,Tc)-(Variable Cost(G1,Tc)+Fixed Cost(G1,Tc))
Sales(G1,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G1,Tc)=Material Cost(G1,Tc)+Inventory Cost(G1,Tc)
where,
Material Cost(G1,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G1,Tc)=15*N(square piece)
Fixed Cost(G1,Tc)=100

Calculation for the measurements – Game 2

Profit(G2,Tc)=Sales(G2,Tc)-(Variable Cost(G2,Tc)+Fixed Cost(G2,Tc))
Sales(G2,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G2,Tc)=Material Cost(G2,Tc)+Inventory Cost(G2,Tc)+Waste Penalty(G2,Tc)+Recycle Cost(G2,Tc)
where,
Material Cost(G2,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G2,Tc)=15*N(square piece)
Waste Penalty(G2,Tc)=20*N(black piece)
Recycle Cost(G2,Tc)=5*N(products recycled)
Fixed Cost(G2,Tc)=100+Recycle Tech(500 if invested, else 0)+Truck Tech(100 if invested, else 0)

Calculation for the measurements – Game 3

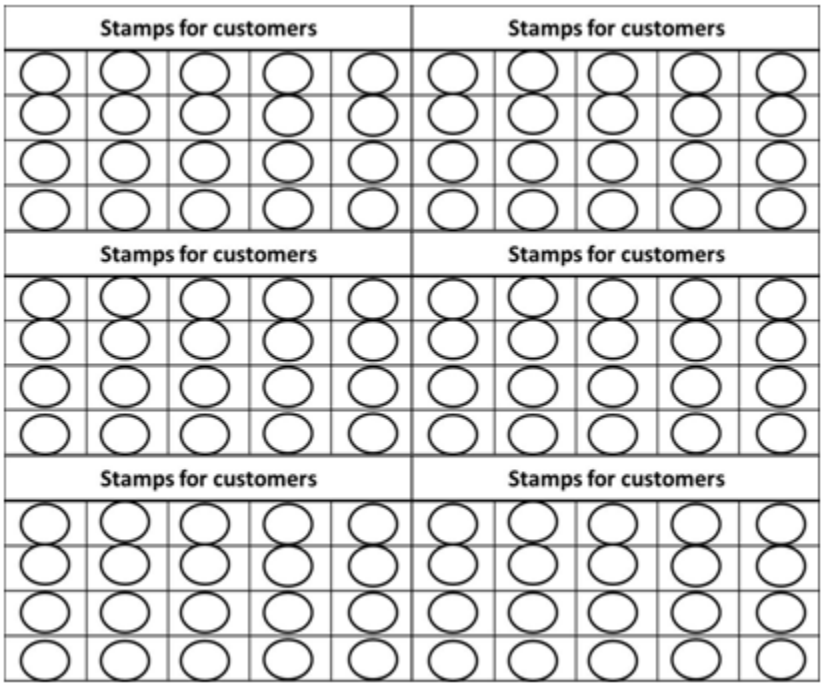
Profit(G3,Tc)=Sales(G3,Tc)-(Variable Cost(G3,Tc)+Fixed Cost(G3,Tc))
Sales(G3,Tc)=120*N(premium product)+60*(normal product)

Variable Cost(G3,Tc)=Material Cost(G3,Tc)+Inventory Cost(G3,Tc)+Waste Penalty(G3,Tc)+Recycle Cost(G3,Tc)+Emission Penalty(G3,Tc)+Energy Consumption Penalty(G3,Tc)
where,
Material Cost(G3,Tc)=60*N(premium material set)+30*N(standard material set)
Inventory Cost(G3,Tc)=10*N(square piece)
Waste Penalty(G3,Tc)=20*N(black piece)
Recycle Cost(G3,Tc)=5*N(products recycled)
Emission Penalty(G3,Tc)=60*N(trips by trucks)
Energy Consumption Penalty(G3,Tc)=100*N(number of players in production)
Fixed Cost(G3,Tc)=100+Recycle Tech(500 if invested, else 0)+Truck Tech(100 if invested, else 0)

Red material ordering sheet				Red material ordering sheet			
	Premium		Standard		Premium		Standard
Red material ordering sheet				Red material ordering sheet			
	Premium		Standard		Premium		Standard
Red material ordering sheet				Red material ordering sheet			
	Premium		Standard		Premium		Standard
Red material ordering sheet				Red material ordering sheet			
	Premium		Standard		Premium		Standard
Red material ordering sheet				Red material ordering sheet			
	Premium		Standard		Premium		Standard

Red customer				Red customer			
	Premium		Normal		Premium		Normal
Red customer				Red customer			
	Premium		Normal		Premium		Normal
Red customer				Red customer			
	Premium		Normal		Premium		Normal
Red customer				Red customer			
	Premium		Normal		Premium		Normal
Red customer				Red customer			
	Premium		Normal		Premium		Normal

Red truck log #1	Yellow truck log #1	Green truck log #1
Red truck log #2	Yellow truck log #2	Green truck log #2
Red truck log #3	Yellow truck log #3	Green truck log #3
Red truck log #4	Yellow truck log #4	Green truck log #4



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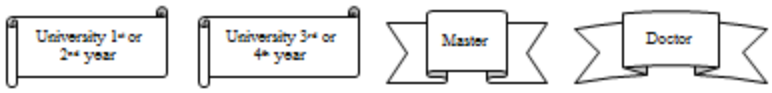
Eco factory game test 2

Game Questionnaire

1. School currently attending: _____
2. School year:



3. Country of origin: _____
4. Major of your study: _____
5. Experience of business game: Y N
6. Do you think there is an eco awareness lag between advanced countries and developing countries? Y N
   What do you think is the reason? _____
7. Which of the following methods in "3R" is most efficient? Please rank them in the order of most efficient to least efficient.
   ___Reuse
   ___Reduce
   ___Recycle

THANK YOU!!!

Material suppliers (case of red factory)

- **Standard set:**
- 10 pieces of squares

- **Premium set:**
- 10 pieces of squares

Operation of factories (case of red factory)

- **Normal product** (sales price: **60 credits**):
  - 2 pure squares
  - 2 impure squares

- **Premium product** (sales price: **120** credits):
  - 4 pure squares

Operation of customer (case of red product)

- Place orders every 2 minute
- Order: 3-6 products

Premium

Normal

Fixed costs						
Square	per piece	15	0	0	0	0
Machine	per player	100				
	total fixed cost		0	0	0	0
Variable costs						
Material ordered	per standard	30	0	0	0	0
	per premium	60	0	0	0	0
	total vc		0	0	0	0
Eco measure fixed costs						
Investment of reuse/recycle machine		500				
Upgrade to a bigger truck		100				
	total eco fc		0	0	0	0
Eco measure variable costs						
Waste penalty	per waste	20	0	0	0	0
Emission penalty	per trip	60	0	0	0	0
Energy penalty	per player in production	100				
Material reused/recycled	per unit	5	0	0	0	0
	total eco vc		0	0	0	0
Sales						
Sales	per premium product	120	0	0	0	0
	per normal product	60	0	0	0	0
Total sales			0	0	0	0
Profit			0	0	0	0

Appendix (Questionnaires)

非常感謝您願意抽時間回答這份問卷調查, 在問卷的最後面別忘了留下您的電子郵件地址以便參加抽獎, 謝謝!
Thank you very much for your time. Please do not forget to leave your e-mail address at the end of this questionnaire if you wish to participate in the prize drawing!

您的性別:
Your gender:

- 男 Male
- 女 Female

您的國籍:
Your nationality:

您現在是幾年級生:
Your current student classification:

- 大學1-2年 University first/second year
- 大學3年以上 University third year and above
- 碩士 Master
- 博士 doctor
- 其他院校 Other institutions
- 非學生 Non student

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您的主修/專業 (可複選):
Your major/research topic (select all that applies):

- 商學 Business
- 工程 Enginner
- 農學 Agriculture
- 科學 Science
- 電腦科學 Computer Science
- 藝文 Art/Literature/History/Language
- 教育 Education
- 社會學 Social Science
- 醫學 Medical
- 其他 Others

您目前就讀的學校位於 (國家或地區):
Location of your current school (Country or State):

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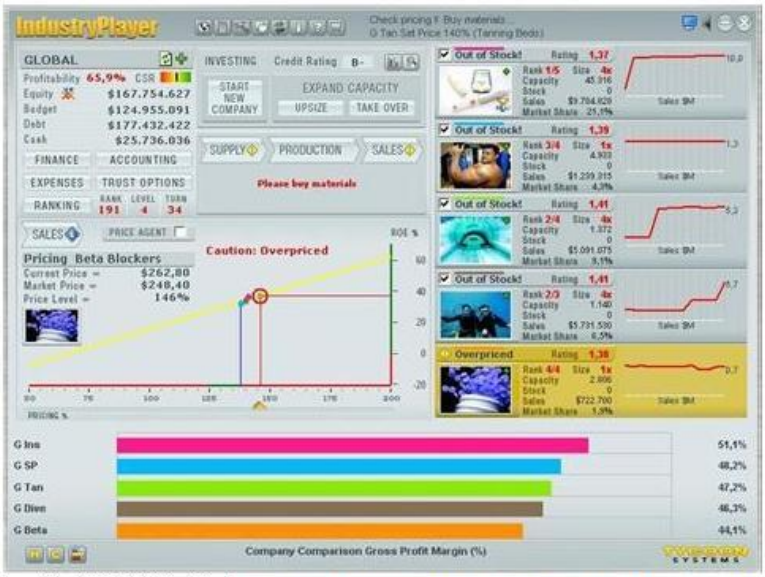
簡介
Brief introduction

(桌面商業遊戲例子) (example of a board type business game)



(電腦商業遊戲模擬例子) (example of a computer simulated business game)

"商業遊戲"是指用玩遊戲的方式來學習。透過商業遊戲，學生們可以把上課學習到的知識，以實際操作，小組討論等等的方式應用出來。商業遊戲的內容有很多種：社會現象，商業策略，環境理論等都有。主要的目的是把書本的概念實物化，增加理解的容易度。
"Business game" is a tool used mainly for education. It provides a way for students to apply knowledge acquired in classrooms through physical operations, group discussions and etc. There are many existing business games with contents ranging from social phenomenon, business strategies, to environmental behaviors. The main function of a business game is to transform concepts into operations that can be physically carried out by students, thus increasing the ease to understand.

您有參與商業遊戲的經驗嗎:
Have you ever participated in any form of business games:

- ◯ 有 Yes
- ◯ 沒有 No

>>

您參與商業遊戲的次數:
Number of times you participated in business games:

- ◎ 1-2次 1-2 times
- ◎ 3-4次 3-4 times
- ◎ 5次以上 5 times or more

您參與商業遊戲的地點 (可複選):
Locations where you participated in business games (select all that applies):

- ☐ 學校 School
- ☐ 商業場所 Business institutes
- ☐ 訓練營 Training camp/workshop
- ☐ 私人研究 Individual research/design
- ☐ 其他 Others

您參與過的商業遊戲的型式 (可複選):
Format of the business games you have participated in (select all that applies):

- ☐ 電腦模擬 Computer Simulation
- ☐ 桌面遊戲 (棋盤, 玩具) Board/Building block
- ☐ 活動式 (戶外, 團體活動) Outdoor/Group game
- ☐ 其他 Others

您對商業遊戲作為一種教學工具的看法:
Your opinion on business games as education tools:

實用價值 Effectiveness ☆☆☆☆☆

喜好程度 Enjoyment of business games ☆☆☆☆☆

下列不同形式的商業遊戲中, 哪種是您最想使用的:
If available, you will most likely want to use which of the following types of business game:

- 電腦/公式模擬 Computer/Formula simulation
- 桌面/棋盤遊戲 Board/Building blocks game
- 人體運動遊戲 Physical game

請按您的喜好重新排列以下商業遊戲的特色的重要性 (用鼠標拖曳):
Please rearrange the importance of the following characteristics of a business game according to your opinion (drag and move with the mouse):

團隊精神 Encourages teamwork

趣味性 Fun

真實性 Realism

啟發思考 Encourages thinking

教學互動 Enables interaction

>>

SDM
System Design and Management

您目前最關心下列何項對環境造成污染的因素:
Which of the following factors contributing to environmental issues do you care about the most:

- 交通運輸 Transportation
- 工業生產 Industrial/Production
- 日常生活 Emission from daily living (Electricity, water usage etc)

請根据您的想法依照環保效果高到低的順序排列環保意識提倡的"3R"概念 (再利用, 回收利用, 減少)(用鼠標拖曳):
Please rearrange the following "3R" (Reuse, Recycle, Reduce) concepts according to effectiveness (high to low) based on your opinion (drag and move with the mouse):

再利用 Reuse

回收利用 Recycle

減少 Reduce

您會想要參與一個模擬工廠生產的商業遊戲，幫助您更了解如何處理污染和工業垃圾嗎？
Would you want to participate in a business game simulating production process in factories, and help you understand more about waste and pollution management?

- 是 Yes
- 否 No

您認為發展中國家的環保意識有落後於發達國家嗎:
Do you think developing countries are lagging behind developed countries in terms of environmental awareness:

- 是 Yes
- 否 No

您認為落後的原因是什麼:
What do you think is the reason for the lag:

- 政策 Govenrment policy
- 錢 Money
- 教育程度 Education Received
- 其他 Others

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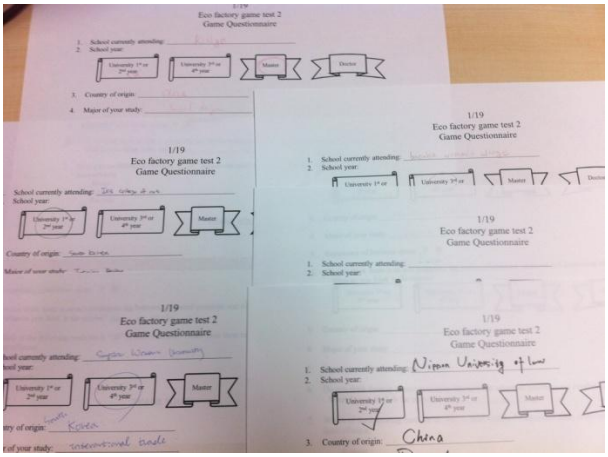
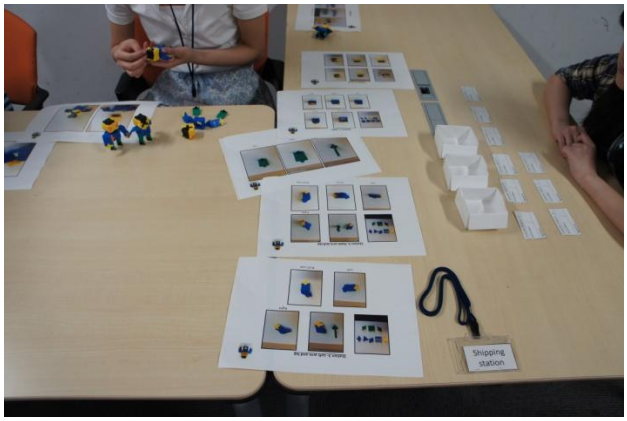
Appendix (Photos of the tests)




Shipping
station