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Design and Implementation of a Six Sigma Game to Develop Entrepreneurship in Engineering Students*

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Using Lego, we proposed a six sigma game to enhance entrepreneurship for engineering students. The game considers not only the importance of quality in the product design and development phase but also aspects such as project management, IP awareness, ethics, and green technology for technology-based entrepreneurship. In particular, we let the participants choose one from a number of available Lego sets of two generations, in which a tradeoff relationship exists between technology and cost. The effects of the proposed game varied over different education levels.

Keywords: Lego; technology management; quality; entrepreneurship; six sigma game

1. Introduction

Engineering students are expected to play a key role in the high-tech industry. In order for them to be successful contributors, entrepreneurship is also needed. For this reason, many institutions have developed courses aimed at teaching entrepreneurship to engineering students [1].

Entrepreneurial education typically involves some type of practice, including games [2, 3]. An entrepreneurship game which is based on theory has the crucial potential to activate the research related to entrepreneurship and boost classroom experience [4]. In addition, the use of management games to teach engineering has the advantage of enabling participants by putting them into complex, realistic project situations [5]. By participating in these types of activities directly rather than learning theoretically, it is possible to improve the creative expression of students, as free configurations and entrepreneurship games provide creative thinking opportunities by allowing them to create or modify structures. This allows them to improve their creativity, entrepreneurship, sense of economy, and logic of situations. Therefore, a game based on entrepreneurship plays a key role as a tool for education.

However, most existing entrepreneurship games only focus on plans of operation, strategies, and sales of complete products. These types of games only emphasize the aspect of entrepreneurial activities to students, skipping what factors are important in relation to product planning and development process. This type of entrepreneurship education is not proper for engineering students who want to start a business based on technology in the near future. Thus, it is necessary to have technology-based entrepreneurial games that provide students with chances to experience the process of selecting proper technology for the design and manufacture of products under several constraints, marketing and preparing for the next generation of products that satisfy multiple objectives. As a result, technology-based entrepreneurial game is needed to contribute to increase participant's creativity and activeness.

In this research, we design a Lego-based entrepreneurship game for engineering students. Lego items have been used to teach engineering students about design, creativity, and structured programming [2]. Using Lego sets, we propose a six sigma game that enhances not only the importance of quality in the product design and development phase but also the importance of project management, IP awareness, ethics, green technology and technology-based entrepreneurship. Specifically, we attempted to impose the aspect of competition based on multi-generation demand by allowing the participant group to choose one of the available Lego sets from among two generations, which have a tradeoff relationship between technology and cost. The multi-generation demand model reflects the diffusion patterns of successive generations of a technology in marketing [6].

From this study, we expect that the proposed Lego-based entrepreneurship games will provide students with confidence not only in production but also in entrepreneurship by allowing them to experience all of the necessary stages of entrepreneurship.

This paper is organized as follows. Section 2 reviews the six sigma concept, the multi-generation component selection process, the constraints, and the concept of the performance evaluation. Section 3 introduces the proposed six sigma game for

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entrepreneurship based on technology. Section 4 analyzes the effects of the six sigma game. Section 5 includes a discussion and the conclusion.

2. Literature review

2.1 Theory of entrepreneurship education

Entrepreneurial education is one of key factors to increase the entrepreneurial attitudes of participants [7]. In this paper, we introduce entrepreneurial education based on the six-sigma game for engineering student. This game is one of experiential learning programs designed based on the theory of entrepreneurship education.

Theories of entrepreneurship education are divided into two classes: entrepreneurship theory and management theory [8].

According to the entrepreneurship theory, entrepreneurial education is supposed to provide an insight into the role of entrepreneur and entrepreneurial process with participants and helps to develop key skills such as creative problem-solving, diagnostic skills, and communication skills. Education program should focus on generation and management of business opportunities. Recognition of entrepreneurial opportunity can be generated from not only his/her specific knowledge but also from unique capacity to boost his/her own knowledge [8, 9]. In order to increase the ability for detecting entrepreneurial opportunity, our proposed game is designed to provide game participants with the opportunity to experience the total process of entrepreneurial activity.

On the other hand, management theory which focuses on entrepreneurship education concentrates on increasing entrepreneur's potential for production planning, people organizing, capitalization, and budgeting [10]. According to the management theory, entrepreneurship education deals with business plans with the description of business area, management team, market segment, marketing plan, business system and organization, implementation and risk assessment, and financing. Our proposed game also reflects management theory because this game covers a business life cycle from product design stage to marketing stage. Based on the management theory, entrepreneurship education considers both internal and external conditions for business success. Internal conditions are associated with resource-based view theory while external condition reflects psychological marketing and industrial organization theories [8]. We develop the entrepreneurship game which considers technological competitiveness based on resource, competition with rival and these contents reflect internal and external conditions in business progress. Detailed information is shown in Section 3.1.

In general, the objective of entrepreneurship education is divided into two categories: entrepreneurship education in the broader sense (EE i.b.s), and entrepreneurship education in the narrow sense (EE i.n.s). The group interested in EE i.b.s has academic interest in the theme of entrepreneurship. The purpose of EE i.b.s is more and more people will be interested in small enterprises, self-employment and entrepreneurship [11]. On the other hand, the group interested in EE i.n.s has interest in becoming entrepreneurs. The course of EE i.n.s, concentrates on practical business affairs regarding the start-up such as financing, law and tax [11, 12].

Our proposed education program falls in closely with EE i.b.s because this program focuses on experiential learning not directly fostering entrepreneur. Especially, the group interested in EE i.b.s is more heterogeneous regarding its motivation to learn. However it can be said in general that due to the relatively high level of academic interest, the search for scientifically-based knowledge rather than direct active competency is often in the foreground [13]. When develop the program based on EE i.b.s, Koch [13] recommend to include at least the following content when designing an application-based, interdisciplinary program: managerial economics, national economics, law, and psychology. These elements are fully reflected in proposed program.

The entrepreneurship education should consider entrepreneurial perceptions and intentions [14, 15] and influence attitudes towards start-up [16]. There are some empirical studies on the effects of entrepreneurship education. The entrepreneurship education has an impact on perception which is related to the fascination and feasibility of start-up [16, 17]. According to Linan et al. [7] theory of entrepreneurial education is closely related to "theory of planned behavior" and "theory of entrepreneurial education" and the author found that individual's perception for perceived social norm, opportunities, and personal attitudes influenced entrepreneurial intention. We expected that our proposed education program can help students take an interest in entrepreneurship.

2.2 Lego games

In this section, we review previous studies about Lego games developed for engineering education or entrepreneurship games typically utilized in the area of business education. In addition, we briefly review the multi-generation diffusion model. The Lego Group developed Lego, which is a line of construction toys [18]. Lego games help to develop creativity and imagination while allowing people to have fun at the same time [19].

Building activities also provide additional, more concrete representations such as goals, target market, and constraints. Because students may have individual learning styles, the use of multiple representations increases the repertoire of models for students. Moreover, because it is very easy to build different configurations using Lego parts, students can be very creative in designing and testing their own designs [20]. Given these advantages, many engineering education programs utilize Lego games. Ringwood et al. [21] investigated a teaching method for undergraduate engineering students based on Lego. To develop hands-on creativity in students, McNamara et al. [22] incorporated Lego blocks into engineering education from kindergarten to graduate school. As a result, students became interested in engineering and excited about learning math and physics after creating models with the blocks. Nagchaudhuri et al. [23] investigated Lego robotic products to boost student creativity in precollege programs.

These previous studies contributed to engineering education using Lego blocks to boost students' creativity. However, previous studies did not consider Lego games or the multi-generation diffusion concept for competing technology. These concepts apply to all Lego games applied to engineering education, with the same set of Lego materials given to students so that they were left without any other choice. In entrepreneurship, it is very important to decide which technologies to adopt when multiple -generations of technologies coexist in the market. A multi-generation diffusion concept is applied to forecast new product demand considering competition and substitution by the next generation of technology. Using this concept, students can learn about the impact of the adoption of different generations of technology, all of which can have a strong impact on entrepreneurship.

As mentioned above, many Lego games have been developed so that engineering students may realize the importance of engineering and basic science concepts such as math and physics. However, entrepreneurial aspects that consider technological evolution in the product development phase and its effects on the market along with the importance of IP management have not been incorporated.

In our Lego-based entrepreneurship game, we want to emphasize the importance of considering competing multi-generation technology in the product design and development phase. The expectations for students are for them to realize not only the importance of quality engineering in the product design and development phase but also technology management for entrepreneurship in the planning phase.

The concept of the multi-generation diffusion model is an important area in this study. The multi-generation demand model finds the diffusion patterns of successive generations of a technology in terms of the marketing [6]. There are several related studies, as follows. Norton and Bass [24] studied the evolution of technology generations using what they termed the Norton and Bass multi-generation diffusion model. They noted that a manager should forecast the substitution level of a new product class for an existing one in a manner that defines substitution patterns. Sohn and Ahn [25] applied a multi-generation diffusion model for economic assessments of new technology based on the Norton and Bass model, Monte Carlo simulation and Taguchi designs. Bohlin et al. [26] studied the diffusion of new technology generations in mobile communications technologies, showing several remarkable differences in diffusion patterns over generations.

The main concept of the multi-generation diffusion model is that demand for a new product is influenced by old or competitive products. This is very important because every business is in competition with others. In the six sigma game proposed here, we expect students to experience the importance of the consideration of the multi-generation diffusion in entrepreneurship.

2.3 Entrepreneurship education

Various institutions support entrepreneurs during the difficult process of developing management plans and obtaining funding to start their new enterprise [27]. Since the mid-1990s, academic organizations have been increasingly involved in activities for the creation of new firms [28]. Recently, universities have made an effort to design programs for entrepreneurial education in various ways to assist their students [29]. This has been accelerated as academic patenting and licensing activities have significantly increased [30].

The major objectives of entrepreneurial education and training programs are to develop entrepreneurs, institute an attitude of self-dependence, and stimulate entrepreneurship by applying appropriate learning processes. Regarding the entrepreneurship education in the United States, universities have engineering students acquire knowledge and skills from field experience and case studies to build a healthy entrepreneurial spirit, also holding a variety of competitions, forums, and seminars [31]. In the U.K., there is increasing attention being paid to the potential of university entrepreneurial education to develop new high-quality firms [32]. In the U.S., the number of schools with an independent faculty for entrepreneurship to offer entrepreneurial courses increased from 20 in 1994 to more than 160 in 2003 [33]. Universities help students to gain knowledge about entrepreneurship and obtain the necessary entrepreneurial talent and skills [34].

Entrepreneurial teaching covers managerial approaches, and many elements in entrepreneurial education have been inspired by the applicability of general management theory. Entrepreneurial education deals with business plans, including descriptions of business areas, management teams, market segments, marketing plans, business systems and organizations, implementation and risk assessment, and financing. Modern entrepreneurship theory focuses on opportunity recognition in a business environment as a central aspect of understanding entrepreneurship [8]. However, both recognition and the realization of a perceived opportunity are important.

A variety of entrepreneurial games or programs have been utilized to increase students' entrepreneurial levels of perception. Hamilton et al. [35] provided a technological entrepreneurship program for an engineering curriculum. They investigated accrued experiences and dealt with intellectual property issues. They also examined the impact of the program in terms of graduates' future plans in entrepreneurship. Peterman and Kennedy [36] analyzed the effect of entrepreneurial education in terms of perceptions of the desirability and feasibility of starting a business. Hindle [37] introduced a theory for teaching entrepreneurship using simulation games and indicated that the 'adequate suspension of disbelief', 'unambiguous communication', 'technical reliability' and a 'cost-benefit analysis' are four important attributes for a successful game. Schwartz and Teach [38] introduced the CONGRUENCE™ game intended for groups of students to learn entrepreneurship. They designed an experiential game that covered the areas of marketing, operations, finance, and human resources. The game experience equipped students with an understanding of the relationships among team-building; team member skill sets; and the alignment between beliefs, ideas, and goal.

3. Proposed game

As mentioned above, we developed a technology-based entrepreneurship game using Lego to provide students with ample opportunities to realize not only the importance of quality in the product design and development phase but also the importance of project management and technology management for entrepreneurial activity.

3.1 Six sigma game for technology-based entrepreneurship

Six sigma is a comprehensive quality initiative that considers measured and reported performances as important, focusing on customer concerns and using project management tools and methodology [39]. The main purpose of the proposed game is to provide students ample opportunities to realize not only the importance of quality in the product design and development phase but also that of project management and technology management for entrepreneurial activity, as noted above. The main targets in this study are students who are currently in engineering programs or those who may become involved in an engineering area.

The six sigma game is designed such that those who would create products consider various constraints in the given time while only using the allowed components. Products devised by individual teams are evaluated in terms of the sigma level of their defects, reliability, durability, production cost, marketability, design, ethics and competitiveness. In this study, we propose a Lego game for technology-based entrepreneurship. Its manual is shown in Table 1. This proposed game was developed based on the previous version of a six sigma game introduced in Sohn and Ju [40]. In the previous version of the six sigma game, the authors focused solely on six sigma concepts such as quality engineering, product design, and development. In this paper, we extend this concept to consider perceptions of entrepreneurship, ethics and multi-generation as well.

In the game situation, participants are faced with various problems, such as the tradeoff between the defect rate and cost and that between cost and design, both of which are fundamentally influenced by the choice of the raw materials. Ultimately, through the process of the game, students learn the importance of quality engineering, technology management and project management. A summary of the manual is given in Table 1.

3.2 Procedure of the six sigma game for technology-based entrepreneurship

The detailed steps of the proposed game are explained below.

The design stage

The main purpose of this step is the concept design of a product. In detail, it is necessary for students to understand the specifications and constraints of the product they are supposed to produce. In the design stage, students are supposed to discuss as a team the overall plans and individual roles assigned for project management. As the first step of this stage, students have to decide which Lego set they will be using. Cost and defect information for each Lego set is given in the Appendix and is available to students to guide their purchase decision. As described in the Table A in the Appendix, the newer version has

Table 1. Summary of the Proposed Lego Game

Title	**Six sigma game for technology-based entrepreneurship**
Content	Two different sets of Lego are given and only one is chosen to be used as raw material. One is an older version and the other is newer version with more variety of parts but with a cost that is twice that of the older version but with better quality. With the selected Lego set, in a limited amount of time (40 min), a toy must be created for a child (4∼7 years old) with a length of 25 cm and a height of 15 cm; it should be a transportation vehicle such as a car, a motorcycle, or some other type of moving vehicle. It is necessary to recognize the importance of design, manufacturing, and green and sales management. Including a test and evaluation, a total time of forty minutes is assigned.
Learning effect / expectation	Students are faced with problems that involve the choice of raw material, handling defects, time, cost, resources, and the marketability of a product with the selected parts. Through this process, students can actually experience a real situation involving technology management, quality management, project management, cost management, design management that considers sustainability as well as appearance, and IP management during the product development stage. An overall improvement of entrepreneurship is expected.
Related theory	Six sigma, technology management, marketing, quality engineering, decision analysis, entrepreneurship
Assignment	Suggest a business model to which each participant can contribute.

more parts but its parts cost twice as much as the older version. There are green items in both generations of Lego sets which are again twice as expensive as the regular parts, but they do not incur any salvage cost when the product is discarded. The salvage cost of regular parts is an additional 10% at the end of the product lifetime with these parts. There is also the potential for a recall with these parts.

Also in this stage, students need to discuss a R&D strategy as well.

The manufacturing stage

The second step is manufacturing. In this phase, it is necessary to devise a product in consideration of not only quality but also the production cost, aesthetic design and basic requirements of the specification. Students are supposed to utilize only the chosen set of Lego parts. During this process, it is necessary to consider what parts are needed for the students to produce the required product efficiently. Participants can also hire consultants, but there is an additional charge. Worksheets can be also used. Also, creativity is required to come up with an interesting design. Time management is an important aspect that students need to learn here as well.

The test stage

The third step is to test a prototype product to verify whether it satisfies the basic requirements (size of 24×15cm, driving ability of at least 1m, and durability such that it will survive a drop of 25 cm). When these requirements are not met, the product is excluded from the final assessment.

The evaluation stage

In the final step, products are evaluated in terms of three aspects: the defect rate, production cost, and aesthetic design. By summing up the individual scores for each element, final rankings are calculated.

The management stage

Students are then supposed to present their product with a brand name and are asked to explain their expectation of the initial market share, the maximum market potential and the market life.

Furthermore, students are required to predict potential demands and calculate expected returns. Through this process, they can recognize what they need to consider for entrepreneurship.

Additionally, we cover ownership issues related to the intellectual property of new products and technologies.

Additional points

This game is supposed to provide participants with information regarding the overall engineering and business process, from developing a product to commercialization. In this process, it is important to consider sustainability issues with green technology and ethics management for the good of mankind.

Among them, the factor of accessories refers to all components not mentioned, and although cost and defect problems occur, the accessories have a positive effect on the design. Moreover, consulting, limited to three times, is allowed for those who want to divide their problems.

In the evaluation process, the defect rate of the product is obtained based on the structure of component part, and the total cost is calculated by adding all of the consulting and parts costs to the salvage cost. Aesthetic design is also evaluated on a ten-point scale (higher is better). In order to combine all of these aspects, we change the defect rate and cost so that they can be evaluated on a ten-point scale, as follows: 1 (worst of the teams) — 10 (best team). They are then summed. Through this process, each team is evaluated.

4. Implementation and result

Students at different level have different attitudes about teaching and learning, as well as different responses to specific classroom environments and instructional practices [41]. We implement the proposed game with three different age groups: first-year science high-school students, industrial engineering junior and senior undergraduates, and graduate students who were taking quality engineering and technology quality management courses at a university located in Seoul, Korea. The game was implemented after introducing the six sigma concept to both the undergraduate and graduate students during their regular coursework in December of 2010. The science high-school students were invited to the university to perform this game in November of 2010. The high-school students were selected based on their special aptitude in science and mathematics; they were assumed to be superior in those fields but had not been exposed to engineering and management. The undergraduate students were industrial engineering majors and did not have work experience, while the graduate students were a mixture of full-time and part-time students who were working while they attended their classes. The graduate students' undergraduate majors varied and included computer science, mechanical engineering, statistics, management and industrial engineering. In order to measure the performance of the proposed game, we designed a survey form.

4.1 Survey design

To measure the performance of the proposed game, we established 24 survey questions (Q1–Q24) covering the five areas of awareness of the concepts of the game, teamwork, changes in perceptions on career and entrepreneurial activity after experiencing the game, satisfaction with the composition of game, and perceptions of ethics. We surveyed these questionnaires from participated students. Regarding

Table 2. The List of Subcategories, Contents of Questions, and Measurement Scales

Sub category	Questions	Measurement Scale
Awareness of the concepts of the six sigma game	Understanding the concept of multi-generation diffusion (Q1)	Five-point Likert scale
	Degree of importance of manufacturing factors that participants consider during the game (cost, defect rate, design, market demand, standards, reliability, green technologies, do not consider) (Q2)	Ordinal scale (Ranking)
	Degree of importance of manufacturing factors that they perceive after the game (cost, defect rate, design, market demand, standards, sustainable green technologies, reliability) (Q3)	Ordinal scale (Ranking)
	Association between the game and entrepreneurship (Q4)	Five-point Likert scale
Teamwork	Satisfaction with role (Q5)	Five-point Likert scale
	Harmony among team members (Q6)	Five-point Likert scale
	Consideration of team members (Q7)	Five-point Likert scale
	Degree of participation (team management, initial planning of products, defect management, cost management, exterior design management, reliability management, manufacturing, intellectual property management and entrepreneurial ideas created) (Q8)	Five-point Likert scale
Changes in perception on career and entrepreneurial activity after experiencing the game	Interest in entering into engineering-related fields (Q9)	Five-point Likert scale
	Improvement of interest in entrepreneurship (Q10)	Five-point Likert scale
	Improved understanding of the importance of intellectual property (Q11)	Five-point Likert scale
	Increasing curiosity about entrepreneurial activity (Q12)	Five-point Likert scale
	Increase in problem-solving skills (Q13)	Five-point Likert scale
	Decreased fear of failure in entrepreneurial activity (Q14)	Five-point Likert scale
	Increase in knowledge about related fields (Q15)	Five-point Likert scale
Composition of the game and satisfaction	Properness of time (Q16)	Five-point Likert scale
	Novelty of content (Q17)	Five-point Likert scale
	Adequacy of composition (Q18)	Five-point Likert scale
	Immersion of the game (Q19)	Five-point Likert scale
	Level of difficulty (Q20)	Five-point Likert scale
Perception of ethics	Degree of copying other teams' design (Q21)	Five-point Likert scale
	Degree of copying other teams' process of development (Q22)	Five-point Likert scale
	Consideration of the side effects of a product (Q23)	Five-point Likert scale
	Consideration of sustainability through green technology (Q24)	Five-point Likert scale

the awareness of the concepts of the game, the respondents were required to report the degree of understanding of the concept of multi-generation diffusion and the degree of the importance of the manufacturing factors that participants considered during and after the experiential learning process. Categories for the overall satisfaction of participants were assessed in the part that measured satisfaction with the composition of the game with the factors of time, novelty of the content, adequacy of the composition, immersion of the game, and its level of difficulty. The degree of participation was assessed with the sharing of active roles as well as the performance of individual roles in the teamwork category. Entrepreneurship was measured in terms of the improvement of one's entrepreneurial mind, i.e., an improvement in one's interest in entrepreneurship, increased curiosity about entrepreneurial activity, and a decrease of fear of failure in entrepreneurial activity through the experience of creating a product in the game.

The participants were also asked to report changes in perception after experiencing the six sigma game in terms of their interest in a related field and the level of improvement in their problem-solving skills. Finally, we considered the degree to which other teams' designs were referenced, the development process, and the use of green technology in terms of the perceptions of ethics.

Overall, this survey is designed to generate feedback to improve entrepreneurship and the perception of engineering. Table 2 shows the categories, questions, and their measurement scales.

4.2 Result

The three groups of students who participated in the six sigma game were first-year science high-school students, a university undergraduate class, and graduate students who had some work experience. The total numbers of participants are 62 which consist of 19 (high school), 30 (undergraduate), and 13 (graduate) students in each group. Among them, the number of male students and female students are as given in Table 3.

Table 4 shows associated values of Cronbach's α testing the relationship between each factor and individual questions, along with the result of confirmatory factor analysis. According to the Cronbach's α test, the relationships of all factors were confirmed except for teamwork (Q5, Q6, and Q7) and perception on ethics (Q21, Q22, Q23, and Q24).

In addition, the result of analysis of variance (ANOVA) is given to test if the effects of six sigma game were different over different groups of students (high school, undergraduate, and graduate program). In Table 4, the p-values of Q7 (consideration of team members) and Q23 (consideration of the side effects of a product) are greater than the 0.05, therefore the null hypothesis of no group effect

Table 3. Gender ratio by each education level

Education Level	Male	Female
High school	17 (89%)	2 (11%)
Undergraduate	17 (57%)	13 (43%)
Graduate	10 (77%)	3 (23%)

Table 4. Result of Cronbach's α test for reliability and analysis of variance

Category	Question	Standardized Cronbach's α	Loading	Weight	P-value
Awareness of concepts about six sigma game*	Q1	0.621	0.849	0.588	<0.0001
	Q4		0.850	0589	
Teamwork*	Q5	0.486	0.895	0.559	0.028
	Q6	(without Q7, 0.745)		0.895	0.559
	Q7		1.000	1.000	0.294
Changes of perception on career and entrepreneurial activity after experiencing the game*	Q9	0.861	0.782	0.207	<0.0001
	Q10		0.509	0.135	
	Q11		0.703	0.186	
	Q12		0.798	0.211	
	Q13		0.835	0.221	
	Q14		0.691	0.183	
	Q15		0.776	0.205	
Composition of Game and Satisfaction*	Q16	0.794	0.81	0.288	<0.0001
	Q17		0.64	0.228	
	Q18		0.852	0.303	
	Q19		0.607	0.216	
	Q20		0.808	0.287	
Perception on ethics* (Partially)	Q21	0.383	0.947	0.528	0.0452
	Q22	(without Q23 and Q24,	0.947	0.528	
	Q23	0.887)	1.000	1.000	0.1924
	Q24		1.000	1.000	0.0281

* Significant at the 0.05 level.

is not rejected. Except for Q7 and Q23, we found that there is a significant group effect.

Subsequently, in order to analyze the effect of six sigma game at the level of each question, we conducted χ^2 test as shown in Table 5.

(1) *Awareness of concepts about six sigma game*

In terms of their understanding of the concept of multi-generation diffusion (Q1), there were significant differences among the three groups. The degree of understanding the concept of multi-generation diffusion was higher in the group of high-school students than the other groups. In terms of an association between the game and entrepreneurship (Q4), the high-school students and the graduate students answered positively on Q4 but the university students responded that the proposed game was relatively uncorrelated with entrepreneurship. This result reflects that science high-school students are more receptive to new ideas and knowledge.

(2) *Teamwork*

There are no significant group differences in satisfaction with role play in the six sigma game (Q5) or in the level of consideration of team members (Q7). None of the three groups realized that they were supposed to assign individual roles for the game and consider their team members. In addition, harmony among team members (Q6) showed significant differences among the three groups. Looking at response rates among the three groups, almost 90% of the high-school and undergraduate students reported that while playing the six sigma game, their team members were well harmonized. The graduate

Table 5. Result of the six sigma Game (Unit: people (percentage))

Category	Question	Response	High school	Undergraduate	Graduate
Awareness of concepts about six sigma game	Q1*	Equal to and more than 4 points	19 (100.00%)	12 (40.00%)	10 (76.92%)
		Equal to and less than 3 points	0 (0.00%)	18 (60.00%)	3 (23.08%)
	Q4*	Equal to and more than 4 points	17 (89.47%)	16 (53.33%)	12 (92.31%)
		Equal to and less than 3 points	2 (10.53%)	14 (46.64%)	1 (7.69%)
Teamwork	Q5	Equal to and more than 4 points	13 (68.42%)	18 (60.00%)	5 (38.46%)
		Equal to and less than 3 points	6 (31.58%)	12 (40.00%)	8 (61.54%)
	Q6*	Equal to and more than 4 points	17 (89.47%)	27 (90.00%)	8 (61.54%)
		Equal to and less than 3 points	2 (10.53%)	3 (10.00%)	5 (38.46%)
	Q7	Equal to and more than 4 points	6 (31.58%)	11 (36.67%)	7 (53.85%)
		Equal to and less than 3 points	13 (68.42%)	19 (63.33%)	6 (46.15%)
Changes of perception on career and entrepreneurial activity after experiencing the game	Q9*	Equal to and more than 4 points	16 (84.21%)	8 (26.67%)	10 (76.92%)
		Equal to and less than 3 points	3 (15.79%)	22 (73.33%)	3 (23.08%)
	Q10	Equal to and more than 4 points	8 (42.11%)	8 (26.67%)	5 (38.46%)
		Equal to and less than 3 points	11 (57.89%)	22 (73.33%)	8 (61.54%)
	Q11*	Equal to and more than 4 points	15 (78.95%)	7 (23.33%)	11 (84.62%)
		Equal to and less than 3 points	4 (21.05%)	23 (76.67%)	2 (15.38%)
	Q12*	Equal to and more than 4 points	16 (84.21%)	14 (46.67%)	10 (76.92%)
		Equal to and less than 3 points	3 (15.79%)	16 (53.33%)	3 (23.08%)
	Q13*	Equal to and more than 4 points	15 (78.95%)	12 (40.00%)	5 (38.46%)
		Equal to and less than 3 points	4 (21.05%)	18 (60.00%)	8 (61.54%)
	Q14*	Equal to and more than 4 points	16 (84.21%)	15 (50.00%)	9 (69.23%)
		Equal to and less than 3 points	3 (15.79%)	15 (50.00%)	4 (30.77%)
	Q15*	Equal to and more than 4 points	18 (94.74%)	8 (26.67%)	12 (92.31%)
		Equal to and less than 3 points	1 (5.26%)	22 (73.33%)	1 (7.69%)
Composition of Game and Satisfaction	Q16*	Equal to and more than 4 points	9 (47.37%)	2 (6.67%)	5 (38.46%)
		Equal to and less than 3 points	10 (52.63%)	28 (93.33%)	8 (61.54%)
	Q17*	Equal to and more than 4 points	18 (94.74%)	20 (66.67%)	13 (100.00%)
		Equal to and less than 3 points	1 (5.26%)	10 (33.33%)	0 (0.00%)
	Q18*	Equal to and more than 4 points	16 (84.21%)	10 (33.33%)	11 (84.62%)
		Equal to and less than 3 points	3 (15.79%)	20 (66.67%)	2 (15.38%)
	Q19	Equal to and more than 4 points	16 (84.21%)	22 (73.33%)	12 (92.31%)
		Equal to and less than 3 points	3 (15.79%)	8 (26.67%)	1 (8.33%)
	Q20*	Equal to and more than 4 points	12 (63.16%)	7 (23.33%)	10 (76.92%)
		Equal to and less than 3 points	7 (36.84%)	23 (76.67%)	3 (9.09%)
Perception on ethics	Q21	Equal to and more than 4 points	0 (0.00%)	1 (3.33%)	2 (15.38%)
		Equal to and less than 3 points	19 (100.00%)	29 (96.67%)	11 (84.62%)
	Q22	Equal to and more than 4 points	0 (0.00%)	2 (6.67%)	1 (7.69%)
		Equal to and less than 3 points	19 (100.00%)	28 (93.33%)	12 (92.31%)
	Q23	Equal to and more than 4 points	4 (21.05%)	3 (10.00%)	3 (23.08%)
		Equal to and less than 3 points	15 (78.95%)	27 (90.00%)	10 (76.92%)
	Q24*	Equal to and more than 4 points	6 (31.58%)	1 (3.33%)	3 (23.08%)
		Equal to and less than 3 points	13 (68.42%)	29 (96.67%)	10 (76.92%)

* Significant at the 0.05 level.

students were older and may not have been less flexible in terms of cooperation.

(3) *Changes of perception of career and entrepreneurship after experiencing the six sigma game*
Interest in entering a related field (Q9), an improved understanding of the importance of intellectual property (Q11), increased curiosity about entrepreneurial activity (Q12), and increased knowledge of related fields (Q15) were all found to be low in the group of university students. However, increased curiosity about entrepreneurial activity (Q12) was remarkably high in the group of high-school and in the graduate students. In addition, only the high-school students reported that their problem-solving skills (Q13) increased, while a fear of failure in entrepreneurial activity (Q14) showed the greatest decrease in the graduate students. Overall, regarding changes in perception after experiencing the six sigma game, the high-school students answered all questions positively while the university students tended to respond to most questions negatively. This may be due to time pressure felt by the undergraduate students, who had a class immediately after the game.

(4) *Composition of the game and levels of satisfaction*
All participants reported that the given time limit of 40 minutes (Q16) was insufficient. Our six sigma game was new (Q17) to the group of graduate students. In terms of the adequacy of the composition (Q18), the university students showed lower satisfaction scores than the other groups, although graduate students' level of satisfaction was higher than that of the high-school students. Compared to the other groups, the graduate students felt that the level of difficulty of the six sigma game (Q20) was high. Moreover, the most striking feature regarding the composition of the game and the level of satisfaction was the adequacy of the time given to play it (Q16). Although the responses to this question were negative in the three groups, the positive response rate of the high-school students was higher than those of the other groups.

(5) *Perception on ethics*
In the questions about ethics perceptions, there were no significant differences in most of the answers except for Q24 (consideration of sustainability through green technology). The response rate regarding the degree that sustainability was considered through green technology (Q24) was low in all three groups. Although it is important to use green technology, because the use of green technology was associated with a cost increase, the students avoided using the green parts of the Lego set.

Question Q2 (the degree of importance of manufacturing factors that students perceived during the game) in Table 6 was measured in terms of ranking. In the calculation of the total score, if participants choose an item for first place, a score of eight points is given, and if an item is selected for eighth place, one point is given. Next, the total score was calculated as the sum of the individual scores. Q3 (The

Table 6. Results of the six sigma Game (Unit: score)

Category	Question	Level	High school	Undergraduate	Graduate
Awareness of the concepts of the six sigma game	Q2	Cost	111	90	69
		Defect	65	73	56
		Design	108	164	79
		Market demand	53	72	48
		Standards	85	91	70
		Reliability	61	70	70
		Green technology	30	29	35
		Not considered	12	68	12
	Q3	Cost	81	109	53
		Defect	75	110	53
		Design	85	117	51
		Market demand	86	114	53
		Standards	54	112	52
		Reliability	80	104	57
		Green technology	68	94	42
Teamwork	Q8	Team leader	65	93	38
		Initial planning products	69	97	43
		Defect	50	76	29
		Cost	58	71	34
		Design	72	92	42
		Reliability	65	81	38
		Manufacturing	82	107	51
		IP management and ideas drawn	61	80	33

importance of the degree of manufacturing factors that they perceived after the game) and Q8 (the degree of participation) were measured on a five-point Likert scale. A score of five points was given if an item was chosen for first place, and the total score is calculated as it was with Q2.

Regarding the importance of the manufacturing factors during the game (Q2), the high-school students considered cost and design as the most important factors, while design was regarded as the most crucial factor for the undergraduate students. On the other hand, the important factors for graduate students were standards, reliability, and cost.

In the importance of the degree of manufacturing factors after the game (Q3), most factors received similar scores. Therefore, after the six sigma game, this shows that the participants learned that all components have important meanings.

The results pertaining to the degree of participation (Q8) in the six sigma game were similar in the three groups. Most students tended to focus on manufacturing a product, whereas they paid less attention to cost and defects. Although it is necessary for students to distribute roles by considering various factors, the role distribution was not considered properly due to the limited time.

Through the six sigma game, we uncovered the uniqueness of the each group in terms of their age and levels of social experience. High-school students generally answered the questions positively. They were curious about their interests and are sensitive to new learning experiences. Moreover, because they study at a science high school that usually teaches subjects such as mathematics and physics to increase their reasoning skills, high-school students are familiar with assembling Lego sets in an allotted time. Thus, their level of acceptance and their adaptive speed in the six sigma game were faster than those of the other groups of students. On the other hand, the university students tended to respond to most questions negatively. Students in their last years at Korean universities usually tend to consider securing employment first rather than entrepreneurial activity. Moreover, in the survey, the graduate students reported what they learned not only from social experience but also from indirect experience such as working with research papers. Graduate students who have extensive experience directly or indirectly considered more varied and substantive factors such as cost, design, standards, and reliability as compared to the other groups of students.

Furthermore, in the survey, it was required that the students report their thinking about the learning outcomes. The high-school, university, and graduate students were free to write what they felt, negative or positive, about the six sigma game as feedback.

Comparing the characteristics of the three groups, undergraduate and graduate students do not tend to consider the manufacturing process from product planning to commercialization with a systematic viewpoint due to the limited time, while the high-school students were not affected by the time constraint. Moreover, through the six sigma game, the high-school and university students learned the importance of considering role distribution, efficiency, and managing defects before production. In order to increase the quality of the products, they learned that predictions of potential customers and consideration of standards and safety are important when manufacturing products. Nevertheless, the comments above were relatively rare in the reports of the graduate students.

After experiencing the six sigma game, participants proposed various business models. An automatic car review mirror to measure distances, a USB memory stick that can be connected to a computer regardless of the direction in which it is inserted, an integrated toothbrush and toothpaste product, and applications for mapping products in major supermarkets using smart phone were introduced by the undergraduate students. After finishing the six sigma game, the high-school students also presented their business ideas. They proposed a variety of ideas considering customers and environment, such as green chemistry/laboratory waste containers, a physical power system using piezoelectricity, and miniaturization of new mobile devices and materials. From the graduate students, business models were proposed, such as a refrigerator that manages expiration dates, a detachable automatic calorie device, and pre-assembled Lego parts.

5. Discussions

In this research, we proposed a six sigma game based on the theory of entrepreneurial education. In terms of management theory, entrepreneurship education covers a business life cycle from product design to marketing stage. Using Lego, we proposed a six sigma game that enhances not only the importance of quality in the product design and development phase but also the importance of project management and technology management for entrepreneurial activity. Specifically, we tried to impose a measure of competition based on multi-generation demand and the effects of green management.

In addition, we surveyed high-school, university, and graduate students in order to measure the effects of the game. The tool was divided into several subcategories, including teamwork, entrepreneurship, the composition of game and the level of satisfaction, and an awareness of engineering.

Looking at the result of the survey analysis of each group, most of the high-school students were curious and interested in the six sigma game and in entrepreneurial activity. On the other hand, Korean university students, even those in the graduating classes, tend to consider finding work first rather than entrepreneurial activity. The graduate students were mostly interested in entrepreneurial activity related to what they have learned from not only social experience but also from indirect experiences such as writing research papers.

After the game, high school and graduate students responded that their perception was increased with respect to the interest in entrepreneurship, curiosity about entrepreneurial activity, knowledge about related fields. These factors are directly or indirectly associated with entrepreneurial opportunity and showed that our proposed game contributed to respondent's engagement with potential entrepreneurial activity. This backs up the aspect of entrepreneurial theory reflected on our proposed game.

In terms of management theory, we analyzed participant's activity, knowledge about the concept of the six sigma game. When comparing the importance of various manufacturing factors before and after the six sigma game, we found that participants notice the importance of each factor such as cost, defect, design, and reliability more evenly. It can be interpreted that participants realized the significance of whole process of business in a better manner. Especially, this trend was noticeable among undergraduate and graduate students.

6. Conclusions

Recently, entrepreneurship has been actively investigated in various areas. Specifically, it has drawn the attention of engineering educators in view of the fact that engineers who have an entrepreneurial background have much potential and the power to succeed. A widely known means of entrepreneurial education is through the use of games. Entrepreneurial games have the potential to activate entrepreneurship research and to augment classroom experiences. In order to plant entrepreneurship, we reformed previous six sigma game.

Although there are different characteristics among the three groups as high-school, university, and graduate students, common features can also be found. The three groups of students learned the importance of considering role distribution, efficiency, and quality before producing a product, and they realized that predictions of potential customers and consideration of standards and safety are important when manufacturing products. From the stage of planning to the stages of design and production, the game experience increased the levels of interest and curiosity related to entrepreneurship. We expect that the proposed game will assist individuals who have the potential to start new businesses. In addition, the proposed game has a benefit for corporate entrepreneurship given its ability to improve teamwork and creativity while reducing moral hazard.

Additionally, in the game, we simplified the calculation for the defect rate of product as additive procedure. However, in real case, defect rate of a system should be obtained following the structure of assembled components. This point needs to be updated in the implementation.

Although we implemented the proposed game with high-school or older students, it can be extended even to elementary school students in view of the popularity of use of Lego. The implementation of the proposed game for elementary and middle-school students can help to increase their interest in engineering and can give them an entrepreneurial spirit. Furthermore, international comparison is also an important issue to improve Korean entrepreneurial education reflecting environmental conditions such as economic situations and education policy. These issues are left for further study.

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Appendix

Table A. Part Description, Cost, Percent Defective Values

Old Generation				**New Generation**			
Part	**Quantity**	**Cost/ unit($)**	**Percent defective**	**Part**	**Quantity**	**Cost/ unit($)**	**Percent defective**
Black Block (16)	2	1.6	0	Black Block (15)	10	3	0
Black Block (12)	2	1.2	0	Black Block (13)	2	2.6	0
Black Block (10)	2	1	0	Black Block (9)	11	1.8	0
Black Block (8)	2	0.8	0	Black Block (7)	4	1.4	0
Black Block (4)	2	0.4	0	Black Block (6)	4	1.2	0
Black Block (2 × 2 holes)	4	0.4	0	Black Block (5)	4	1	0
Black Block (2 × 1 holes)	3	0.2	0	Black Block (1)	21	0.2	0
Yellow Block (12)	2	1.2	0	Dark Gray Block (15)	4	3	0
Yellow Block (4)	4	0.4	0	Dark Gray Block (13)	9	2.6	0

Old Generation				New Generation			
Part	Quantity	Cost/ unit($)	Percent defective	Part	Quantity	Cost/ unit($)	Percent defective
Yellow Block (2)	2	0.2	0	Dark Gray Block (11)	3	2.2	0
Yellow Block (1)	2	0.1	0	Dark Gray Block (9)	5	1.8	0
No holes Black Block (10)	6	0.5	0	Dark Gray Block (7)	5	1.4	0
No holes Black Block (8)	3	0.4	0	Dark Gray Block (5)	5	1	0
No holes Black Block (4)	5	0.2	0	Dark Gray Block (3)	9	0.6	0
No holes Black Block (3)	2	0.15	0	Dark Gray Block (2)	10	0.4	0
No holes Black Block (2)	2	0.1	0	Dark Gray Block (1)	34	0.2	0
No holes Black Block (10*2)	1	1	0	No holes Black Block (4)	1	0.4	0
No holes Black Block (6*2)	1	0.6	0	No holes Black Block (2*2)	3	0.4	0
No holes Black Block (4*2)	1	0.4	0	Gray Block (9)	4	1.8	0
No holes Black Block (3*2)	4	0.3	0	Gray Spindle (7)	15	2.8	6
No holes Black Block (6*2)	1	0.6	0	Gray Spindle (5)	29	2	6
No holes Yellow Block (3*2)	1	0.3	0	Gray Spindle (3)	36	1.2	6
No holes Yellow Block (2)	4	0.1	0	Gray Block (1)	24	0.2	0
No holes Yellow Block (1)	1	0.05	0	Black Spindle (12)	4	4.8	6
Gear set	1	5	30	Black Spindle (10)	3	4	6
Spindle (10)	4	2	6	Black Spindle (8)	7	3.2	6
Spindle (8)	9	1.6	6	Black Spindle (6)	11	2.4	6
Spindle (6)	4	1.2	6	Black Spindle (4)	27	1.6	6
Spindle (5)	9	1	6	Gear set	1	10	30
Spindle (4)	4	0.8	6	Tire	4	10	20
Spindle (3)	5	0.6	6	Connection Part (Block Connection)	N	0.2	0
Spindle (2)	12	0.4	6	Accessories	N	0.4	5
Tires	4	5	20				
Connection Part (Block Connection)	N	0.1	0				
Accessories	N	0.2	5				

Any part with green dot is twice as expensive as regular parts but guarantees a low recall probability and cost due to waste so as to reduce the extended producer's responsibility.

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