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A Study on the Correlations among Environmental Education, Environment-Friendly Product Development, and Green Innovation Capability in an Enterprise

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ABSTRACT

High-tech industry creates economy for Taiwan; nevertheless, it is wondered whether it also results in environment crises. With the excellent geo-environment, fast growth of parks, and global product marketing, Taiwan is successfully promoted to the third of information industry and the fourth of semiconductor industry globally after developing for two decades. In consideration of the rising demands for environment-friendly products, it is a primary issue for hi-tech industry in Taiwan to develop environment-friendly products conforming to market demands and to further get rid of the vicious circle of price competition by enhancing employees' environmental literacy through environmental education. Aiming at supervisors and employees of enterprises in Hsinchu Science Park, total 500 copies of questionnaire are distributed in this study. 327 valid copies are retrieved, with the retrieval rate 65%. The research results conclude that 1.environment-friendly product R&D shows significantly positive correlations with green innovation capability, 2.environmental education reveals remarkably positive correlations with environment-friendly product R&D, and 3.environmental education presents notably positive correlations with green innovation capability. Based on the research results, suggestions are proposed in this study, expecting to assist hi-tech industry in developing environmental education and grasping green business opportunities to further get rid of the vicious circle of price competition.

Keywords: high-tech industry, environmental education, environment-friendly product R&D, green innovation capability

INTRODUCTION

Under the waves of ecological catastrophe, caused by the depletion of resources, ozone hole, and warming of oceans on the Earth, and green consumption, the needs for environment-friendly products are also increasing. Advanced countries like the US and European Union have promoted various environmental regulations and environmental standards to strictly examine the imported goods and form the green barrier for the international trade. To develop environment-friendly products, establishing product attributes with environmental protection and successfully including the idea of environmental protection into the core thoughts of corporate business decision-making and marketing programs are irresistible green challenges as well as green business opportunities for businesses in Taiwan who have Europe, the US, and Japan as the major export markets.

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State of the literature

- To develop environment-friendly products, establishing product attributes with environmental protection and successfully including the idea of environmental protection into the core thoughts of corporate business decision-making and marketing programs are irresistible green challenges.
- Some environmental problems, like air, water, and waste, which could endanger the living environment, are hidden in high-tech industry in parks that it is worth noticing for protecting the environment.
- Environmental education therefore becomes a primary issue for high-tech industry in Taiwan to master green business opportunities, develop environment-friendly products conforming to market needs, and further get rid of the vicious circle of price competition.

Contribution of this paper to the literature

- The major obstacle to the development of environment-friendly products lies in the trust from buyers, while the key to acquire buyers' trust relies on the entire process of production, sales, discard, recycle, and reuse of suppliers 'products being secure and conforming to environmental standards.
- Product R&D must combine with global custom market orientation and the ecological environmental protection and social commitment of the enterprise to satisfy customer requirements. Environmental education is therefore necessary for the enhancement.
- A value-oriented model should be established for the promotion of environmental education: Environmental education training should be regarded as a delivery medium for the employees forming exchange and creating value through network interaction and reciprocal experiences.

Science parks are the heavyweights for the high technology in Taiwan. High-tech industry creates economy for Taiwan; however, it is wondered whether it also results in environmental crises. Because of the excellent geo-environment, the rapid growth of parks, and the global product marketing, Taiwan is promoted to the third of information industry and the fourth of semiconductor industry globally after the two-decade development so that it becomes the Silicon Valley in Asia and the model of green silicon island.

Nonetheless, the enhancing production capacity increases the use of chemicals, toxic chemicals, and organic solvent for various industries in parks. Consequently, public safety and environmental protection problems cannot be ignored. High-tech industry creates economy in Taiwan, while the caused environmental problems should not be ignored. Sustainable development can be preceded under the promotion of both economy and environmental protection. By referring to the experiences in the US Silicon Valley, the economic prosperity and the living environment should be taken into account. Some environmental problems, like air, water, and waste, which could endanger the living environment, are hidden in high-tech industry in parks that it is worth noticing for protecting the environment. It therefore becomes a primary issue for high-tech industry in Taiwan to master green business opportunities, develop environment-friendly products conforming to market needs, and further get rid of the vicious circle of price competition.

LITERATURE AND HYPOTHESIS

Environmental education

Hagen (2012) defined environmental education as the educational process to achieve the objective of environment improvement. It was the processes of value cognition and concept clarity to understand and emphasize the skills and attitudes required for the relationship between humans and the culture and the biophysical environment. Environmental education instructs people to make decisions when facing real problems in environmental quality and to develop the behavior criteria for self-development. Bateson & Martin (2013) proposed that environmental education was the education process, involving in the relationship between people and nature, artificial environment, including population, pollution, resource distribution and exhaustion, conservation, transportation, technology, urban and rural plans, and the relationship with the entire human environment. Borges (2013) indicated that the specific teaching objective of environmental education was to establish environmental awareness, environmental concept knowledge, environmental attitudes, environmental

action skills, and environmental action experiences, revealing that environmental education was an education idea to establish environmental behavioral capability (Liu, 2011). Yu et al. (2013) mentioned that the promotion of environmental education aimed to cultivate the awareness and concerns of people, either in cities or countryside, about the mutual relationship with economy, society, politics, and ecology, which provided each person with opportunities to acquire knowledge, value, attitudes, commitment, and skills to protect and improve the environment, so as to create a new environmental behavior model for individuals and the society. Dunkley et al. (2012) argued that environmental education did not simply deliver knowledge and establish skills; more importantly, it was to change the consumption-oriented mind of people to form the value of environment sustainability. Wu (2013) stated that cultivating a responsible environmental citizen through the enhancement of environmental protection knowledge and skills and the formation of attitudes and value could specifically reform personal life or action to actively participate in environment improvement and protection and further change the social structure.

Referred to Chang (2013), environmental education is divided into three of domains of cognition, affection, and psychomotor in this study, where cognitive domain contains environmental concept and knowledge, affective domain includes the cultivation of attitudes, value, and behavior, and psychomotor covers the skills to solve environmental problems.

Environment-friendly product R&D

Chen (2013) regarded environment-friendly product development as "environment-friendly new product development". Environment-friendly product R&D could be considered as the combination of a series of information processing, through which environment-friendly product R&D convers market opportunities and needs into production knowledge. Bashkite et al. (2014) emphasized that technology and marketing program were complementary at each stage of product development in the environment-friendly product development process model. In this case, each stage was collected and evaluated the information for making decisions. Meanwhile, an enterprise had to understand and overcome the insufficient marketing and technology in order to enhance the success rate of environment-friendly product development as well as to completely practice environment-friendly product R&D. Hsiao et al. (2011) proposed 13 steps for environment-friendly product R&D, including concept generation, screening, preliminary market analysis, preliminary technology analysis, market study, product development, internal product testing, customer product testing, market testing, pre-commercial finance analysis, and commercialization. Michaels proposed similar concepts in 1989 and organized the steps of concept generation, screening and analysis, development and testing, pricing, market testing, market prediction, marketing planning, and product introduction for environment-friendly product R&D. In new environment-friendly product R&D process, Chen& Chang (2013) regarded R&D strategies as the basis of environment-friendly product R&D, in addition to the mastery of valuable information. Kwon et al. (2014) pointed out environment-friendly product R&D as the key in the survival of an enterprise and the motivity to remain the competitive advantages. In the environment-friendly product R&D process, an enterprise has to rapidly promote new environment-friendly products as well as really satisfy customer needs and resist the threats from competitors. For this reason, it is important to correctly analyze the information of consumer markets so as to assist an enterprise in planning environment-friendly product R&D strategies suitable for the enterprise. Since environment-friendly product R&D strategies are the basis of new product development, it would affect the innovation of an enterprise developing environment-friendly products. Referring to Chiang et al. (2011), the measurement of environment-friendly product R&D contains

(1) Level of technology: The difference of an enterprise's environment-friendly product technology from the same businesses.
(2) Level of support: The degree of an enterprise investing in developing environment-friendly products.

Green innovation capability

In current markets, all industriesare engaging in innovative programs (Aaker, 2012). An enterprise with constant innovation could survive under the pressure of competitors and consumers (Chen& Chang, 2013). Innovation capability could be discussed from the aspects of product, procedure, process, and diversity (Jou et al., 2013). 1. Product innovation capability: Referring to new products producedby specifically developing new products or improving original products (Chang& Chen, 2013). 2. Procedure innovation capability: Referring to innovative improvement in the manufacturing process or transport process of productsso as to reduce product costs and enhance the efficiency or efficacy of products (Lin et al., 2011). 3. Process innovation capability: Referring to defining innovation from the aspects of product production and manufacturing process and the integration of results and processes (Chen& Chang, 2012). 4. Diversity-aspect innovation capability: It advocates that product, procedure, technology, and management should be classified in the definition of innovation (Motyl&Filippi, 2014). "Innovation" refers to the adoption of a new idea and behavior. From resource base theory, innovation is defined as to change the output of resources that innovation capability is the new ideas of internal facilities, systems, policies, procedure, products, and services of an enterprise (Chou, 2014).

Referring to Watanabe et al. (2014), the software/hardware equipment and R&D innovation process used for the products or processes of an enterprise considering the enhancement of environment management and the conformity to environmental standards are called green innovation capability, which is measured by "innovation style" and "novelty".

(1) Innovation style: New product, new production, or new sales are used for defining the innovation style of an enterprise developing environment-friendly products.
(2) Novelty: An enterprise adopting new environmental protection ideas, raw material or material, and appearance design or function for the innovation of new environment-friendly products.

Research hypothesis

Hsiao et al. (2011) regarded environment-friendly product development as a strategic process that an enterprise had to set up strategies and objectives, allocate resources in various product development programs, and develop and create various new green products and processes so as to achieve the objectives. Kandalaft et al. (2014) proved the effect of the environment-friendly product development on the green innovation capability of a company and considered that environment-friendly product development strategies were the basis of green innovation capability, which would affect the innovation of the enterprise developing new green products. Apparently, environment-friendly product development strategies and processes would influence the presentation of green innovation capability. For the measurement of environment-friendly product development, Jou et al. (2013) mentioned that the development process of new products could be realized to become green products when the application of new technology could produce new creation. Lin et al. (2011) regarded the support from high-level supervisors as a key success factor in environment-friendly product development. Motyl & Filippi (2014) indicated that the environment-friendly product development did not simply considered technology, but covered finance, human resource, and management. The following hypothesis is then proposed in this study.

H1: Environment-friendly product development shows notably positive correlations with green innovation capability.

Yeh et al. (2011) pointed out the practice content of environmental education, including environmental education personnel empowerment training, environmental learning center management, environmental education promotion activity design and execution, environmental education course and interpretation program planning and execution, environmental propagation film shooting, and environmental education innovative product development. Bashkite et al. (2014) considered that, an enterprise should completely understand the advantages and disadvantages of environmental education promotion and current threats and opportunities to grasp thorough information and achieve certain effectiveness when proceeding business planning, as environmental education could extend the depth and width of environment-friendly product R&D (Kwon et al.,

2014). Albersa et al. (2014) regarded the growth of green industry and suggested that an enterprise could promote the environment-friendly product R&D with environmental education by increasing the resources of green exhibition and education with strategic alliance. Accordingly, The following hypothesis is then proposed in this study.

H2: Environmental education shows significantly positive correlations with environment-friendly product R&D.

Yazdanifard & Mercy (2011) stated that an enterprise had to acquire competitive advantages by rapid greening. Watanabe et al. (2014) mentioned that, in addition to responding to the environment with the environmental protection measure of green innovation, an enterprise should actively change the employees' environmental attitudes, value, and behavior model through environmental education and deliver the vision of a sustainable green enterprise to the employees; the employees integrated such a green idea into daily life and corporate operation and enhance the green innovation capability so that the enterprise could sustainably develop and maintain competitive advantages. Chen et al. (2014) indicated that an enterprise would have more bargaining chips and acquire more business opportunities by simply integrating the idea of producing green products, which were beneficial to environment and were able to create infinite business opportunities, into corporate culture through environmental education to enhance the green innovation capability and create competitive advantages by more actively stepping into the field of green products. Yazdanifard & Mercy (2011) argued that an enterprise simply changing the manufacturing process and product design for the requirements of environmental regulations was not a real green company. Merely when green organizational culture was introduced into the corporate culture through environmental education and practiced in the employees' daily life and corporate operation would an enterprise sustainably develop to enhance the employees' green innovation capability and maintain the competitive advantages. The following hypothesis is then proposed in this study.

H3: Environmental education reveal remarkably positive correlations with green innovation capability.

RESEARCH SUBJECT AND METHODOLOGY

Measurement of research variable

(1) Environmental education

Referring to Chiang et al. (2011), environmental education is divided into 1.cognitive domain, 2. affective domain, and 3.psychomotor.

(2) Environment-friendly product R&D

Referring to Chiang et al. (2011), environment-friendly product R&D is divided into 1.level of technology 2.level of support.3. Green innovation capability

Referring to Watanabe et al. (2014), it is divided into (1)innovation style and (2)novelty.

Research subject and research design

Industries in Hsinchu Science Park are classified into integrated circuit industry, computers and peripherals industry, communication industry, optoelectronics industry, precision machinery industry, and biotechnology industry, where the output value of integrated circuit industry, as the first industry in the park, is about 70% of the total output value of the park, the revenue of optoelectronics industry, as the second industry, is about 20% of the total output value of the park, and computers and peripheral products industry is the third, followed by communication industry, precision machinery industry, and biotechnology industry. Taking Hsinchu Science Park as the research subject, the supervisors and employees of the enterprises in Hsinchu Science Park are sampled and distributed and collected the questionnaire via emails. Total 327 valid copies out of 500 distributed questionnaires are retrieved, with the retrieval rate 65%. SPSS is utilized for analyzing the data, and Analysis of Variance is applied to test the hypotheses.

Table 1. Regression Analysis of environmental education and environment-friendly product R&D

Dependent variable	**Environment-friendly product R&D**			
Independent variable	**Technological level**		**Support**	
Environmental education	β	ρ	β	ρ
Cognitive domain	2.166**	0.000	2.238**	0.000
Affective domain	2.327**	0.000	1.844*	0.013
Psychomotor	2.042**	0.000	2.356**	0.000
F	28.531		33.469	
P	0.000***		0.000***	
R2	0.287		0.316	
Adjusted R2	0.263		0.297	

Note: * stands for p<0.05, ** for p<0.01, and *** for p<0.001.

Analysis method

Regression Analysis is applied in this study to discuss the correlation among environmental education, environment-friendly product R&D, and green innovation capability.

ANALYSIS AND DISCUSSION

Factor Analysis of environmental education

The environmental education scale, with Factor Analysis, is extracted three factors of "cognitive domain" (eigenvalue=5.438, α=0.82), "affective domain" (eigenvalue=4.372, α=0.86), and "psychomotor" (eigenvalue=3.964, α=0.80). The commonly accumulated covariance explained achieves 76.283%.

The environment-friendly product R&D scale, with Factor Analysis, is extracted two factors of "technological level" (eigenvalue=3.677, α=0.88) and "support" (eigenvalue=3.251, α=0.90). The commonly accumulated covariance explained reaches 82.416%.

The green innovation capability scale, with Factor Analysis, is extracted two factors of "innovation type" (eigenvalue=2.851, α=0.91) and "novelty" (eigenvalue=2.354, α=0.90). The commonly accumulated covariance explained achieves 84.663%.

Correlation Analysis of environmental education and environment-friendly product R&D

Regression Analysis is utilized in this study for testing the hypotheses and the theoretical structure. The first regression, **Table 1**, reveals the regression equation reaching the significance ($F=28.531$, $p<0.001$). Environmental education presents significant effects on technological level in environment-friendly product R&D, where "cognitive domain", "affective domain", and "psychomotor" in environmental education show remarkably positive effects on technological level in environment-friendly product R&D, with the significance ($\beta=2.166$, $p<0.01$; $\beta=2.327$, $p<0.01$; $\beta=2.042$, $p<0.01$). The second regression, **Table 1**, reveals the regression equation achieving the significance ($F=33.469$, $p<0.001$). Environmental education appears notable effects on support in environment-friendly product R&D, where "cognitive domain", "affective domain", and "psychomotor" in environmental education show remarkably positive effects on support in environment-friendly product R&D, with the significance ($\beta=2.238$, $p<0.01$; $\beta=1.844$, $p<0.05$; $\beta=2.356$, $p<0.01$). H2 is therefore supported.

Table 2. Regression Analysis of environmental education, environment-friendly product R&D toward green innovation capability

Dependent variable	**Green innovation capability**							
Independent variable	**Innovation type**				**Novelty**			
Environmental Education	β	ρ	β	ρ	β	ρ	β	ρ
Cognitive Domain	2.362**	0.000			2.425**	0.000		
Affective Domain	2.575***	0.000			2.633***	0.000		
Psychomotor	2.123**	0.000			2.241**	0.000		
Environment-Friendly Product R&D								
Technological Level			2.743***	0.000			2.822***	0.000
Support			2.816***	0.000			3.044***	0.000
F	35.731		38.225		41.623		47.184	
P	0.000***		0.000***		0.000***		0.000***	
R2	0.327		0.358		0.396		0.427	
Adjusted R2	0.306		0.339		0.384		0.402	

Note: * stands for p<0.05, ** for p<0.01, and *** for p<0.001.

Correlation Analysis of environmental education and environment-friendly product R&D toward green innovation capability

Regression Analysis is applied to test the hypotheses and the theoretical structure in this study. The first regression, **Table 2**, shows that the regression equation reaches the significance (F=35.731, $p < 0.001$). Environmental education presents notable effects on innovation type, where "cognitive domain", "affective domain", and "psychomotor" in environmental education reveal significantly positive effects on innovation type, with the significance ($\beta = 2.362$, $p < 0.01$; $\beta = 2.575$, $p < 0.001$; $\beta = 2.123$, $p < 0.01$). The third regression, **Table 2**, shows that the regression equation achieves the significance (F=41.623, $p < 0.001$). Environmental education appears notable effects on novelty, where "cognitive domain", "affective domain", and "psychomotor" in environmental education present remarkably positive effects on novelty, with the significance ($\beta = 2.425$, $p < 0.01$; $\beta = 2.633$, $p < 0.001$; $\beta = 2.241$, $p < 0.01$). Accordingly, H3 is supported.

The second regression, **Table 2**, reveals that the regression equation reaches the significance (F=38.225, $p < 0.001$). Environment-friendly product R&D shows notable effects on innovation type, where "technological level" and "support" in environment-friendly product R&D appear remarkably positive effects on innovation type, with the significance ($\beta = 2.743$, $p < 0.001$; $\beta = 2.816$, $p < 0.001$). The fourth regression, **Table 2**, reveals that the regression equation achieves the significance (F=47.184, $p < 0.001$). Environment-friendly product R&D appears significant effects on novelty, where "technological level" and "support" in environment-friendly product R&D show notably positive effects on novelty, with the significance ($\beta = 2.822$, $p < 0.001$; $\beta = 3.044$, $p < 0.001$). As a result, H1 is supported.

CONCLUSION

The research results reveal that the better environmental education could have hi-tech industry better grasp the mainstream technology, leading technology, and superior technology of environment-friendly products to those in the same industry, and even the unique technology for patents. Besides, environmental education could assist hi-tech industry in the environmental attitudes and value to have better performance on the innovation type and novelty of environmental products through the company regarding environment-friendly products as the key

performance indicator of product R&D, presenting support and encouragement from high-level supervisors, being willing to invest in more manpower and budgets, and actively acquiring international environmental protection certificates or patents. For hi-tech industry, the promoted environment-friendly products, which were either the innovation of producing new products, adopting new production or new sales, and even opening new markets or new customers or the reinforcement of product novelty by including new environmental ideas, using new materials, combining popular design elements, or presenting functions, could help hi-tech industry provide environment-friendly products meeting customers' requirements to further enhance customer satisfaction with the green marketing performance of the enterprise. Hi-tech industry could grasp environmental knowledge, through environmental education, to further promote the mainstream, leadership, or uniqueness of the developed products. Moreover, hi-tech industry being willing to invest more resources and the high-level supervisors supporting the environmental education and the R&D of environment-friendly products could promote customer satisfaction with the green marketing performance of the enterprise.

SUGGESTION

According to the research results, the following suggestions are proposed in this study.

1. Establishing a green supply chain with the power of high-tech industry to become the optimal choice for purchasing environment-friendly products: Under the global competition, especially the competition of Mainland China and Korea, independent management is no longer suitable for current environments. The major obstacle to the development of environment-friendly products lies in the trust from buyers, while the key to acquire buyers' trust relies on the entire process of production, sales, discard, recycle, and reuse of suppliers 'products being secure and conforming to environmental standards. In this case, high-tech industry is suggested to integrate the industry, with alliance and even cross-industry alliance, provide the green supply chain with the production, sales, discard, recycle, and reuse conforming to international environmental standards, and develop the national image of environmental protection kingdom based on the international brand trust to have Taiwan becomes the first choice of environment-friendly product purchase. It would greatly help the industry in Taiwan developing environment-friendly products and mastering green business opportunities.
2. Product R&D: Hi-tech industry is suggested to enhance the employees' environmental literacy by reinforcing the environmental education so as to establish the unique technology of environment-friendly products and acquire international patents for reinforcing the product competitiveness. Besides, product R&D must combine with global custom market orientation and the ecological environmental protection and social commitment of the enterprise to satisfy customer requirements. Environmental education is therefore necessary for the enhancement. In consideration of the international market status of hi-tech products in Taiwan, parity R&D is suitable, i.e. to establish the competitive advantages of the industry with the strategy of fine quality and plain prices. It is also suggested that hi-tech industry could reinforce environmental literacy with environmental education to smoothly acquire international certificates or patents for the environment-friendly products as well as include environmental concept in the corporate core strategies.
3. A value-oriented model should be established for the promotion of environmental education: Environmental education training should be regarded as a delivery medium for the employees forming exchange and creating value through network interaction and reciprocal experiences. When the employees present higher participation and perceived benefits, more expectation to the activity would be provided. With the employees' feedback and opinions, hi-tech industry could understand the direction to improve the environmental education training for advancing the quality of green products and to improve or re-design environmental education through role positioning and the creation of maximal environmental education value with the employees to further create higher value.

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