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Constructing Indicators of Competence Development in the Photovoltaics Industry

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Abstract
With worldwide growth of photovoltaics (PV), the production of solar energy has accelerated. In 2004, Taiwan's solar cell production value was nearly NT$2.6 billion, and its global market share was 3%, while only 38.14 MW were produced. Talent is the foundation of any organization and it achieves its goals and development usually through educational trainings. This study constructed indicators of competence development in the PV industry based on literature review. A questionnaire survey among experts from industries, government, and academia was conducted and the Fuzzy Delphi Method was employed to investigate the development of PV professional knowledge and its indicators and to provide a reference for relevant future research. The findings can be applied in industrial, government, and academic policy making and accreditation mechanism.
Keywords: *Photovoltaics, Talent Development, Fuzzy Delphi Method.*

Introduction
In recent years, green technology is increasingly becoming the developmental focus since people are highly dependent on fossil fuels, so it causes shortness and skyrocketing price of conventional energy sources. The present fossil fuel storage can only be used for another 43 years. The oil price increased from US$17.47 per barrel in 2001 to US$116.56 per barrel in 2008, the highest recorded price in history, and the Brent crude oil price is expected to reach and exceed US$100 per barrel (Executive Yuan, Republic of China, Taiwan 2008). The other important reason is global warming. According to British Petroleum (BP)'s report in April 2005, the biggest challenge in the 21st century is global warming caused by extensive greenhouse gas emissions. Environmental protection and green energy industry are highly important in slowing down the global warming effect induced by excessive emissions of greenhouse gases and addressing the lack of conventional energy sources. As a result of the Kyoto Protocol signed on February 16, 1997, average greenhouse gases emissions in 2008-2012 were 5.2% lower than in 1990 (Ministry of Economic Affairs 2007).

With rapid growth of the global photovoltaic (PV) market, the PV industry continues to attract investments from many firms in Taiwan. Taiwan ranks fourth in the world in solar cell production value, with seven Taiwanese companies producing upstream silicon, 45 producing solar cell modules, and 29 producing downstream systems. Among them, Motech ranks eighth in the world and solar cell products comprise 98% of its exports with Europe as the main market (Motech Industries Inc. 2006). PV products imported from Japan, US, Slovakia, Germany, and Hong Kong account for 97.51% of Taiwan's imports. Taiwan's exports to Japan have grown and are greater than imports from Japan, indicating a high developmental potential of the Taiwanese PV industry (Tseng, Li, & Lin 2008). The expansion rate of Taiwanese solar cell firms reached 4-50% in 2011 and their total production capacity of 8,825 MW was the second highest worldwide (Ho 2012).

Due to limited understanding of PV industry properties by the practitioners of the Department of Investment Services, Ministry of Economic Affairs (2008), the PV technology and quality cannot be effectively improved. Vocational skills necessary for PV practitioners can be understood from governmental policies and PV training courses. The educational goal of universities' PV research departments is PV talent development. This study aimed to help developing PV departments address the future needs for PV talents and examine the current PV talent development policies, which was the first motive of this study.

It may be difficult for the industry to apply many of the R&D results obtained from universities. Under such circumstances, the Center for Academia and Industry Collaboration (CAIC) at National Chiao Tung University provides a largely effective platform for collaboration. The CAIC has a unified platform for service provision and involves departments engaged with intellectual property management, technology transfer, industry-university collaboration planning, and innovation incubation. The center seeks to realize synergy through resource integration and increase service capacity for value creation (Chiu 2012). According to the Industrial Technology Research Institute (2006), universities and colleges are institutions that supply human resources and their curriculum should focus on practice supported by theory and instruction of professional ethics and service concepts in order to meet the industrial demand for human resources. Therefore, curricula should be designed such that they prepare graduates capable and qualified to perform their job and develops PV professional talents. This study examined to what extent curriculum design conforms to the industrial demand for PV competence, which was the second motive of this study.

This study was conducted from the perspective of competence development. The competence of PV personnel may affect the willingness to participate in the PV industry. PV educational training in Taiwan is in its initial stage; therefore, this study analyzed whether PV human resource development in universities and colleges in Taiwan correspond to industry demands. Strengths and weaknesses of PV-related curricula were discussed to provide practical and theoretical perspectives and reference for the policy makers in PV talent development.

Literature review

Professional competence

The concept of competence was first proposed in the early 1970s by David McClelland, a Harvard University professor, who considered competencies as the job attitude, cognitive, and personal characteristics essential for outstanding workers. In education, professors' positive attitude and competence are key factors that influence educational outcomes (Busch & Richards 2000). In industry, competence influences product quality (Lovén & Helander 1997).

Malcolm and Knowles (1970) defined competencies as knowledge, skills, and attitudes required for work. According to Butler (1978), competencies refer to knowledge, skills, values, and attitudes that a person should possess to achieve goals of daily life and work. Bloland (1987) defined competencies as skills, cognition, and attitudes necessary for successful performance of specific tasks. As proposed by Jarvis (2002), competencies are skills, knowledge, and attitudes necessary to achieve a goal within a specific time.

PV curricula in higher education

Due to the continuing development of PV industry around the world, local development of semiconductor technology, and sufficient sunlight typical of sub-tropical climate, solar energy industry continues to grow in Taiwan. The growing need for PV practitioners has resulted in wide establishment of PV talent development institutes and universities. Since 2008, universities have been founding PV-related departments and courses, including a PV industry program in National Taipei University of Technology, a PV special project in National Taiwan University of Science and Technology, a PV and marine energy course in National Taiwan Ocean University; and solar cell technology programs in National Tsing Hua University and Yuan Ze University.

Initial investigation showed that required courses in PV departments are established according to educational goals and developmental features of each university. Required and elective courses of each department have their own features depending on a university's conventional development and the department's structure. Therefore, currently, PV professional courses have not yet reached consensus in establishing principle professional skills.

Methodology

Fuzzy Delphi Method

This study employed Fuzzy Delphi Method to examine main PV talent development strategies through questionnaire analysis. Delphi Method is the expert judgment method that was originally developed by the RAND Corporation as a forecasting method adopted by industry and aimed at acquiring reliable and consistent opinions from a group of experts (Dalkey & Helmer 1963). This method is often used as a forecasting and decision making tool to improve group decision making techniques (Dalkey 1969). Fuzzy Delphi Method is conducted in an anonymous way, with the focus on a specific issue. The method is based on the experiences and knowledge of experts who answer questionnaires in several rounds and have an opportunity to realize each other's ideas. Finally, all opinions are combined and the statistical analysis is conducted to determine the level of experts' consensus on questions (Murry & Hammons 1995; Gupta & Clarke 1996).

The Delphi method has such disadvantages as much time and high cost associated with the collection of experts' opinions, fuzziness of experts' opinions, low response rate, and the risk to ignore other experts' opinions by considering only median and mean values (Liang, Lee, & Huang 2010). Murray, Pipino, and van Gigch (1985) used the fuzzy theory to address disadvantages of the traditional Delphi method and applied a semantic change approach to solve the ambiguity of questions and answers in the traditional Delphi questionnaires. (Ishikawa, Amagasa, Shiga, Tomizawa, Tatsuta, and Mieno (1993) used fuzzy scoring and cumulative frequency distribution to collect experts' opinions into a fuzzy number. The process is called Fuzzy Delphi Method. A method that uses fuzzy numbers to organize experts' opinions can handle with semantic ambiguity in traditional Delphi method, and keep the original meanings of experts' messages.

Klir and Yuan (1995) adopted fuzzy clustering and triangular fuzzy numbers to explain and represent different patterns of the consensus function using Fuzzy Delphi questionnaires. (Xu and Yang 1999) adopted the Fuzzy Delphi Method by using triangular fuzzy numbers for experts' opinions, with two end points of a fuzzy triangle representing the maximum and the minimum of experts' opinions and a geometric mean representing consensus among most experts. The average membership function value was set to 1 and a triangular fuzzy number was established for each expert's decision, where any value between the maximum and the minimum indicated possible decision of the expert.

Fuzzy Delphi Method Procedure:

(1) Collect opinions of a decision making group
    Obtain experts' evaluation indexes for the importance of each factor using semantic variables in the questionnaire.
(2) Establish triangular fuzzy numbers
    Calculate a triangular fuzzy number of the importance of each factor based on the experts' opinions. This study used geometric means of the generalized model proposed by Klir and Yuan (1995) as the Fuzzy Delphi Method to acquire group consensus.
(3) Defuzzification
    Fuzzy numbers are not exact values and cannot be compared if not diffuzified.
(4) Select appraisal indicators
    Establish threshold value t, and filter the most suitable appraisal indicators from many initial appraisal indicators.

Questionnaire content and design

Aiming to provide an understanding of PV competence development in Taiwan, this study used previous studies as references and developed the "PV R&D and manufacturing design competence development indicator questionnaire." First, experts were invited to check the questionnaire and it was then revised according to their suggestions. The Fuzzy Delphi Method was used to conduct a survey among experts from the industry, academia, and government.

Questionnaire development

The research tool of this study was the "PV R&D and manufacturing design competence development indicator questionnaire" based on previous studies and developed through the following steps:

(1) Literature review: data were analyzed and organized based on previous research related to PV competence development.

(2) Editing the expert questionnaire: collecting questionnaire data and results to compile the expert questionnaire. The questionnaire included three dimensions: “knowledge,” “skills,” and “attitude.”

(3) Inviting experts to evaluate questionnaires and revising and finalizing the questionnaire: a total of 20 experts from the digital industry, government and academia were invited to delete and modify the principles to ensure the validity of the questionnaire.

Questionnaire content

The expert questionnaire in this study was based on the literature review. The questionnaire was divided into three dimensions, namely, "knowledge,” "skills,” and "attitude,” which included 6, 15, and 5 principals, respectively. The questionnaire was revised and finalized after three rounds of evaluation by five experts. Experts’ opinions were organized as shown in Tables 1 and 2.

Table 1. First-round expert questionnaire revision

Indicator	Suggestions	Item
Knowledge	Revise	Separate "Practice-oriented and advanced courses" into "Practice-oriented courses" and "Advanced courses"
	Add	Political economy
		International relations
		Business management
		Social education
Skills	Revise	Include "Work report writing," "Foreign languages," and "Management planning" as "Skills"
		Delete "Competencies and abilities" as it is similar to "Knowledge" items
	Add	Device fabrication technology
		Analysis of properties
		International business negotiation
		Global and national energy resource planning
		Good problem-coping skills
		Strong R&D skills
Attitude	Add	Enthusiasm
		Environmental and sustainable development
		The concept of a unified "global village" community

Table 2. Second-round expert questionnaire revision

Indicator	Suggestions	Item
Knowledge	Revise	Combine "Political economy," "International relations," "Business management," and "Social education" into "Interdisciplinary knowledge"
Skills	Revise	Rename "Work report writing" as "Work documentation writing"
		Delete "Management planning," "International business negotiation," "Global and national energy resource planning," and "Professional autonomy." Combine "Crisis management skills" and "Good problem-coping skills" under the attitude indicator "Responsive problem-solving skills." Combine "Good communication skills" and "Altruism" under the attitude indicator "Interpersonal communication skills." Integrate "Self-assessment" into the attitude indicator "Self-learning and development." Combine

		"Prospective decision-making," "PV multi- and interdisciplinary application", "Innovative technologies," and "Strong R&D skills" under the attitude indicator "Innovation skills."
	Add	Information and knowledge management
Attitude	Revise	Delete "Company rules," "Environmental and sustainable development," and "Profession as a lifelong mission."
		Combine "Enthusiasm," "Participation in related conferences," and "Development of professional skills" into "Pursuance of knowledge." Combine "Professional ethics" and "Concept of a unified global village community" into "Professional identity."

Opinion analysis was organized based on the above recommendations of experts and the final questionnaire was built after discussion between authors. The questionnaire was expanded to seven dimensions, namely, "evaluation of training needs," "evaluation method of training needs," "on-the-job training," "off-the-job training," "evaluation of training outcomes," "evaluation method of training outcomes," and "career development," which included 6, 6, 5, 6, 4, 5, and 2 principals, respectively.

In this study, the formal questionnaire used the Fuzzy Delphi Method. The importance level of each item as evaluated by each participant is represented by the absolute number of lines.

The degree of importance ranged from 0 to 10 (low to high) and each questionnaire item represented a principle. The degree of importance was marked by a responder within the range of potential degrees of importance.

Questionnaire distribution

The purpose and procedure of this study were explained to participating experts by phone or via E-mail. After obtaining the consent from each expert, questionnaires were sent to participants via mail (with an enclosed return envelope) or email. Participants were reminded of the deadline by which they should return questionnaires and asked if they encountered problems, so as to avoid unnecessary loss of data.

Questionnaire analysis

This questionnaire was analyzed using the Fuzzy Delphi Method. The developmental indicators for PV talent were extracted to understand the important factors for their assessment.

Interviewee data

The purpose of this study was to research and produce indicators for the training of PV R&D and manufacturing personnel. Therefore, a list of 62 PV-related experts in universities, industries, and the government was compiled. After contacting the experts, 20 indicated that they were willing to participate in the study; nine of the experts were in academia, five were in the PV industry, and six held government positions.

Screening of developmental indicators

The Fuzzy Delphi Method compiled the experts' opinions in order to further assess the indicators. The experts' fuzzy numbers are shown in Table 3. A threshold value of t>6 was used to screen the indicators.

Table 3. Fuzzy Delphi questionnaire results

Dimension	Item	Triangular fuzzy numbers (min, mean, max)	Fuzzy value
Knowledge	Core PV knowledge	(5, 8.21, 10)	7.74
	Basic knowledge	(5, 8.03, 10)	7.68
	Practical knowledge	(3, 7.29, 10)	6.76
	Interdisciplinary knowledge	(4, 5.18, 10)	6.39
	Prospective professional knowledge	(2, 6.58, 10)	6.19
Skills	Application of theory	(4, 7.21, 10)	7.07
	Foreign languages	(2, 7.26, 10)	6.42
	Device fabrication technology	(2, 7.18, 10)	6.39
	Information and knowledge management	(2, 6.58, 10)	6.19
	Work documentation writing	(1, 7.21, 10)	6.07
	Analysis of properties	(1, 7.16, 10)	6.05
Attitude	Self-learning and development	(5, 7.79, 10)	7.60
	Responsive problem-solving skills	(5, 7.71, 10)	7.57
	Innovation skills	(5, 7.66, 10)	7.55
	Pursuance of knowledge	(4, 7.58, 10)	7.19
	Interpersonal communication skills	(4, 7.03, 10)	7.01
	Professional identity	(2, 7.42, 10)	6.47

After applying Fuzzy Delphi Method, all expert evaluation indicators had threshold above 6, which indicated the approval of all indicators by experts from industry, government, and academia.

Conclusion and suggestions

Contributions

This study has made the following contributions:

(1) Literature related to the development of PV competence was collected and developmental indicators for PV R&D and manufacturing competence were explored. This study can serve as a reference for future research.

(2) The main purpose of this study was to establish an evaluation model for PV R&D and manufacturing competence. Indicators and literature were collected and a set of 26 indicators over three dimensions was proposed for the cultivation of PV R&D and manufacturing competence.

(3) Expert questionnaires were given to professionals in academic, industrial, and governmental PV-related fields in order to select key developmental indicators for PV R&D

and manufacturing competence and to understand the importance of each indicator and dimension.

(4) A total of 17 indicators were included after implementation of the Fuzzy Delphi Method. The fuzzy importance value was t>0.7 for seven indicators, including "Basic knowledge" and "Core PV knowledge" in the dimension of knowledge, "Application of theory" in the dimension of skills, and "Responsive problem-solving skills," "Interpersonal communication skills," "Self-learning and development," and "Innovation skills" in the dimension of attitude. These findings indicated the importance of basic and core knowledge for PV competence and high consideration of responsive problem-solving skills, interpersonal interaction skills, self-development, and innovation skills.

Limitations and suggestions

The following suggestions are made based on the limitations of this study:

(1) Competence indicators developed using the Fuzzy Delphi Method and their practical application it can improve the development of indicators for PV competence development.

(2) The participants selected for this study were from the PV R&D and manufacturing department; however, there are various PV departments. Therefore, the use of only one department for the construction of developmental indicators for PV competence limits their functionality and actual performance. Future studies can consider involving other department staff in order to remedy this shortcoming.

(3) This study considered time and cost during the design and data analysis of the expert questionnaire and collected the experts' consensus by using the Fuzzy Delphi Method. Future studies can consider incorporating other methods to interpret the final results or collect data.

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