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Project of Developing Talents in Photovoltaics Industry in Taiwan

Feng-Hsiang Chang[1], Chih-Yung Tsai[2*]

1Department of Leisure, Recreation and Tourism Management, Tzu Hui Institute of Technology, Pingtung 926, Taiwan

2Department of Education, University of Taipei, Taipei 100, Taiwan.

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ABSTRACT

With worldwide growth of photovoltaics, the production of solar energy has been accelerated. In 2004, Taiwan's solar cell production value was near NT$2.6 billion, and its global market share was 3% while only 38.14 MW was produced. Talent is the foundation of an organization, and it achieves its goals and development usually through educational training. Photovoltaics (PV) talents in Taiwan can be trained through school education and institution training; however, our educational training on PV industry is just beginning, we do not have in depth analysis and discussion so far. The aims of the present study were as follows. First of all, the current status of PV talent development at school was investigated. Second, this study examined the strategies of developing talent in the PV industry. Fuzzy Delphi Method was adopted and multiple questionnaires were administered to photovoltaic specialists and scholars to analyze the background and the present status of talent development. The findings can be applied in industrial, government, and academic policy making and accreditation mechanism.

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 a skyrocketing price of conventional energy sources. The present fossil fuel storage can only be used for another 43 years, so its price continues to grow. Average Brent crude oil price increased from US$25.754 in January 2001 to US$112.48 in January 2013 [1]. 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 gases 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 [2].

More and more countries worldwide have been investing in green energy industries such as photovoltaics (PV) and wind power generation, among which PV has the greatest development potential and industrial opportunity [3]. In 2010, the central government purchased PV mainly through public infrastructure investment projects. Local governments served as an example to purchase PV and thus promote nationwide demand. In 2010, NT$748.54 and 363.19 million were invested into PV engineering and PV labor market, respectively [4].

Talent is the impulse for industrial progression. Vocational Training Bureau (VTB), Council of Labor Affairs, Executive Yuan, established e-newspaper which has analyzed current industries development trends starting from July 2009 and listed six emerging industries in Taiwan, namely, tourism, outsourcing, culture and creation, environmental protection, medical and care services, and optoelectronics. Industry, government, and academic specialists were invited to six conferences from July to October 2009. Staff from human resource departments was invited in particular in order to inform the industry about the dimensions and predicaments of its need for talents.

Due to limited understanding of PV industry properties by the practitioners of the Department of Investment Services, Ministry of Economic Affairs [5], 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' photovoltaic research departments is PV talent development. This study was motivated by the need to help develop PV departments address the future needs for PV talents and examine the current PV talent development policies.

Talent is the basis of an organization, and it achieves its goals and development usually through educational trainings. According to the United Nations Environment Program(UNEP) 2008 reports "Green Jobs", by 2030, the employment in PV, wind power, and biofuelindustries will increase by almost 10 times up to 20 million jobs. Chiu, Tsai, Chung, and Tien [6] indicated an increasing need for PV human resources due to the industry's rapid development in Taiwan. Universities successively established PV-related departments; therefore, exploration of the current status of PV talent development was the second motive of this study.

Most research on talent development in national industries is concerned with medical and healthcare[7-11] and digital industries [12-16]. There were also studies on talent development in cultural and creative [17,18], sports [19-21], academia [22-25], agriculture [26], military [27,28], and service [29] industries. Yet talent development research in PV industry is rare. This study investigated current talent development status and constructed relevant standards in collaboration with experts from industry, government, and academia. The findings can provide practical and theoretical perspectives and serve as a reference for the policy makers in PV- talent development.

LITERATURE REVIEW

Talent Development Program

Talent cultivation and development must be based on education. Education is the process of learning morality, intelligence, physical fitness, gregariousness, and aesthetics from childhood to old age (from preschool to university or above). Although such a learning process is individual, all learners are similar in that they grow their knowledge and moral and shape their basic characters and skills through education. This educational process is the basis of vocational training, learning, and human resource development which is successful if such basis is strong. In contrast, when the educational basis is fragile, training and development must encounter obstacles. Therefore, education is the priority of talent development. Education establishes the basis for human resource application and development, and may affect the results of recruitment in institutions/organizations. This indicates that education is an integral part of talent development. The main functions of education according to the recent decrees include:

1. Establishing the basis for the general education of talents (general education function).
2. Providing technological and vocational training (specialized education function).
3. Strengthening guidance and counseling on recurrent education (talent education function)
4. Promoting the connection between education and training (training as the extended education).

In recent years, according to the survey research, effective human resources training could increase productivity by (1) 3.2% through a 60% increase in production value, (2) 6% through 10% more working hours, and (3) 8.6% through a 10% improvement in education degree. Employee education involves family, school, and social education processes before employment (education) and, refresher courses, learning, training, and human resource development after employment (re-education). Both education and re-education processes are closely related. Therefore, education is the foundation of talent training. Training, learning, and human resource measures after employment are the extension of education. Talent education is a long lasting process. Thus, both processes before and after employment have continuous and/or cohesive interactions [30].

Educational Trainings in PV Industry

PV talent training is divided school education and industrial training. School education refers to all PV-related courses provided at university while industrial training refers to employees' training at work.

PV courses in school education

Due to the continuing development of PV industry around the world, local development of semiconductor technology, and sufficient sunlight typical of a sub-tropical climate, solar energy industry continues to grow in Taiwan. The growing need for PV practitioners has resulted in the 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.

This study investigated various PV courses established by different universities. The explanations are as follows:

1. Yuan Ze University (2008) main purposes of solar cell technology program was to integrate solar energy and optoelectronics courses and provide comprehensive planning of and systematic connection between the courses in order to allow students to apply basic general education and professional course training in practice and gain comprehensive and sufficient knowledge through theory and experiments and to cultivate highly-skilledPV talents.
2. National Taipei University of Technology's (2010) research on PV course planning in the context of Taiwan is at its initial stage. Therefore, development of PV professional courses suitable for Taiwan's higher education is an important issue calling for immediate attention. With regard to planning and developing PV education from the perspective of talent cultivation, PV professional education in Taiwan should include core PV knowledge courses, courses about PV-related industries, and practical courses. The content should emphasize professional skills and hands-on operations so that students can develop a comprehensive understanding of PV and be able to apply their skills through creative thinking. Courses for PV-related industries should teach students to make connections from acquired PV knowledge to PV-related industries.
3. National Tsing Hua University (2007) founded Solar Cell Technology Program that included three categories of courses, namely, basic courses (Energy Technology and Environment, Theory of Solar Cell, Theory of Electrochemistry, and Introduction to Organic Semiconductor), courses about related industries (Theory of Semiconductor Devices, Semiconductor Production, Introduction to Solid State Physics/Introduction to Solid State Physics I, Switching Mode Power Supply, Basics of Photoelectric Materials and Devices, Photovoltaics Interface Systems, Advanced Solar Cells, and Fundamental on Organic Photovoltaics), and practical courses (Solar Cell Laboratory and Project Study). Students are required to complete 15 credits or more to complete the program.
4. National Taiwan University of Science and Technology (2008) opened Solar Cell

Technology Program consisting of a total of 15 courses, including required courses (such as Solar Cell Devices and Applied Electrochemistry) and elective courses (such as Electrochemical Reaction Engineering, Electrical Materials, Chemical Vapor Deposition and Application, Advanced Solid State Chemistry, Macromolecular Materials, and Physical Chemistry of Surfaces). Students are required to complete 15 credits or above.

5. National Taiwan Ocean University (2008) opened a PV program, which includes core courses (Photovoltaic Advanced Materials for Optoelectronics (Special Topics), (Green) Fuel Cell, Fabrication and Application of Opto-electro Thin Films, Optical Energy and Material Application, Frontier Lectures in Electrical Engineering & Computer Science, Introduction to Ocean Energy, and Creative Topics Workshop) and practice-oriented and advanced courses (Semiconductors Nano-processes Technology, Integrated Optics and Application, Optoelectronic Semiconductor Devices (Physics), Modern Optics, Semiconductor Manufacturing Technology, and Modern Physics). Students are required to accomplish at least 20 credits and above.

6. National Central University (2008) opened a PV program, which includes 8 required (Photovoltaic Creative Practice and Application) and elective courses (Solar Energy Engineering, Photovoltaics, Introduction to Nano-optoelectronics, Photovoltaic Materials and Devices, Materials of Hydrogen Energy, Hydrogen Energy, and Fuel Cell). Students are required to complete 15 credits or above.

7. National Cheng Kung University (2009) opened a program on green technologies, which includes required(Introduction to Energy Technology, Green Materials, and Innovative Design of Green Technology) and elective courses (Applied Technology of Fuel Cells, Green Innovation and Product Development, Resources Recycle, and Green Design), which require their students to complete 12 credits or above.

8. National Kaohsiung University of Applied Sciences (2007) opened green energy technology program. The program contains core (Photovoltaic Technology and Application, Fuel Cell and Energy Technology, Wind Power Systems, and Green Power Conversion), elective (Organic Solar Cell Theory and Manufacturing and Fuel Cell Key Experiments and Design), applied (Solar Cell Model Design, Application, and Practice), and practical courses (Creative Topics). Students are required to complete 18 credits or above.

9. Feng Chia University (2009) opened biomass energy and green technology program, which includes 15 required (Innovation Design of Biomass Energy and Green Technology, Introduction

to Biomass Energy and Green Technology, Environmental Economics, and Environmental Accounting), elective (Environment and Energy, Ecological Engineering Methods, Solar Cell Technology, Power Systems (I), Lecture on Architecture, and Internal Combustion Engines), and practical courses (Creative Topics). Students are required to complete 9 credits or above.

Photovoltaic engineering laboratory at National Kaohsiung University of Applied Sciences provides college/university students with teaching and experiment in relating basic PV courses and graduate students with the environment for advanced PV research.

The Economic Development Bureau of Kaohsiung City Government commissioned National Kaohsiung University of Applied Sciences to hold “2009 International Green Applied Design Workshop and Green Talent Development Training Project” and “Energy Management and Basic Service” and “Solar Cell Application” sessions to provide talent training and integrate green and green-to-be industries in Kaohsiung areas.

The National University of Tainan established the Department of Greenergy, which benefited industries in Southern Taiwan.

Liao, Shih, and Lee [31] suggested that due to the fact that higher education in Taiwan is based on a departmental system, talent development is not flexible to catch upon needs of rapidly changing industries. University teachers and courses are unable to cater to the demands of developing industries or absorb and teach the knowledge and skills required in these emerging fields.

Yet the demand for PV talents is growing faster than school system training could provide. Therefore, this study investigated talent development indicators through the survey of industrial, government, and academic specialists to reduce disequilibrium of supply and demand between industry and university.

In addition, even though the demand for professional talents changes faster than their supply by universities, university general education is important in medium- and long-term talent development policies, while in the short run, supporting measures may be adopted.

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 in 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.

PV courses in industrial training

Through initial investigation, this study found that Taiwanese PV corporations differ in their educational training methods, programs, and resources.

This study aimed to develop PV talent development criteria due to the lack of consensus on such criteria in current PV educational training.

METHODOLOGY

Methodology

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 [32]. This method is often used as a forecasting and decision making tool to improve group decision making techniques [33]. 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 [34,35].

The Delphi method has such disadvantages as much time and high cost associated with the collection of experts' opinions, the fuzziness of experts' opinions, low response rate, and the risk to ignore other experts' opinions by considering only median and mean values [36]. Murray, Pipino, and van Gigch [37] used the fuzzy theory to address disadvantages of the traditional Delphi method and applied a semantic change approach in solving the ambiguity of questions and answers in the traditional Delphi questionnaires. Ishikawa et al. [38] used fuzzy scoring and cumulative frequency distribution to collect experts' opinions into a fuzzy number. The process is called Fuzzy Delphi Method. This method can handle with semantic ambiguity in traditional Delphi method, and keep the original meanings of experts' messages.

Fuzzy Delphi Method is used to represent decisions of experts' groups and combines traditional Delphi method with the fuzzy theory. Fuzzy Delphi Method can reduce survey frequency, save time cost, increase the response rate, and address vagueness in the survey process. In Fuzzy Delphi Method, experts' original meanings are not easily distorted, which allows experts to fully express their opinions [39].

Fuzzy Delphi Method follows three major steps: 1. Establishment of assessment items for influencing factors; 2. A collection of experts' opinions and decisions; and 3. An evaluation of the consistency among experts.

Klir and Yuan [40] adopted fuzzy clustering and triangular fuzzy numbers to explain and represent different patterns of the consensus function using Fuzzy Delphi questionnaires. Hsu and Yang [41] 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 a 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 a 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 for 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 [40] 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, and filter the most suitable appraisal indicators from many initial appraisal indicators.

Questionnaire Content and Design

Aiming to provide an understanding of PV personnel training in Taiwan, this study used previous studies as references and developed the "PV R&D and manufacturing design talent 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 talent 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 personnel training.
(2) Editing the expert questionnaire: collecting questionnaire data and results to compile the expert questionnaire. The questionnaire included four dimensions: “needs assessment”, “training method”, “evaluation of training outcomes”, and “career development”.
(3) Inviting experts to evaluate questionnaires and revising and finalizing the questionnaire: a total of 20 PV experts 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 four dimensions, namely, "needs assessment", "training method", " evaluation of training outcomes", and "career development", which included 4, 2, 3, and 4 principals, respectively. The questionnaire was revised and finalized after three rounds of evaluation by five experts. Experts' opinions were organized as shown in Table 1.

Opinion analysis was organized based on the above recommendations of experts and the final questionnaire was built after discussion with the advisor. 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.

Table 1. Expert questionnaire revision

Questionnaire revision	
Recommendation	Indicators
Add	Divide "needs assessment" into "content" and "methods". Assessment methods should include survey/questionnaires, interviews, observation, tests, file review, and focus group discussions.
Add	List all types of "training method", including mentoring, job rotation, job agency, practical training, special task assignments, lectures, case studies, group training, special training, E-learning, and design competitions.
Add	Divide "evaluation of training outcomes" into "content" and "methods". Assessment methods should include worksheets, tests, human resources assessment, evaluation of results, and comprehensive evaluation.
Add	List two patterns of career development.

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. Developmental indicators for PV talent were extracted to understand the important factors for their assessment.

Participant Information

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. Experts' fuzzy numbers are shown in Table 2. A threshold value of t>6 was used to screen the indicators.

Table 2. Fuzzy Delphi questionnaire results

Dimension	**Indicator**	**Triangular fuzzy numbers (min, mean, max)**	**Fuzzy value**	**Note**
Evaluation of training needs	Formulation of related course content	(5, 7.55, 10)	7.52	
	Assessment of future trends and demands in the international market	(5, 7.42, 10)	7.47	
	Selection of trainers with practical experience	(4, 7.71, 10)	7.24	
	Selection of suitable trainees	(3, 7.03, 10)	6.68	
	Arrangement of training schedule	(3, 6.97, 10)	6.66	
	Arrangement of training venue	(1, 6.24, 10)	5.75	Rejected
Evaluation method of training needs	Interview	(2, 6.82, 10)	6.27	
	Testing	(2, 6.34, 10)	6.11	
	Survey/questionnaire	(2, 6.11, 10)	6.04	
	Observation	(2, 6.08, 10)	6.03	
	Focus group discussion	(2, 6.05, 10)	6.02	
	File review	(2, 5.63, 10)	5.88	Rejected
On-the-job training	Mentorship	(4, 7.03, 10)	7.01	
	Work rotation	(4, 6.87, 10)	6.96	
	Internship training	(3, 7.58, 10)	6.86	
	Special task assignment	(3, 6.82, 10)	6.61	

	Vocational training	(3, 6.58, 10)	6.53	
Off-the-job training	Training groups	(3, 6.71, 10)	6.57	
	Lecture	(3, 6.34, 10)	6.45	
	Project training	(2, 6.92, 10)	6.31	
	Case study	(2, 6.77, 10)	6.26	
	E-learning	(1, 6.37, 10)	5.79	Rejected
	Role-play	(2, 5.03, 10)	5.68	Rejected
	Simulation	(2, 5.47, 9)	5.49	Rejected
	Character simulation	(2, 4.87, 9)	5.29	Rejected
	Sensitivity training	(2, 4.76, 9)	5.25	Rejected
	Design competition	(1, 6.13, 8)	5.04	Rejected
Evaluation of training outcomes	Basic objectives (including trainees' responses, learning efficacy, behavioral changes, learning outcomes, and attitudes)	(5, 7.58, 10)	7.53	
	Personal performance	(3, 6.97, 10)	6.66	
	Group performance assessment	(3, 6.58, 10)	6.53	
	Return on investment or cost-effectiveness	(2, 6.50, 10)	6.17	
Evaluation method of training outcomes	Comprehensive appraisal	(3, 7.13, 10)	6.71	
	Outcome evaluation	(3, 6.98, 10)	6.66	
	Testing	(2, 6.45, 10)	6.15	

	Worksheet	(2, 5.81, 10)	5.94	Rejected
	Human resources assessment	(2, 5.71, 9)	5.57	Rejected
	Questionnaire	(2, 5.50, 9)	5.50	Rejected
Career development	Multiple developments	(3, 7.18, 10)	6.73	
	Double track development	(2, 6.87, 10)	6.29	

After scoring using the Fuzzy Delphi Method, most indicators passed the threshold value. Yet some did not. In the evaluation method of training needs dimension, file review was rejected. In off-the-job-training, six indicators were rejected, namely, role-play, character simulation, sensitivity training, simulation, E-learning, and design competition. In the evaluation method of training outcomes dimension, three indicators were rejected, namely, questionnaire, worksheet, and human resources assessment. A total of ten indicators were rejected.

CONCLUSION AND SUGGESTIONS

This study has made the following contributions:

1. Literature related to the development of PV talent was collected and developmental indicators for PV R&D talent 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 talent. Indicators and literature were collected and a set of 39 indicators over seven dimensions was proposed for the cultivation of PV R&D and manufacturing talent.
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 talent and to understand the importance of each indicator and dimension.
4. Ten of the indicators were not included after implementation of the Fuzzy Delphi Method. Six of the failed indicators were in the off-the-job training dimension. It is believed that the reason behind this is that the experts felt off-the-job training was restricted by time constraints, making it more difficult to arrange. Yet the experts suggested that if time allows in the future,

they would not exclude the possibility of off-the-job training. Three of the rejected indicators were in the evaluation method of training outcomes dimension, namely, questionnaire, worksheet, and human resources assessment, as the scores for these three indicators in the industry were much lower than those in academia and the government. The experts considered the difficulty in implementing the three methods of evaluation in the industry and, therefore, these three methods of evaluation of training outcomes were not included by the experts. The remaining 29 indicators passed the t>6 thresholds for evaluation standards.

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

1. Talent indicators developed using the Fuzzy Delphi Method and their practical application it can improve the development of indicators for the cultivation of PV talent.
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 R&D talent 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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