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Critical factors that influence the success of cultivating seed teachers in environmental education

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Taiwan is a densely populated industrialized country with high-polluting industries. In particular, petrochemical, steel, thermal power, and electronics plants consume a high level of energy. Furthermore, vehicle exhaust emissions are a major contributor to pollution. Collectively, these problems have resulted in high levels of greenhouse gas emissions. To solve these problems, the government of Taiwan has been active in promoting policies aimed at cultivating seed teachers in field of environmental education. In addition, courses on environmental protection have been made mandatory for students at all levels of education, from elementary school to university. To enhance the effectiveness of cultivating seed teachers in this field, this study adopted the analytic hierarchy process and utility theory to identify critical factors influencing the success of this initiative in environmental education. The results may serve as a reference in the formulation of future policies to environmental protection and education.

Keywords: greenhouse gas emissions, pollution, analytic hierarchy process (AHP), utility theory, biodiversity

INTRODUCTION

High levels of greenhouse gas emissions worldwide have contributed to global warming, climate change (Jeong & Kim, 2015), rapid melting of polar ice, and elevated sea levels. Despite the efforts of many countries to solve this problem, greenhouse gas emissions and atmospheric CO_2 levels have not been adequately controlled because the underlying problem has not been addressed. For the sake of stimulating economic growth, many countries have allowed industrial activity to damage the environment in order to ensure the survival and competitiveness of their industries. In addition to severe environmental damage, such activity has also

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contributed to unexpected climate disasters that have caused considerable harm to human life, damage to property, and disruption to biodiversity (Scott et al. 2012).

The Kyoto Protocol, G8 summit, G7 summit, and levying a carbon tax has not been able to solve problems related to the increasingly severe threat posed by greenhouse gas emissions.

Human negligence has resulted in global environmental damage. In the face of technological and economic development, the pursuit of economic gain and other materialistic motives have led to an increase in the production of various necessity and luxury goods. Consequently, energy consumption continues to increase to meet daily living requirements. In addition, to reduce the production costs, enhance market competitiveness, and increase profits, enterprises often opt to use cheap energy alternatives that cause serious pollution problems, thereby exacerbating environmental pollution. For society to achieve a sustainable future, engineers must give equal consideration to the environmental, social, and economic factors (Mihelcic et al. 2007).

During social and economic development, people typically overlook social responsibility and caring for the environment, and through such negligence, they cause environmental damage and pollution. Environmental protection is everyone's responsibility and everyone in a civilized society should be educated on the importance of environmental protection (Canney & Bielefeldt 2015).

State of the literature

- Focus on popularization of environmental education; enhance the people's awareness of environmental protection.
- Environmentaleducationis an innovativecourse.
- To explore thecritical successfactorsof the Professional Knowledge of Seed Teachers in Environmental Education

Contribution of this paper to the literature:

- The factors of Social Responsibility, Environmental Sustainability, Citizen Participation, Textbook Selection and Teaching, and Environmental Education have a considerable influence on understanding environmental protection.
- To develop Environment seed teachers' professional ability, it will help improve the effectiveness of environmental policies to promote.
- Fostering seed teachers in environmental education must be considered as a long-term goal because ongoing education related to environmental protection facilitates gradually changing people's adverse habits and solving environmental problems.

The total amount of CO_2 emissions in Taiwan in 2012 was 256.61 million metric tons (0.81% of global CO_2 emissions), which was ranked 24th worldwide. That year, the average CO_2 emissions per person was 4.51 tons worldwide and 10.95 tons in Taiwan, which was ranked 20th worldwide and 11th in Asia. Moreover, the amount of CO_2 emissions per person in Taiwan was higher than that in China and Japan (EPA, 2015). Table 1 shows the contributions of various sectors to CO_2 emissions in Taiwan in 2013. The industrial sector contributed by far the highest proportion of CO_2 emissions (49.0%), followed by the transport sector (14.1%), with the agricultural sector contributing the least (1.1%).

Table 1. Contribution of CO_2 Emissions According to Sector in Taiwan (2013)

Item	Sector	Annual Average (%)
1	Energy sector	10.7%
2	Industrial sector	49.0%
3	Transport sector	14.1%
4	Agricultural sector	1.1%
5	Service sector	12.9%
6	Residential sector	12.3%
Sum		100.1%

The reason behind such a distribution is that most farmlands were subsidized by the government and became fallow. Collectively, the industrial sector and transport sector accounted for 63.1% of all CO_2 emissions, showing that pollution in Taiwan is mainly caused by industrial activity and motor vehicles. New energy technologies can effectively reduce such pollution, although it is crucial for such developments be based on industrial requirements (Shyr & Lo 2012). Because of high CO_2 emissions, the government of Taiwan is planning to levy a carbon tax in the future, which would have a marked influence on the economy. In recent years, the government has endeavored to reduce CO_2 emissions in Taiwan by promoting polices related to energy conservation (Logman et al., 2015), carbon-emission reduction, and environmental protection (e.g., water conservation, electricity subsidies, subsidies for upgrading home appliances, solar and alternative energy generation, green residential buildings, and green building materials, green procurement, environmental education, and funding greenification in communities). However, such efforts have not led to a substantial reduction of CO_2 emissions in Taiwan. Between 1990 and 2012, equivalent dioxide equivalent (CO_2) in Taiwan increased from 136.7 million tons to 270.7 million tons, an increase of approximately 98.1%; in addition, CO_2 emissions accounted for 96.21% of all greenhouse gas emissions (EPA, 2015). In Taiwan, the highest average monthly temperature since 1947 was recorded in July 2014, and this was attributed to climate change and global warming caused by high CO_2 emissions (Chen 2014). Because of the country's high level of energy consumption and industrial development, greenhouse gas emissions have exacerbated the urban heat island effect in Taiwan, resulting in an annual increase in average temperature. Over the past 100 years, the average temperature in Taiwan has increased by 0.8 °C. Figure 1 shows the change in average temperature (CWB 2015).

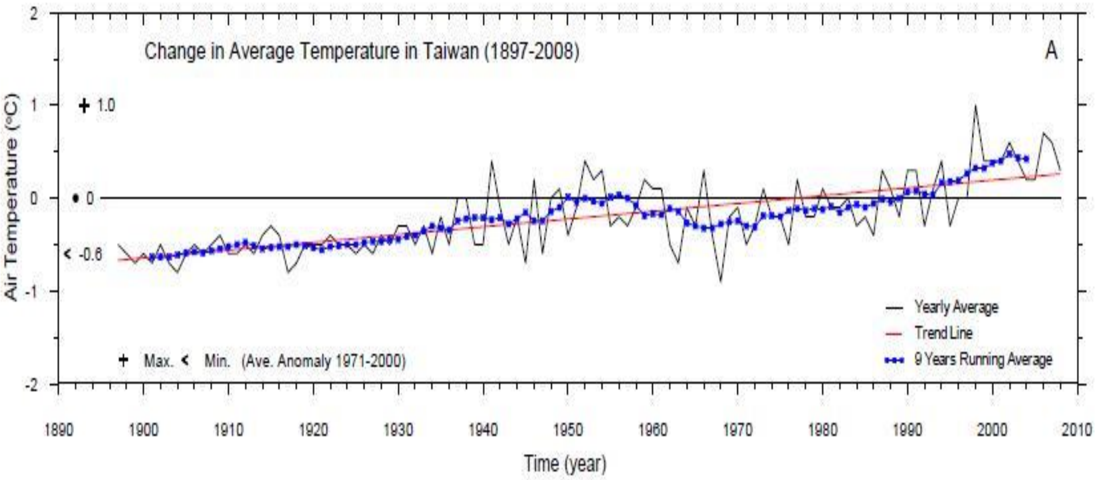


Figure 1. Change in average temperature in Taiwan (1897–2008)

In addition to Taiwan's high levels of CO_2 emissions and energy consumption, environmental pollution and public safety are ongoing concerns. For example, in 2014, a leaking pipeline of a chemical plant in Kaohsiung City resulted in a devastating explosion and fire, causing loss of life, damage to property, and pollution to the environment. Additionally, electronics factories illegally discharging wastewater have caused pollution to rivers and farmland, and noncompliance with regulations on industrial waste disposal has caused toxic pollution. An even more serious and long-standing problem is pollution from motorcycle exhausts that do not comply with the regulations. In Taiwan, low understanding of the importance of environmental protection and a lack of regard for public authorities have contributed to serious air, water, and land pollution. Such problems have been attributed to governmental negligence and incomprehensive policies. To ensure environmental sustainability, environmental policies must be comprehensive and public awareness of the importance of environmental protection must be raised.

Prior to the 2014 Asia–Pacific Economic Cooperation (APEC) summit, the government of China implemented a policy to reduce air pollution in Beijing; during the APEC summit, reduced pollution levels were visibly reduced, a phenomenon that has since been referred to as “APEC blue.” The success of the short-term policy measure not only indicated that air pollution is the direct result of economic development, but also that pollution generated by households and vehicles can be ameliorated through implementing appropriate policy measures. Therefore, effective policies, public cooperation, and encouraging enterprises to forgo economic interests are crucial factors in solving environmental problems. Problems pertaining to global environmental protection and improvement cannot be solved through the efforts of only one country; rather, countries worldwide must develop and implement appropriate policies and encourage public cooperation. Accordingly, APEC blue justifies optimism regarding environmental protection. If other countries were to exercise a comparable level of commitment in implementing such policies and were willing to temporarily sacrifice economic development and financial gain through cooperating with the general public, then the problems of environmental pollution could be immediately improved by controlling the CO_2. However, such an approach conflicts with national economic development and personal interests; consequently, compromising is difficult. If civilization and social development only increase material desire and if energy consumption only leads to further economic competition between countries, then civilization and social development can be regarded as contributing to environmental damage and the depletion of nonrenewable energy resources. Thus, sustainable energy development and environmental protection policies are crucial because they are aimed at satisfying the energy needs of the present generation without compromising the same needs of future generations (Huntzinger et al. 2007).

APEC blue can serve as a reference for authorities promoting relevant policies and provides compelling evidence regarding the effectiveness of environmental protection initiatives. Because human activity has caused widespread environmental damage, society has a responsibility to restore the environment to ensure that it is suitable for human habitation and that weather abnormalities do not become more frequent. Through education, destructive habits and customs can be transformed and a common understanding can be established (Prokop, & Kubiatko, 2014). All people must contribute to protecting the environment. Accordingly, seed teachers are undergoing training to deliver courses in environmental protection at various education levels (from elementary school to university) with the aim of raising public awareness on the importance of environmental protection in order to achieve the goal of fostering an environmentally responsible society.

The Development of Professional Knowledge of Seed Teachers In Environmental Education

In recent years, many universities worldwide have been promoting social-based education models (Cardenas 2011). Environmental education is a crucial type of social education (Erdogan & Marcinkowski, 2015). Relevant courses should elucidate how human activity and industrial waste contribute to air, water, and land pollution, as well as topics on energy consumption, resource management, and recycling. Accordingly, seed-teacher training must be focused on exploring the aforementioned issues about environmental pollution, and such training must be rigorous to ensure that seed teachers are competent for promoting environment education at all levels of education. The following sections describe how seed teachers in environmental education understand environmental pollution.

Air-pollution events

The pollutant standards index (PSI) is an air quality index indicating particulate matter (PM_{10}), SO_2, NO_2, CO, and O_3 levels in the air. Measurements are performed at monitoring stations throughout the day, and the effects of pollution on human health are determined by computing a subindex for each pollutant (according to each pollutant's ambient air concentration), among which the maximum value is taken as the PSI. Elderly adults and patients with chronic lung disease, heart disease, anemia, or stroke are advised to avoid outdoor activities and remain indoors when PSI values exceed 100 (installing an air filter indoors is recommended), and healthy people are advised to avoid outdoor activities at PSI values exceeding 200 (Huang2011). Table 2 shows how the PSI values are applied to describe the impact of pollutants on human health, and Table 3 shows the concentration of air pollutants at specific PSI values (EPA 2015). Air-pollution events resulting from human activities of daily living are typically associated with emissions from industrial waste gas, gaseous chemicals, restaurant waste, vehicle exhausts, thermal power stations, and steel mills, as well as radiation from nuclear power plants.

Table 2. PSI Values and Corresponding Impact on Human Health

PSI value	0-50	51-100	101-199	200-299	300 or above
Impact on human health	Good	Moderat	Unhealthful	Very Unhealthful	Hazardous

(Data source: Environmental Protection Administration, Executive Yuan, R.O.C.)

Table 3. Levels of Air Pollutants and PSI

PSI value	**PM_{10}: the average value for 24 h**	**SO_2: the average value for 24 h**	**CO: the max. average value for 8 h**	**O_3: the max. value for 1 h**	**NO_2: the max. value for 1 h**
	Mg / m^3	**ppb**	**ppm**	**ppb**	**ppb**
50	50	30	4.5	60	-
100	150	140	9	120	-
200	350	300	15	200	600
300	420	600	30	400	1200
400	500	800	40	500	1600
500	600	1000	50	600	2000

(Data source: Environmental Protection Administration, Executive Yuan, R.O.C.)

The PSI data in Table 4 show that the annual average PSI values in Northern Taiwan, Hsinchu and Miaoli, Central Taiwan, Yunlin and Chiayi, Kaohsiung and Pingtung, Yilan, and Hualien and Taitung exceeded 100 in 2012–2014. Yilan, Hualien, and Taitung have low PSI values because tourism is the main industry in those regions. Northern Taiwan has a large population and Central Taiwan is frequently visited by tourists during holiday periods, and thus vehicles are the main source of pollution in these regions. Yunlin and Chiayi have the second-highest PSI values because of chemical plants in the area. The main sources of pollution in Yunlin and Chiayi are combustion waste from chemical plants. The most severe air pollution has been recorded in Kaohsiung and Pingtung, which are heavily industrialized regions (e.g., chemical plants, thermal power plants, oil refineries, steel mills, shipyards, offshore fishing ports) with high population densities and vehicle registrations. In the most heavily polluted areas of Kaohsiung and Pingtung, PSI values is 20- to 30-fold more likely to exceed 100 than in Hualien, Taitung, and Yilan. The main contributing factor to air pollution in Kaohsiung and Pingtung is energy overuse, and most air pollutants are from industrial activity and vehicle exhaust emissions (Table 4).

Table 4. Incidence of The Annual Average PSI Values Exceeding 100 in Taiwan (2012–2014)

Year	Northern Taiwan	Hsinchu and Miaoli	Central Taiwan	Yunlin / Chiayi	Kaohsiung / Pingtung	Hualien /Taitung	Total
2012	0.59	0.11	0.70	0.85	2.70	0.14	0.96
2013	0.39	0.22	0.91	2.96	3.75	0.14	1.53
2014	0.66	0.22	0.52	1.86	3.69	-	1.32

Water pollution events

Most cases of human-caused water pollution involve, industrial wastewater, landfill runoff, waste dumped directly into rivers, suspended particulate, water discharge from thermal and nuclear power plants, and radiation from nuclear power plants and burial sites. Water is essential for animals and plants to survive. Water pollution not only poses a direct threat to aquatic life, but also organisms that consume food sources contaminated with toxic substances. Water pollution also directly influences plant growth and can contaminate plants. Therefore, consuming such seafood and vegetables affect human health. Table 5 presents statistical data about river pollution in Taiwan from 2012 to 2013.

Table 5 shows that the lengths (and proportions) of major rivers affected by pollution were 1093.7 km (37.3%) in 2012, 1134.3 km (38.7%) in 2013, and 1092.3 km (37.2%) in 2014. The level of pollution for most rivers was graded as moderate or severe. River pollution was at its most severe in 2013, and although pollution levels were lower in 2014, the levels are comparable to those recorded in 2012. This shows that recent policies related to environmental protection have not met expectations and that regulations have been disregarded. Unethical industrial plants with low public morality and corporate social responsibility do not understand the importance of improving wastewater treatment. Instead of investing in designing appropriate wastewater disposal systems, such companies have installed underground pipes that discharge industrial wastewater illegally. Moreover, despite the availability of scientific methods for evaluating how industrial wastewater is handled, environmental-protection units have demonstrated a lack of competence in performing their assigned duties. For example, plant inspections have been conducted too infrequently and most cases were reported and made known by the general public. In addition, because offenders have received only light fines, plant managers are willing to risk illegally discharging wastewater because of the tradeoff between the cost of being caught and the cost of installing appropriate waste-management systems. Table 6 shows data on complaints, disputes, and inspections related to pollution in Taiwan in 2013 and 2014. In 2013, the Center for Environmental Complaints received 249,784 pollution-related complaints, among which only 33,382 cases related to wastewater discharge were examined (13.5%). The number of cases increased in 2014 to 273,584; however, only 27,204 of which were investigated for possible breach of wastewater discharge regulations (approximately10%).

Land pollution events

Most causes of land pollution resulting from human activity are identical to those mentioned at the beginning of the previous section. Hence, air and water pollution indirectly contribute to land pollution. Pollution of the land surface and underground can influence crop productivity and threaten the livelihood of farmers. Accordingly, on April 24, 2013, the Executive Yuan promulgated regulations empowering the Environmental Protection Administration (EPA) to assess and grade land and groundwater pollution sites to prevent direct harm to human health and further environmental damage. Heavy metal contaminants found in soil and groundwater as a direct result of industrial activity include arsenic, cadmium, chromium, copper, lead, zinc, mercury, and nickel. The total area of agricultural land in Taiwan is approximately 825,946 hectares. As of August 2014, the total area of agricultural land polluted by heavy metals was 486.3 hectares, decreasing from 799.9 hectares (EPA, 2014). Polices for ameliorating and restoring polluted agricultural land are essential to the sustainable development of agricultural land.

Table 5. River Pollution Data in Taiwan (2012–2014) (Unit: km, %)

Year		**River length**	**Light pollution**	**Moderate pollution**	**Severe pollution**
2012	Central government	2257.8	206.9(9.2%)	502.6 (22.3%)	91.6 (4.1%)
	Local government	634.3	73.9 (11.7%)	198.1 (31.2%)	13.8 (2.2%)
	Other	41.8	3.3 (8.0%)	3.5(8.3%)	--
	Total	2933.9	284.1(9.7%)	704.2(24.0%)	105.4 (3.6%)
2013	Central government	2257.8	199.4(8.8%)	537.7(23.8%)	118.5(5.2%)
	Local government	634.3	52.8(8.3%)	201.4(31.7%)	16.4(2.6%)
	Other	41.8	4.9 (11.7%)	3.2(7.6%)	--
	Total	2933.9	257.1(8.8%)	742.3(25.3%)	134.9 (4.6%)
2014	Central government	2257.8	201.0(8.9%)	492.8(21.8%)	116.1(5.1%)
	Local government	634.3	65.6(10.3%)	190.4(30.0%)	14.5(2.3%)
	Other	41.8	7.6 (18.2%)	4.3(10.3%)	--
	Total	2933.9	274.2(9.3%)	687.5 (23.4%)	130.6(4.5%)

Table 6. Pollution Petitions, Disputes, and Inspections in Taiwan (2013–2014)

Year	**Number of inspections on industrial water discharge**	**Number of fines**	**Total fines paid (NT$1,000)**	**Number of inspections on sewage drainage**	**Number of fines**	**Total fines paid (NT$1000)**	**Number of complaints received**
2013	33,382	2,234	337,681.8	7,201	95	14,633.0	249,784
2014	27,204	3,152	286,687.7	5,912	172	23,677.0	273,584

Table 7 presents the status of land and groundwater pollution and remediation cases in Taiwan from January to June 2013. The table shows that land and groundwater pollution are most common in agricultural land and industrial plants, followed by petrol stations, and other locations (e.g., chemical storage tanks). Cases of agricultural land pollution typically involved contamination of irrigation water and groundwater from nearby industrial plants; moreover, untreated wastewater was the primary source of contamination at industrial plants. In addition, the total area of polluted and remediated land differs considerably, indicating that land remediation occurs over a long period and requires considerable human resources and funding, and the effectiveness of treatment is not immediately observable. In Taiwan, only 190,842 m^2 of the 2,628,785 m^2 of land requiring remediation was remediated (approximately 7.3%). Thus, remediation of polluted land is challenging.

When people or animals consume crops contaminated by heavy metals, the metals accumulate in the body, causing severe disease in the long term. Thus, companies that knowingly because pollution consider only their own interests while ignoring the effects to human health, life, and property. Despite this hazard, no strict legal regulations have been formulated in Taiwan to discourage companies from causing pollution.

Table.7 Statistical Data About Environmental Education Certification and Environmental Workshops from 2012 to 2014 in Taiwan (Unit: frequency)

Year	Environmental education certification (frequency)		Environmental workshops (frequency)		
	Education staff certification	Education facilities certification	Environmental Education Act	Air Pollution Control Act	Noise Control Act
2012	796	51	88	5803	397
2013	2075	77	167	5901	638
2014	3278	99	94	5598	882

The influence of environmental education

Environmental education improves people's understanding of public morality and environmental protection. In recent years, the EPA has actively promoted environmental education and seed-teacher training to raise public awareness by educating students of all ages. Environmental education not only helps people understand the importance of protecting the environment, but also fosters a consensus in terms of social responsibility. Table 7 shows data on environmental education certifications and environmental awareness workshops between 2012 and 2014 in Taiwan. Although the educational outcomes from 2012 to 2014 were excellent, the data in Tables 4–6 indicate that environmental education did generate immediate result in reducing the number of air, river, land, and groundwater pollution events.

The learning and core professional abilities of seed teachers has a considerable influence on the quality and promotion of education in general. Seed teachers in environmental protection are tasked with educating people about the importance of environmental protection and how to minimize the environment from being damaged by humans. Thus, assessing the quality of seed teachers in this field is more crucial than simply focusing on issuing education staff certification. Given the numerous causes of environmental pollution, relevant personnel must possess a considerable level of knowledge in various professions to understand scientific examination results. People without basic learning ability cannot become seed teachers in environmental protection through completing only a short-term course, and training such people may become a mere formality. To maintain the quality of seed teachers and promote policies related to environmental education, this study adopted the analytic hierarchy process (AHP) and utility theory to establish a qualitative and quantitative multicriteria decision-making (MCDM) model that facilitates assessing and selecting seed teachers who demonstrate excellence in the field of environmental education.

The learning and professional abilities of seed teachers in environmental education

Seed teachers in environmental education must possess an understanding of basic related theories and practical problems. According to the EPA in Taiwan, qualified seed teachers in environmental education can be paid hourly for teaching services conducted. An environmental education course typically involves 120 hours of instruction in core courses, pollution prevention, and teaching practice. The core courses covered four modules (environmental education, environmental ethics, environmental sustainability, and citizen participation), pollution prevention course also covered four modules (air pollution, soil pollution, water pollution, and waste pollution), and teaching practice covered three modules (teaching materials selection and teaching, instrument operation, and social responsibility advocacy). Trainee seed teachers must complete the required classes and pass an examination to become a certified seed teacher certificate in environmental education.

METHODOLOGY

The causes of environmental pollution can be attributed to national economic development, industrial economic interests, daily life activities, and public disregard of environmental affairs. These interrelated factors can be conceptualized in the form of a structural problem. This compound problem involves interpersonal, socioeconomic, and socioenvironmental competition and cooperation. To train seed teachers to assist in solving the systematic environmental pollution problems, their abilities must first be understood; accordingly, seed teachers can take responsibility for environmental education. An MCDM model can be employed to assess the ability of seed teachers to determine whether they can handle complex problems. Methods for examining systematic problems include system dynamics, the AHP, utility theory, and fuzzy logic theory (Hsueh et al. 2007). The AHP is related to multiattribute decision-making technique and is typically employed to analyze complex problems related to decision-making. However, the AHP can only be used to understand the relative relationship and importance of criteria. When combined with utility theory, it can be used to establish a quantitative assessment model for size comparison. Hence, the AHP and utility theory were integrated to establish an assessment model in this study.

Analytic hierarchy process (AHP)

The AHP, which was first introduced by Saaty, is an MCDM methodology (Saaty, 1980). The AHP can be adopted to clarify the causal relationship between events in a complex system through constructing a hierarchical structure and identifying the factors of influence. Since its introduction in 1980, the AHP has been widely applied in various areas (e.g., engineering, management, medicine, transportation, economy, social science, agriculture, and design). Regardless of whether it is employed in social science or natural science, the AHP is a convenient and adaptive model for conducting qualitative and quantitative analyses. Moreover, the model is easy to adjust and maintain. Previous studies have applied the AHP to assess student performance by examining the factors involved in cultivating student learning motivation (Shieh, et al, 2014) and evaluating the quality of personalized learning scenarios (Kurilovas & Zilinskiene, 2012). The procedure of applying the AHP to establish a decision-making model is described as follows:

1. Define the assessment (decision-making) items.
2. Determine whether the criteria of the assessment items have been met and

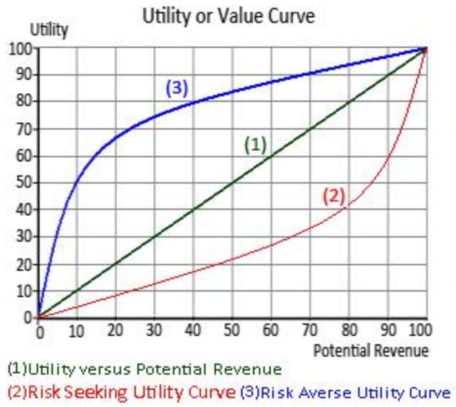
establish a hierarchical causal relationship (each criterion should be independent, reliable, and flexible).

3. Design and administer questionnaires and classify the relative weights of criteria into nine levels (Saaty, 1980; Saaty, 1990)
4. Organize the survey data and perform a pairwise comparison against the matrix of each criterion
5. Ensure that the consistency index of AHP is less than or equal to 1 in order to satisfy requirements for allowable errors. Furthermore, ensure that the consistency ratio is less than or equal to 0.1 to confirm the validity of the survey data.
6. Determine the relative weighting value of each criterion.
7. Construct an AHP MCDM model to provide a reference for making decisions.

Utility theory

Utility theory is a MCDM model. In 1738, Daniel Bernoulli proposed a mathematical model that has since been applied widely in practical economic analysis, such as game theory, statistical decision theory, and subjective probability theory which employ utility theory (Luce 1956). In utility theory, a utility function is employed to represent personal preferences, relative risk, and decision-making attitudes. As shown in Figure 2, the utility curve and the linear function of the utility curve present the advantages of risk taking, which prevents people from making decisions based on their previous experiences; society involves many decision-making situations in which an indifference relationship is more complex than an equivalence relationship is (Luce 1956). Utility theory is related to economic decision-making analysis in which decision-making, costs, and performance must be considered simultaneously. In addition, given that decision-making involves complex factors related to uncertainty, utility theory is typically applied in various areas for decision-making analysis. Previous studies have applied utility theory in evaluating household energy conservation (Hsueh 2012), facilitating green innovation from the perspective of energy and environmental protection, evaluating build–operate–transfer projects (Yan et al. 2011), determining how the insurance market affects investments in safety measures (Abrahamsen and Asche 2011), evaluating approaches to product-line selection (Thevenot et al. 2007).

The learning effectiveness of seed teachers in environmental education is related to the development of their professional competence, which is depicted by the linear utility curve in Figure 2. Therefore, each criterion has a corresponding linear utility function.



The chart in figure (1) illustrates utility versus potential revenue.
The utility curve is a straight line.

$$u_i(y_i) = Ay_i + B$$

The fuzzy scale for each criterion is within (y_u, y_L);
the range between y_u and y_L,
y_{ma} is the point most preferred; and $u_i(y_{ma}) = 1$;
y_{mi} is the worst point, $u_i(y_{mi}) = 0$.

$$u_i(y_{mi}) = 0;\ u_i(y_{ma}) = 1,$$

we can obtain the following equations :

$$u_i(y_{mi}) = A \times y_{mi} + B = 0,\ B = -Ay_{mi}$$

$$u_i(y_{ma}) = A \times y_{ma} + B = 1,\ A = 1/(y_{ma} - y_{mi})$$

Figure 2. Utility Curve and Linear Utility Function

AHP and Utility Theory Assessment Framework

The AHP can only be employed to obtain the relative weights between factors; however, when combined with utility, the anticipated utility value can be obtained, thus providing a quantitative measure for compare effect size, which can provide a reference value for decision-making (Hsueh, 2015). Combining AHP and utility theory not only clarifies the influence of each criterion, but also indicates the advantages and disadvantages of each criterion for a given decision-making category. Because each criterion has its own utility function, the relative weight of each criterion and utility value of each utility function can be compared quantitatively. Figure 3 depicts the assessment framework.

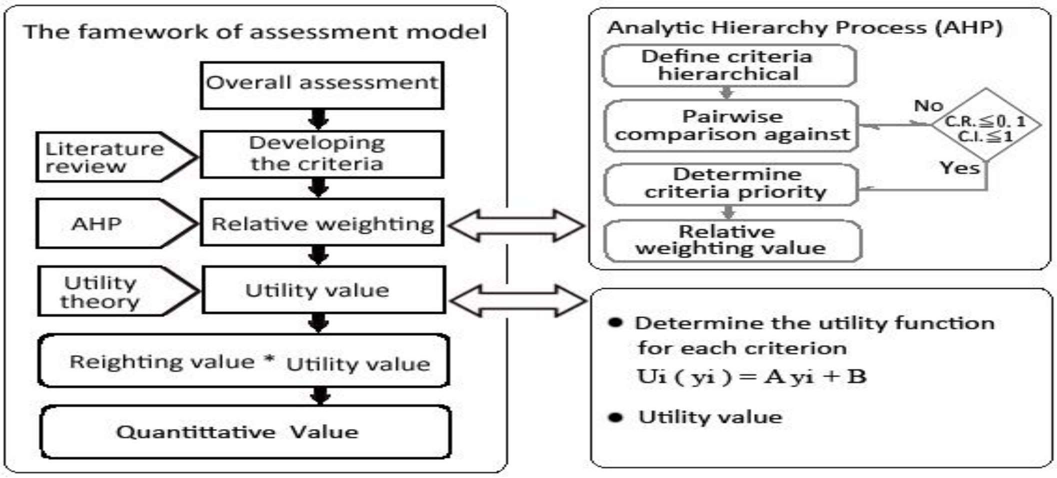


Figure 3. The Assessment Framework for AHP and Utility Theory

Research design

The environmental education course examined in the present study involved 120 hours of class instruction on core courses, public pollution prevention, and teaching practice, which were assigned to Level 1 in the AHP. The core course comprised four modules in Level 2 of the AHP (environmental education, environmental ethics, environmental sustainability, and citizen participation). Public pollution prevention comprised four modules (air pollution, soil pollution, water pollution, and waste pollution) and teaching practice comprised three models in Level 2 of the AHP (textbook selection and teaching, instrument operation, and social responsibility advocacy). Figure 4 depicts the proposed AHP utility model for environmental education.

RESULTS

The relative weighting values of each criterion

In this study, 100 questionnaires were administered, among which 66 were considered valid based on their CI and CR values. The geometric mean was used to perform a pairwise comparison against each criterion. Table 8 shows the relative weighting value of each criterion. The first five critical factors were Social Responsibility, Environmental Sustainability, Citizen Participation, Textbook and Teaching, and Environmental Education. This result implies that seed teachers in environmental education should focus on these five criteria to be suitable for employment in environmental education. Despite their small relative weighting values, four factors related to pollution prevention that were identified as requiring attention are problems related to air pollution, soil pollution, water pollution, and waste pollution, which should not be ignored as this study explores how seed teachers in environmental education effectively make an impact on mitigating environmental problems.

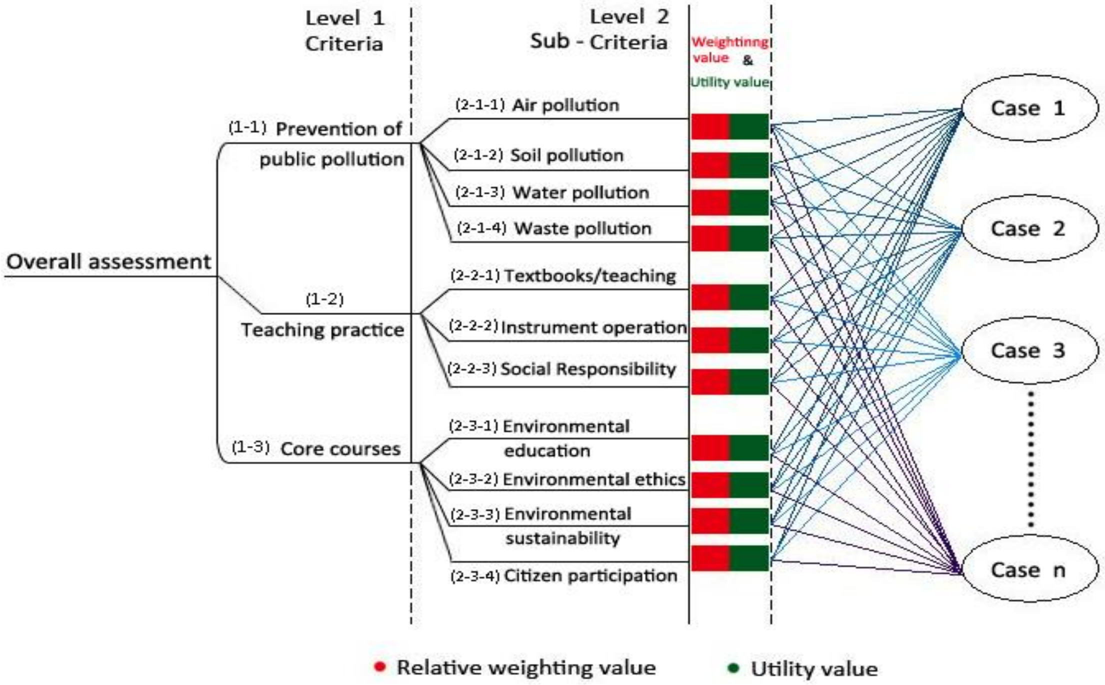


Figure 4. AHP Utility Model for Environmental Education

Table 8. Overall Weight for Each Criterion

Criteria	Comparison against	Level (1) *Wi*	Sub-Criteria	Comparison against	Level (2) *Wi*	Overall *Wi*	Overall Sequence
1-1	1	0.195	2-1-1	1	0.190	**0.037**	11
			2-1-2	2.118	0.307	**0.060**	7
			2-1-3	1.466	0.220	**0.043**	10
			2-1-4	1.600	0.284	**0.055**	8
1-2	2.242	0.351	2-2-1	1	0.323	**0.113**	4
			2-2-2	0.653	0.175	**0.061**	6
			2-2-3	1.278	0.502	**0.176**	1
1-3	1.872	0.454	2-3-1	1	0.219	**0.099**	5
			2-3-2	0.517	0.111	**0.050**	9
			2-3-3	1.487	0.373	**0.169**	2
			2-3-4	1.516	0.297	**0.135**	3
Overall *Wi*					1		

The utility values of each criterion

In this study, utility theory and AHP were adopted to establish a model for assessing the learning effectiveness of seed teachers in environmental education. The utility values must meet the subjective requirements of decision makers, which introduces complexity because people have varying views about utility value. The purpose of expected utility theory is to choose a solution with the maximum expected utility value when making decisions involving risk taking instead of the solution with maximum expected value.

As shown in Figure 2, to determine *A* and *B* in the linear utility function $u_i(y_i) = Ay_i + B$, the maximum value y_u in the assessment interval and the candidate maximum input value y_{ma} for Textbook Selection and Teaching as well as Instrument Operation were set at 10; the remaining criteria were set at 100. The minimum value y_L in the assessment interval was set at 0. The eligible minimum input value y_{mi} represents the expected minimum learning effectiveness. Based on these definitions, the corresponding utility function and value of each criterion were obtained (Table 9).

After determining the utility value $u_i(y_i)$ and weighting value (W_i) of each criterion, expected utility values of the worst and optimal situations were calculated (Table 9) using the following formula (*Wi*% denotes a weighting value):

Expected utility value (EUV)= $\sum_{i=1}^{n}(u_{ri} \times w_i)$

As shown in Table 9, the weighting and utility values were 1. For convenience of explanation, the weighting value was multiplied by 10. The worst and optimal expected utility values were -17.59 and 9.98, respectively.

Table 9. The Utility Value and Weighting Value of Each Criterion

Criteria	(W_i)*10	y_{mi}	y_{ma}	$u_i(y_i) = Ay_i + B$ (u_{ri})	Worst (EUV)	Optimal (EUV)
2-1-1	**0.37**	60	100	$u_i(y_i) = 0.025y_i - 1.50$	-0.56	0.37
2-1-2	**0.60**	70	100	$u_i(y_i) = 0.033y_i - 2.33$	-1.40	0.60
2-1-3	**0.43**	70	100	$u_i(y_i) = 0.033y_i - 2.33$	-1.02	0.43
2-1-4	**0.55**	60	100	$u_i(y_i) = 0.025y_i - 1.50$	-0.83	0.55
2-2-1	**1.13**	5	10	$u_i(y_i) = 0.20y_i - 1.00$	-1.13	1.13
2-2-2	**0.61**	3	10	$u_i(y_i) = 0.143y_i - 0.429$	-0.26	0.61
2-2-3	**1.76**	60	100	$u_i(y_i) = 0.025y_i - 1.50$	-2.64	1.76
2-3-1	**0.99**	60	100	$u_i(y_i) = 0.025y_i - 1.50$	-1.49	0.99
2-3-2	**0.50**	70	100	$u_i(y_i) = 0.033y_i - 2.33$	-1.17	0.50
2-3-3	**1.69**	70	100	$u_i(y_i) = 0.033y_i - 2.33$	-3.94	1.69
2-3-4	**1.35**	70	100	$u_i(y_i) = 0.033y_i - 2.33$	-3.15	1.35
Expected utility value = $\sum_{i=1}^{n}(u_{ri} \times w_i)$					-17.59	9.98

A negative expected utility value implies that the seed teachers' performance was unsatisfactory, and high values indicate that the training outcome were far from achieving the goal. In other words, the seed teachers demonstrated inadequate competence to be suitable for employment in environmental education. By contrast, a high expected utility value indicates excellent training outcomes.

Table 10. Assessment Results for Cases (1), (2), and (3)

Criteria	$(W_i\%)$	Case (1)		Case (2)		Case (3)	
		(y_i)	$(u_{ri})_*(W_i\%)$	(y_i)	$(u_{ri})_*(W_i\%)$	(y_i)	$(u_{ri})_*(W_i\%)$
2-1-1	3.7	60	0	70	0.093	80	0.237
2-1-2	6.0	70	0	80	0.186	90	0.384
2-1-3	1.3	70	0	80	0.133	90	0.275
2-1-4	5.5	60	0	80	0.138	90	0.275
2-2-1	11.3	5	0	6	0.226	7	0.452
2-2-2	6.1	3	0	6	0.153	7	0.305
2-2-3	17.6	60	0	70	0.440	80	0.880
2-3-1	9.9	60	0	70	0.248	80	0.495
2-3-2	5.0	70	0	80	0.155	90	0.320
2-3-3	16.9	70	0	80	0.524	90	1.082
2-3-4	13.5	70	0	80	0.419	90	0.864
(EUV)		0		2.713		5.569	

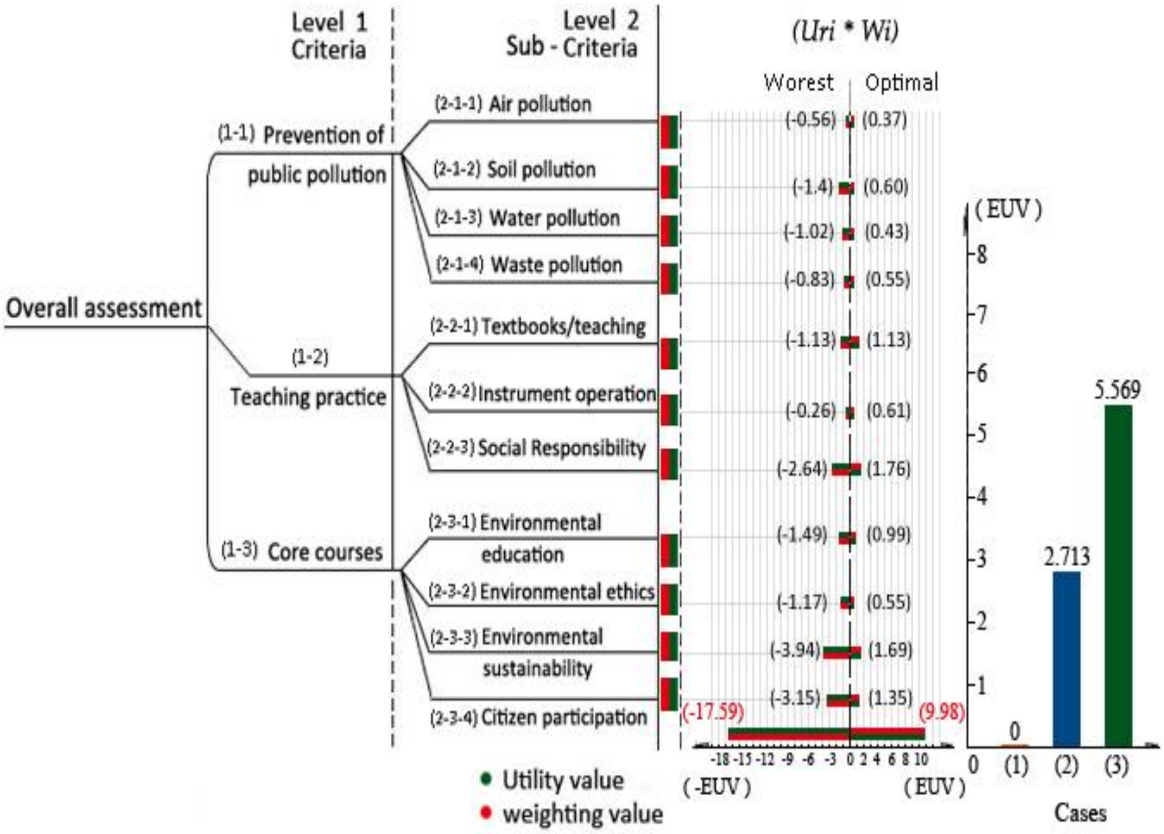


Figure 5. Case Assessment Results

DISCUSSION

In this study, Cases (1), (2), and (3) were employed to explain how the proposed model can be applied. In Case (1), the minimum value y_{mi} for each criterion was selected as a baseline reference. In Cases (2) and (3), the score of each criterion was inflated to demonstrate the model application (Table 10). Regarding the assessment results for the three cases, when the value of y_i for each criterion in Case (1) was an eligible minimum value, the expected utility value was 0. However, this result does not mean that the assessment score was 0; instead, it implies that the scores of seed teachers met the criteria; however, their participation in environmental education was ineffective. In Cases (2) and (3), although the value of y_i for each criterion did not exhibit a marked increase, the expected utility value increased exponentially. The expected utility value can assist decision makers in identifying which situations generate satisfactory results. Figure 5 shows case assessment results.

CONCLUSION

Although Taiwan has actively promoted strategies for fostering seed teachers in order to change social norms related to energy consumption and to raise public awareness on the importance of environmental protection, the data reported herein indicate that environmental pollution has not been improved substantially. However, fostering seed teachers in environmental education must be considered as a long-term goal because ongoing education related to environmental protection facilitates gradually changing people's adverse habits and solving environmental problems.

RECOMMANDATIONS

The results of this study show that the factors of Social Responsibility, Environmental Sustainability, Citizen Participation, Textbook Selection and Teaching, and Environmental Education have a considerable influence on understanding environmental protection. In addition, the expected utility assessment model indicated that seed teachers being qualified in environmental education do not necessarily generate the expected utility value. This model was characterized through conducting a quantitative assessment and merit comparison and therefore may serve as a reference for environmental-protection departments when assessing the effectiveness of fostering seed teachers in environmental education. In addition, the proposed model is highly adaptive and is easy to use and maintain.

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