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Developing indicators for sustainable campuses in Taiwan using fuzzy Delphi method and analytic hierarchy process

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A B S T R A C T

Education is an essential national policy, and developing sustainable campuses has been a goal of education environment policies. This study used a literature review to establish 55 initial for assessing a sustainable campus and performed inductive analyses, after which 28 final indicators were screened out by academic researchers and campus users using the fuzzy Delphi method. The indicators were divided into three major dimensions—policy management, buildings and equipment, and educational activities—which were further subdivided into nine subdimensions; subsequently, a hierarchical analysis expert questionnaire was used for consistency testing. The differences in weights between dimensions and indicators in addition to between expert groups (with distinct backgrounds) were analysed, and sustainable development strategies and priority orders were then inferred. Among the three dimensions, "Buildings and equipment" was recommended for the most immediate attention. The other two dimensions, "Policy Management" and "Educational Activities," were weighted differently by the two groups of experts. This study determined that resource recycling and energy efficiency generate benefits and that conserving energy and reducing carbon footprint are the core of sustainable school grounds.

1. Introduction

Taiwan is a resource-poor island, importing up to 98% of its energy (Bureau of Energy (BOE) of Taiwan (2016). In addition, its energy utilization efficiency is low. With an average of 10.68 tonnes per person, it is ranked 19th in the world in terms of CO_2 emissions, despite the global average emission being only 4.52 tonnes per person; additionally, it is ranked 45th in the world regarding its carbon emission concentration of 0.27 kg CO_2/US$, where the global average is 0.32 kg CO_2/US$ (IEA, 2016). In other words, Taiwan's average CO_2 emissions per capita is 2.36 times the global average, yet its economic output is merely 0.84 times the global average, demonstrating Taiwan's unsatisfactory energy efficiency. Energy saving and sustainable development topics have thus received broad attention in Taiwan in recent years. Taiwan's Ministry of Education began implementing a sustainable campus policy in 2004, which stated that, starting from 2009, new campus buildings must meet the design specifications for green buildings. The green building assessment system contains myriad tools, which can be applied to many building categories. However, it applies only to buildings. Numerous factors affect school grounds aside from their buildings. To date, their sustainable campus policy has been a crucial policy for and is highlighted annually by the Ministry of Education. However, varied opinions have been voiced on how campus sustainability should be assessed, including which indicators or assessment items should be adopted; thus, a broader and more in-depth discussion is required to achieve a consensus.

School and other education buildings have been the focus of building energy consumption in various countries. For example, school buildings account for 13% of all building energy consumption in the United States, where they consume the fourth highest percentage of power, preceded only by retail (32%), offices (18%), and hotels and restaurants (14%) (Pérez-Lombard et al., 2008). In terms of total electricity consumption in the United States, school

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buildings account for 10.8% of all building electricity consumption and are ranked third in the sector, preceded only by offices (20.4%) and retails and malls (20.4%) (Energy Information Administration, 2012). School buildings are also ranked third in terms of category of building energy consumption in the United Kingdom, behind commercial and office buildings (Department of Energy and Climate Change, 2017). Relevant data on Taiwan is lacking, but according to the energy consumption data declared by high voltage customers in nonproductive industries as disclosed by the BOE, school building energy consumption accounts for 14.4% of all high voltage energy consumption, second only to that of hospital buildings (14.9%) (BOE of Taiwan, 2017), indicating the large amount of energy consumed by school buildings. Wang (2016) disclosed that in terms of energy consumption in Taiwan's schools, electricity accounts for 93% of the total energy consumption, implying that the topic of energy must be at the core of sustainable campus development.

2. Literature review

Energy has always been at the core of discussions on sustainable development; thus, saving energy has been regarded the principal subject in studies that assess sustainable campuses (Faghihi et al., 2015; Hasapis et al., 2017; Zhou et al., 2013). Most energy-themed research has used energy monitoring approaches to provide the objects of investigation (usually universities) with various valuable assessment results and recommendations (Deshko and Shevchenko, 2013; Kolokotsa et al., 2016; Yoshida et al., 2017). In addition, numerous studies have been based on energy-induced carbon emission, wherein the corresponding strategies adopted by sustainable campuses were weighted based on the amount of carbon emissions they resulted in (Li et al., 2015; Liu et al., 2017; Zen et al., 2017), providing many carbon reduction strategies based on local school features, which can be used as a reference for areas or schools with similar climatic conditions. Moreover, because of their high energy consumption, universities are encouraged by government units to employ renewable energy, and thus numerous sustainable campus studies have focused on renewable energy usage (Kumar et al., 2017; Park and Kwon, 2016; Talavera, 2014).

The literature thus demonstrates that a suitable energy strategy is at the core of a sustainable school; however, implementing sustainable school ground strategies still requires various additional strategies (Berzosa et al., 2017; Gomez et al., 2017). Numerous studies have been conducted using surveys of user opinion to yield concrete and feasible strategies (Arroyo, 2017; Dlouhá et al., 2018; León-Fernández et al., 2017). Some studies have investigated survey-distributed samples (Jorge et al., 2015; Li et al., 2015) and some have discussed the relationship between sustainability and regional planning (Grindsted, 2018). Other studies have consulted on sustainable school ground strategies or energy-related topics by using analytic hierarchy process (AHP) expert questionnaires (Heo et al., 2010; Kumar et al., 2017), gradually obtaining expert consensus through hierarchical analysis, through the Delphi method (Disterheft et al., 2015), or by focusing on methodological tools, such as fuzzy AHP and fuzzy Delphi method (FDM) (Deb et al., 2017; Suganthi et al., 2015).

Table 1 lists the methods used to assess eco-schools worldwide; some assessment indicators are committed to evaluating technology (CASBEE of Japan), but the majority of indicators assess the overall process of complete implementation (UNEP; Australian Government; Eco-Schools USA; MEP of China; MECSST of Japan). Taiwan has developed EEWH assessment tool for evaluating green buildings, however it is not design for campus. Energy efficiency (carbon emission reduction) is undoubtedly one of the core indicators and is affected by school building design and the air conditioning or other ancillary equipment used within buildings. Environmental-protection-related topics, as well as others such as those on water resources, waste reduction, and indoor environment, are also common key items. To facilitate the implementation of policies, forming eco committees in schools, formulating and implementing plans, holding regular meetings and checking progress, calling for community integration, and even incorporating eco-school topics into curricula can contribute to sustainable campus policy implementation. Each country differs in their assessment indicators or implementation strategies because of their distinct national conditions, hence the necessity for adapting the assessment method according to local conditions.

3. Methodology

Taiwan has 2630 elementary schools, 735 junior high schools, 506 senior high schools, and 158 universities, with a total of 3,946,639 students (Department of statistics, 2017). A more sustainable and comfortable campus environment must be provided for education. To define the indicators of a sustainable campus, it is necessary to gather scholars and experts and determine consensus through discussion. To perform the literature review, this study first established an expert committee, including authors, two experts, and two scholars, divided sustainable school ground indicators into three dimensions: policy management, buildings and equipment, and educational activities. After the committee was formed, Taiwan's current green building assessment indicators were referenced to formulate three major dimensions comprising 55 original indicators. The indicators were developed over 5 years (Taiwan Architecture and Building Center, 2012) and were designed for almost every possible building design and use. However, some are unsuitable for school grounds. They must be modified and classified, and through weighting hierarchical analysis, the appropriate ones can be determined. These assessment indicators applicable to sustainable campuses in Taiwan were then established through FDM, and the relative weight of each indicator was finally determined through the AHP.

3.1. Questionnaire respondents

This study invited 32 experts and scholars to complete the FDM questionnaire (Table 2); additional 16 experts and scholars were invited to complete the AHP questionnaire (Table 3). The scholars and experts include two groups: the first group includes managers who engage in sustainable school grounds affairs, including head teachers, assistant heads of general affairs, heads of general affairs, and heads of environmental education; the second group are university professors and researchers who specialise in related fields, including environmental engineering, environmental education, and green buildings. Additionally, the scholars come from both town centre schools and suburban schools, and school locations are evenly distributed around Taiwan. Compiling the indicators was a multicriteria decision-making process that required the inductive analysis of expert and scholar opinions. The questionnaire was designed for use by experts, who must determine what measures or policies are necessary and how they should be implemented on school grounds. The students were not consulted. The questionnaire respondents were individuals who were responsible for operations related to sustainable campuses or were academic researchers in that particular field. In Taiwan, the director of general affairs of elementary or secondary schools is generally in charge of planning school buildings and supervising their construction, as well as maintaining campus buildings and supervising

Table 1
Worldwide eco-school assessment tools and indicators.

Country or region	Topic or indicator	Content
United Nations Environment Programme's (UNEP) (2015)	Seven steps towards an Eco-school	Form an Eco Committee Carry out an Environmental Review Action Plan Monitor and Evaluate Curriculum Work Inform and Involve Produce an Eco Code
Australian Government (2005) Coincides with the United Nations Decade of Education for Sustainable Development (UNDESD) 2005–2014	Indicators for a sustainable school	Educational Environmental Water Electricity Waste School grounds Social Economic
ECO-Schools USA (Updated, 2017)	Pathways to Sustainable Development	Investigate and increase biodiversity at school and beyond Improve climate literacy and investigate climate change solutions Moving beyond the "3 Rs" Analyze and measure effective ways to conserve energy Promote a healthy lifestyle while connecting to the natural world Find relationships between human health and the building and grounds Design, develop and maintain an outdoor learning laboratory Improve food education and nutrition opportunities at school Outline alternative school transportation methods to reduce the school's carbon footprint Analyze and measure effective ways to conserve water Learning About Forests Watersheds, Oceans and Wetlands
Ministry of Environmental Protection (MEP), China. (Updated, 2017)	Assessment Standards for Eco-Schools	Form an leader institution Support from school Management measures Complete document Environmental education courses involved Environmental education researches Develop environmental education atmosphere Disseminate green lifestyles Green landscaping campus Establish an environmental committee
Ministry of Education, Culture, Sports, Science and Technology (MECSST), Japan (Updated, 2017)	Assessment and certification tools for school buildings	Energy efficiency Resource efficiency Local environment Indoor environment.
Taiwan Architecture & Building Centre. Ecology, Energy Saving, Waste Reduction and Health (EEWH), Taiwan (Updated, 2017)	Assessment and certification tools for buildings	Biodiversity Greenery Soil Water Content Energy Conservation CO_2 Emission Reduction Construction Waste Reduction Indoor Environment Quality Water Conservation Sewage and Garbage

safety; the section chief of general affairs is responsible for school equipment procurement, repair, and maintenance; and the section chief of environmental education is responsible for campus environment maintenance, green landscape planning, energy saving planning and promotion, and resource recycling. These three posts are often held concurrently by teachers, who thus understand the effect of sustainable development on students, enabling them to make specific recommendations for sustainable campus indicators. Thus, such personnel from elementary and secondary schools were recruited in this study. Professors and researchers comprised the respondents from universities; all were involved at the time of this study in sustainable-campus-related projects or had demonstrated concern regarding environmental conservation for a long period. They also taught relevant courses in their university and were familiar with the needs of a sustainable campus environment in elementary and secondary schools.

3.2. FDM questionnaire and implementation

The fuzzy Delphi method is a structured communication method, developed as a systematic, interactive forecasting method which relies on a panel of experts. The experts answer questionnaires in two rounds. After each round, a facilitator or change agent provides an anonymised summary of the experts' forecasts from

Table 2
FDM questionnaire respondents.

Category	Title	School level	Number of respondents
Campus Use	Director of General Affairs	Elementary School	3
	Section Chief of Environmental Education	Elementary School	3
	Section Chief of General Affairs	Elementary School	2
	Principal	Secondary School	1
	Director of General Affairs	Secondary School	3
	Section Chief of Environmental Education	Secondary School	3
	Section Chief of General Affairs	Secondary School	2
	Director of General Affairs	High School	3
	Section Chief of Environmental Education	High School	2
	Section Chief of General Affairs	High School	2
Academic Research	Professor (Environmental Engineering)	University	2
	Professor (Environmental Education)	University	3
	Professor (Green Buildings)	University	3

Table 3
Hierarchical analysis questionnaire respondents.

Category	Title	School level	Number of respondents
Campus Use	Principal	Elementary School	1
	Director of General Affairs	Elementary School	1
	Section Chief of Environmental Education	Elementary School	1
	Principal	Secondary School	1
	Director of General Affairs	Secondary School	1
	Section Chief of Environmental Education	Secondary School	1
	Section Chief of General Affairs	Secondary School	1
	Director of General Affairs	High School	1
	Section Chief of Environmental Education	High School	1
Academic Research	Professor (Environmental Engineering)	University	1
	Professor (Environmental Education)	University	2
	Professor (Green Buildings)	University	2
	Researcher (Environmental Education)	Research Centre	2

the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of the panel. During this process, the number of answers decreases, and the group converges towards the correct answer.

The experts' consensus indicators were screened using the centre of gravity method, the procedures of which are as follows: (1) calculate the triangular fuzzy numbers indicating the importance of the initial indicators; that is, collect the experts' importance assessment values for the initial indicators by using the questionnaire and integrate them to calculate the triangular fuzzy numbers representing the importance of each initial indicator. (2) Convert the fuzzy weight W_{wK} of each initial indicator into a single value S_K; the minimum value, geometric mean, and maximum value of the fuzzy numbers of all original assessment indicators are used to establish the triangular fuzzy number W_{wK} = (minimum value of fuzzy number, geometric mean, and maximum value). The fuzzy weight W_{wK} of each initial indicator is subsequently converted into a single value S_K by using the centre of gravity method: S_K = (minimum value of the fuzzy number, geometric mean, and maximum value)/3, where S_K is the threshold value set for screening the more appropriate indicators. After two FDM questionnaire screenings with the original 55 indicators, the experts reached a consensus on only 28 of the original 55 indicators; these 28 formed a framework comprising the three major dimensions that were subdivided into nine subdimensions.

3.3. AHP questionnaire and implementation

The AHP is a structured technique for organising and analysing complex decisions. It has a particular application in group decision making. AHP helps decision makers make a decision that most effectively suits their goals and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem and for evaluating alternative solutions. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to each other two at a time, with respect to their impact on an element above them in the hierarchy.

The 16 experts' questionnaires were integrated based on the experts' assessment of the importance of the assessment dimensions or indicators. The three assessment dimensions are policy management, buildings and equipment, and educational activities. The 28 indicators were classified and categorised as 3, 4, and 2 clusters, and there are 11, 13, and 4 indicators in the three dimensions, respectively. To define the gravity, the factors of the dimensions, clusters, and indicators must be determined. The procedures were as follows: (1) Establish pairwise comparison matrices; that is, the experts compared the respective cluster factors of two subgroups and divided them into nine levels based on their importance, after which they measured the relative importance of a pair of indicators in each level and pairwise comparison matrices were established according to the questionnaire survey results. (2) Determine the level weight factors and obtain the eigenvector using numerical analysis. (3) Consistency test; this study used the consistency index (C.I.; Equation (1)) to determine whether the pairwise comparison matrices constructed by the respondents were consistent, after which a further test was conducted using the consistency ratio (C.R.; Equation (2)). A lower C.I. indicates higher consistency; C.I. = 0 indicates complete consistency before and after the judgement; C.I. > 0 indicates inconsistency. Random inconsistency (R.I.) represents the consistency indicators generated at various levels. The C.R. must be within 0.1 for the consistency of a matrix to be acceptable.

$$\text{C.I.} = \frac{\lambda_{max} - n}{n - 1} \tag{1}$$

where λ_{max} is the maximum eigenvalue and n is the rank of the matrix.

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{2}$$

4. Results

This study identified 55 sustainable campus indicators through a literature analysis and an inductive analysis; subsequently, the indicators for sustainable campuses in Taiwan were established using the fuzzy Delphi expert decision-making approach. The hierarchical framework was divided into three levels, wherein the first level consisted of the three major dimensions; the second level had nine subdimensions; and the third level encompassed 28 individual indicators (Table 4). The selection and analysis of the hierarchical dimensions and indicators are described as follows.

4.1. First major dimension (policy management index group) screening

The first dimension originally contained 18 indicators (Fig. 1); the geometric mean of the value of given by the experts to each indicator was adopted as the screening threshold, screening out indicators that did not reach 7.54. For the 32 expert questionnaires, indicators that were agreed upon by 90% of the experts were included. A total of 11 indicators remained in this dimension after the screening. In the first index group, "1-1-1 Purchase environmentally friendly products" had a consensus value of 8.64, indicating that experts were focused on substantive action and that this indicator item was relatively easy to implement. In the second index group, "1-2-3 Equipment Repair and Maintenance" obtained the highest consensus and was also the topic of greatest concern among schools using old equipment. In the third index group, the items achieving the highest recognition ("1-3-1" and "1-3-2") were both related to air conditioning, a challenge faced by many schools in Taiwan during summer. The indicators that were screened out included commitment by school leadership organisations to implementing policies, energy-efficient transportation, the

Table 4
Sustainable campus indicators.

Target	First level	Second level	Third level (Indicators)	
Sustainable Campus Indicators	Policy Management	1–1 Procurement	1-1-1	Environmentally friendly products are purchased with labels that suggest energy saving, environmentally friendly, green material, and water saving aspects
			1-1-2	Manufacturers are chosen according to environmental awareness
			1-1-3	Domestic production and local products are adopted to reduce carbon emissions from transportation activities
		1–2 Management Policy	1-2-1	Organisations to implement energy and resource recycling policies are established
			1-2-2	Resource recycling problems faced by the school are periodically surveyed and listed, and energy consumption information is regularly disclosed
			1-2-3	Regular maintenance of equipment is implemented and equipment that consumes high levels of energy is replaced to reduce power consumption and environmental damage
			1-2-4	Various government energy saving and carbon-reduction-related programmes are participated in to establish a sustainable campus
		1–3 Daily Life Behaviour	1-3-1	The temperature is set to 26 °C–28 °C when the air conditioner is in use
			1-3-2	Air conditioners are used together with circulation fans to reduce energy consumption
			1-3-3	The Energy Saving and Carbon Reduction Convention is implemented
			1-3-4	Healthier, less polluting, and safer means of transportation are used
	Buildings and Equipment	2–1 Energy Saving	2-1-1	Shades over windows facing the sun are installed
			2-1-2	Energy saving light fixtures are used
			2-1-3	Light guide plates or light-coloured diffuse reflecting materials are installed indoors to facilitate the use of natural lighting
			2-1-4	The usage frequency of energy-consuming facilities is coordinated in response to weather and usage amount
		2–2 Resource Reduction	2-2-1	Rainwater storage or reclaimed water use facilities are established
			2-2-2	School administration procedures are digitised to reduce paper consumption
			2-2-3	Dry construction combinations are employed for indoor construction that conform to the conditions of safety factors
			2-2-4	Open-conduit designs are adopted for equipment piping to enable easy maintenance and increased durability
		2–3 Greening and Carbon Sequestration	2-3-1	Green roofs composed of plants (potted plants, roof gardens, and extensive green roofs established on thin layers of soil) are constructed
			2-3-2	Tree-based greening is employed to increase the amount of carbon sequestration
			2-3-3	Drought-resistant plant greening is chosen for low maintenance management
		2–4 Sewage and Garbage	2-4-1	Rubbish classification and resource recovery systems are established
			2-4-2	Compost recovery systems (deciduous compost and kitchen waste compost) are established
	Educational Activities	3–1 Activities and Participation	3-1-1	Energy saving and carbon reduction activities and competitions are organised and promoted
			3-1-2	Various resource and energy recycling concepts are promoted during school rallies and in publications
		3–2 Curriculum Planning and Teaching	3-2-1	School teachers are encouraged to participate in sustainable-campus-related training courses and their promotion is reinforced on campus
			3-2-2	Teachers and students are encouraged to jointly participate in maintaining their sustainable campus, establishing the values and concepts of cherishing the environment

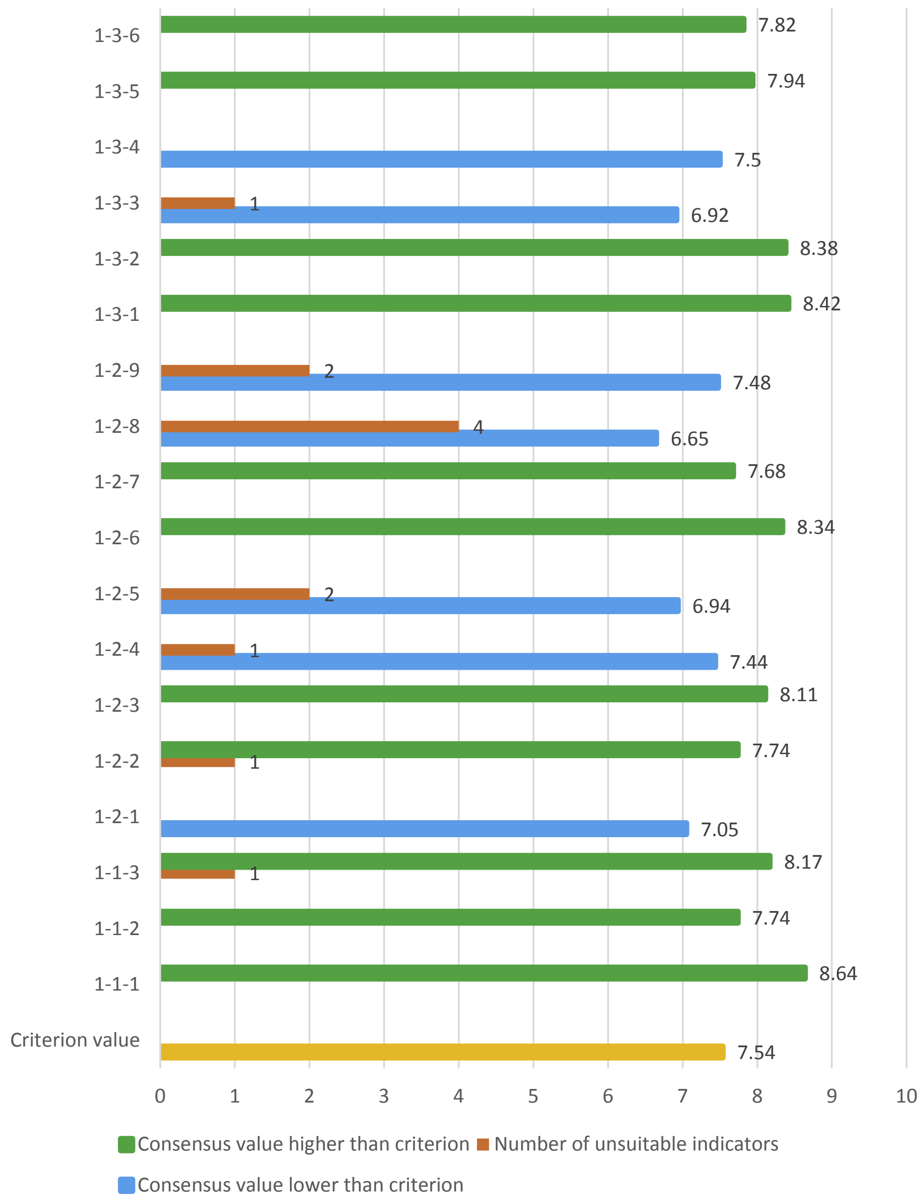

Fig. 1. First major dimension index screening.

establishment of a building energy management system, and the adoption of natural lighting to replace artificial lighting. According to the experts, the removal of these indicators did not imply that they are unrelated to sustainable development; instead, they were removed because actually implementing them on campuses causes considerable difficulties originating from complications in ensuring management policies, a lack of extra budget with which to purchase equipment for energy monitoring, and student complaints regarding a lack of artificial lighting.

4.2. Second major dimension (buildings and equipment index group) screening

The second dimension originally consisted of 25 indicators, 13 of which were retained after the expert questionnaire survey was conducted (Fig. 2). In the first index group, using energy saving light fixtures (such as LEDs) obtained the greatest consensus, and other indicators retained included installing external shades, using light colours indoors to maximize the effects of daylighting, and adjusting electricity facilities according to the weather or spatial needs. However, expert opinion diverged on the indicator item “accurate assessment of the usage amount required according to spatial requirements while installing various energy-consuming equipment (such as air conditioning and light fixtures) and avoid installing excessive fixtures.” Although the consensus value for this indicator exceeded the threshold, some experts argued that aspects such as spatial use, environment, and number of users would have to considered, which often result in difficulties during actual implementation; thus, the indicator was removed. In the second index group, “2-2-2 Digitise school administration procedures and employ double-sided printing to reduce paper consumption” attained the highest consensus value. The indicator “2-2-5 Encourage the use of lightweight steel or wood structures during construction” had the lowest consensus value due to the high cost

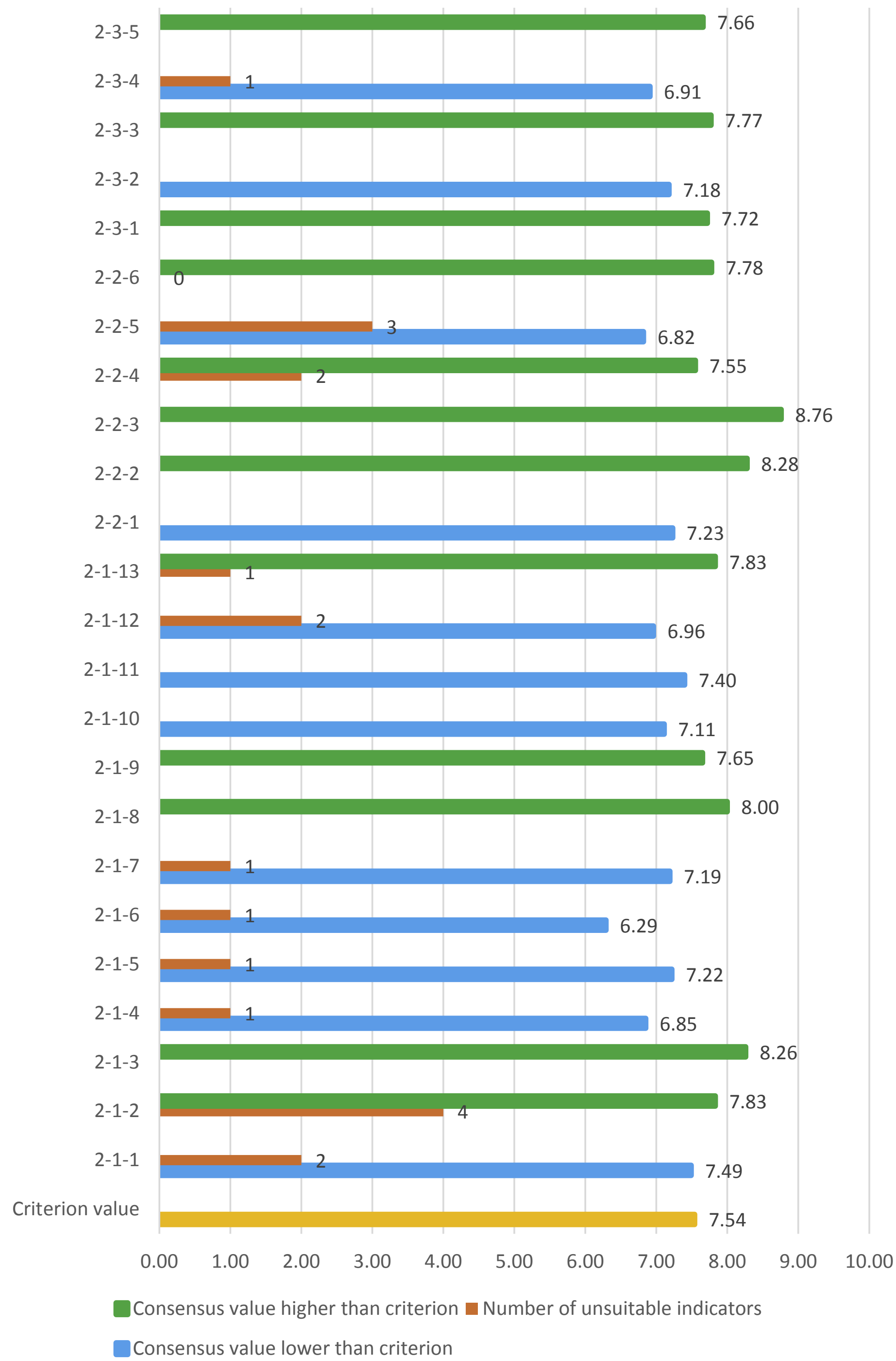

Fig. 2. Second major dimension index screening.

of steel and pest concerns regarding wooden structures. In the third index group, greening and carbon sequestration received universal agreement, although experts were concerned that the vertical greening of campus walls using vines could affect the maintenance of building facades. Overall, indicators involving a slight increase in budget to enhance energy efficiency or the simple adjustment of usage behaviour to reduce resource wastage gained expert approval more easily. Conversely, indicators that required more of a budget increase (e.g., adopting low emissivity glass, installing induction lighting, adopting renewable energy as an alternative energy source) or that could cause building maintenance concerns (planting on roofs) or student safety concerns (using outward-opening windows leads to injury concerns arising from students running in the corridors) did not gain widespread approval.

4.3. Third major dimension (educational activities index group) screening

The third dimension originally contained eight indicators (Fig. 3); four were retained after the expert questionnaire survey. In the first index group, organising energy saving and carbon reduction activities or competitions and advocating resource and energy

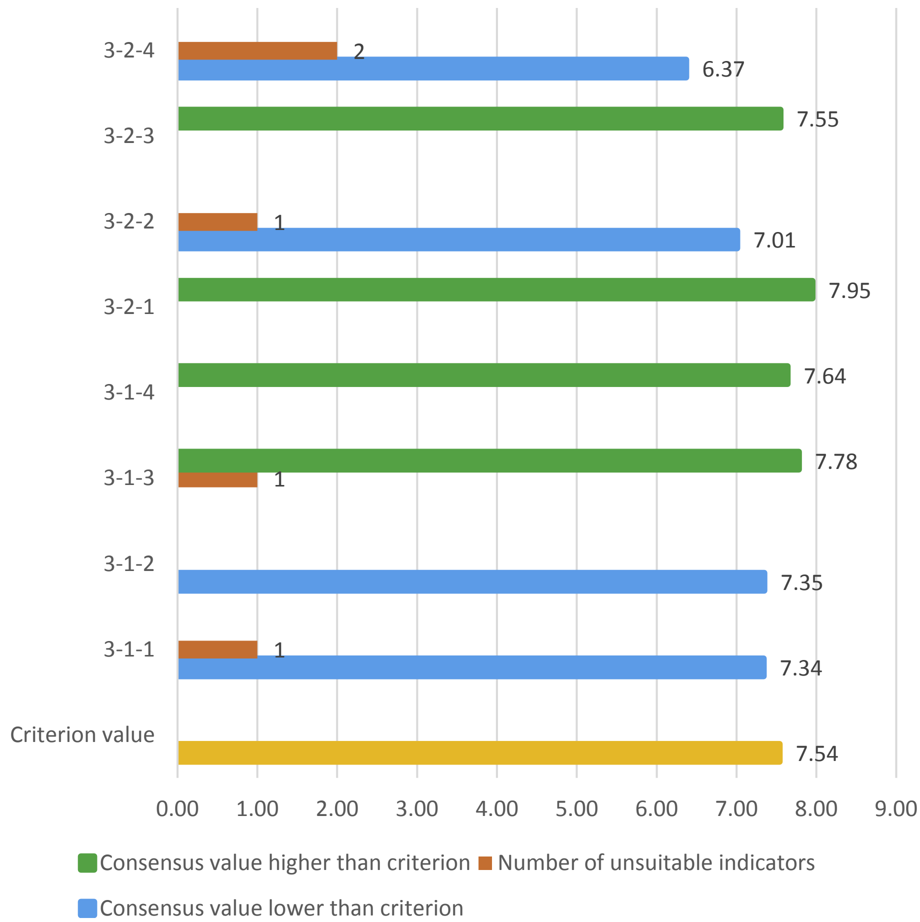

Fig. 3. Third major dimension index screening.

recycling concepts both received expert approval. However, the two indicators involving the co-organisation of environmental protection activities with students' parents or communities did not reach the threshold value. In the second index group, "3-2-1 Encourage school teachers to participate in sustainable-campus-related training courses and reinforce its promotion on campus" obtained the highest approval. Indicators such as encouraging teachers to take extra time to study environmental education and promoting sustainable campus education to communities both failed to reach the threshold value.

4.4. AHP expert questionnaire analysis

The results from the questionnaires were used to establish pairwise comparison matrices, the eigenvalues of which were determined, and subjected to consistency testing. Consistency of the questionnaire results was determined using the C.R., with an allowable range of C.R. $\leq$ 0.1. One questionnaire failed the test and was excluded; the remaining 15 valid questionnaires passed the test and were subjected to weight calculation. Table 5 shows that the major dimension of "buildings and equipment" was deemed to be the most crucial by the two groups of experts consisting of academic researchers and campus user representatives. This dimension also contained the largest number of indicators that were most directly related to energy saving and carbon reduction topics. Table 6 demonstrates that within the subdimensions, the two expert groups agreed that "curriculum planning and teaching" and "energy saving" were the most crucial indicators, indicating that energy saving strategies and carbon reduction implementation helping to promote the idea of a sustainable campus achieved the greatest resonance. The weight of approval of the two groups of experts regarding "procurement" was the lowest, whereas their approval diverged greatly regarding "greening and carbon sequestration; " campus use representatives believed that green plantation helps beautify campuses, whereas academic researchers maintained that greening delivers limited carbon emission reduction effects. Table 7 lists the relative weights of the 28 indicators; the three with the highest weights were all related to

Table 5
Weight difference analysis table for the major dimensions in the first level.

Major dimension	Experts		Academic researchers		Campus use representatives	
	Weight	Rank	Weight	Rank	Weight	Rank
Policy Management	0.275	3	0.312	3	0.247	3
Buildings and Equipment	0.399	1	0.359	1	0.430	1
Educational Activities	0.326	2	0.329	2	0.324	2

Table 6
Weight difference for the subdimensions in the second level.

Subdimension	Experts		Academic researchers		Campus use representatives		Difference
	Weight	Rank	Weight	Rank	Weight	Rank	
Procurement	0.035	9	0.025	9	0.040	9	0.015
Management Policy	0.106	5	0.129	5	0.089	6	0.040
Daily Life Behaviour	0.134	4	0.158	3	0.118	4	0.040
Energy Saving	0.178	2	0.168	2	0.186	2	0.018
Resource Reduction	0.073	7	0.070	7	0.076	7	0.006
Greening and Carbon Sequestration	0.070	8	0.030	8	0.105	5	0.075
Waste Disposal	0.077	6	0.092	6	0.063	8	0.029
Activity Participation	0.137	3	0.155	4	0.123	3	0.032
Curriculum Planning and Teaching	0.189	1	0.174	1	0.201	1	0.027

Table 7
Weight difference for the indicators in the third level.

Index Factors	Experts		Academic Researchers		Campus Use Representatives		Difference
	Weight	Rank	Weight	Rank	Weight	Rank	
1-1-1	0.021	20	0.013	22	0.026	15	0.013
1-1-2	0.005	28	0.004	28	0.006	28	0.002
1-1-3	0.009	27	0.008	25	0.008	27	0.000
1-2-1	0.027	14	0.038	12	0.021	20	0.017
1-2-2	0.025	17	0.036	13	0.019	22	0.017
1-2-3	0.040	9	0.042	11	0.0366	11	0.005
1-2-4	0.013	25	0.014	20	0.012	26	0.002
1-3-1	0.026	16	0.030	15	0.023	18	0.007
1-3-2	0.020	22	0.024	17	0.017	24	0.007
1-3-3	0.056	5	0.059	6	0.053	5	0.006
1-3-4	0.032	11	0.044	9	0.024	17	0.020
2-1-1	0.050	7	0.066	4	0.037	9	0.029
2-1-2	0.067	4	0.054	7	0.077	3	0.023
2-1-3	0.027	15	0.016	19	0.0369	10	0.021
2-1-4	0.034	10	0.032	14	0.036	12	0.004
2-2-1	0.023	18	0.029	16	0.018	23	0.011
2-2-2	0.020	21	0.021	18	0.020	21	0.001
2-2-3	0.011	26	0.007	26	0.013	25	0.006
2-2-4	0.020	23	0.013	21	0.025	16	0.012
2-3-1	0.022	19	0.012	24	0.031	14	0.019
2-3-2	0.029	13	0.012	23	0.041	7	0.029
2-3-3	0.018	24	0.005	27	0.033	13	0.028
2-4-1	0.047	8	0.020	8	0.041	8	0.021
2-4-2	0.031	12	0.042	10	0.022	19	0.020
3-1-1	0.083	2	0.091	2	0.076	4	0.015
3-1-2	0.054	6	0.065	5	0.047	6	0.018
3-2-1	0.071	3	0.080	3	0.081	2	0.001
3-2-2	0.108	1	0.094	1	0.120	1	0.026

"environmental education; " on average, the indicators under the "policy management" dimension had lower weights. The indicators with greater cognitive weight differences between the two groups of experts were in the indicators under the second major dimension (buildings and equipment). Reviewing the content, the academic researchers were concerned about the specific energy saving and carbon reduction benefits brought about by implementing the indicators, whereas the campus use representatives emphasised the peripheral benefits derived from the implementation of the indicators.

5. Discussion and conclusion

All three dimensions showed importance for their implementation. "Buildings and equipment" was recommended for the most immediate attention because it involves direct resource recycling and generates energy efficiency benefits and that saving energy and carbon footprint reduction are the core of sustainable campuses. The nine subdimensions address the implementation of sustainable campus policies; thus "curriculum planning and education" is a prioritised indicator. Among the 28 final indicators, "encourage teachers and students to jointly participate in maintaining their sustainable campus, and establish the values and concepts of cherishing the environment" was recommended for prioritisation.

Comparing the weight and importance ranking differences between the two groups of experts, all experts agreed that "buildings and equipment" should be the top priority. However, the academic researchers considered the three dimensions to be more similarly important than the campus use representatives, who gave greatly different weights to each dimension. This was because campus use representatives are members of elementary and secondary schools and generally believe that, as a result of the universal and in-depth development of energy saving and sustainability awareness, achieving increased effects through policy management that is even more stringent than current practices will present great challenges. Thus, they place more emphasis on the installation of energy saving hardware equipment and systems.

According to the second-level analysis results, the experts hoped that topics regarding sustainability, energy saving, and carbon reduction can be promoted among teachers and students through integrating the concept of sustainability within education, thereby achieving the goal of resource and energy recycling. “Greening and carbon sequestration” obtained the most divergent opinions, with the campus use representatives placing more emphasis on campus greening. Although the carbon sequestration effect of campus greening was questioned by the academic researchers, the greening and beautification of campuses does improve appearance and environment quality. The third-level analysis results showed unanimous agreement among the experts that the implementation of sustainable campus resource and energy recycling should be concurrent with joint maintenance and preservation. In addition, the results indicated again that the campus use representatives placed more emphasis on campus greening compared with the academic researchers, echoing the “greening and carbon sequestration” results in the second level.

The results of the study indicated that certain green purchases for the school environment should be considered first. For example, newly constructed buildings must comply with the newly adopted regulations on ecofriendly buildings and equipment purchases; in particular, equipment consuming substantial energy (e.g. air conditioning, lighting, drinking fountains, lifts, and teaching equipment) must conform to energy-saving laws and bear the energy-saving logo. These measures are crucial to reducing energy consumption and carbon dioxide emissions. Additionally, green school construction should be integrated into schools’ classroom activities. Moreover, energy-saving competitions integrated with local sustainable education activities (e.g. energy-saving innovations, energy-saving design, and ecofriendly living practices) can be held to encourage teachers and students to maintain sustainable school grounds and establish the concept of environmental treasure.

This study categorised the 28 final initiatives identified in the literature into three major dimensions and nine subdimensions. Some content is similar to that of other countries; for example, environmental protection, resources, and energy are promoted by most countries (i.e., the Australian government; Eco-Schools USA; and MECSST of Japan). These topics enjoy widespread recognition, and among them, energy saving attracts the most attention. The present study had similar results to studies in the United States (Faghihi et al., 2015), Greece (Hasapis et al., 2017), and in Tianjin (Liu et al., 2017) and Guangdong Province of China (Zhou et al., 2013). As the topics were applied in schools, this study presents similar considerations to almost all assessment tools and indicators used in all countries regarding the integration of eco behaviour in education (UNEP; Australian Government; Eco-Schools USA). Moreover, this study investigated schools, and thus, most indicators emphasise school-based green concepts that conform to certain other countries (i.e., the MEP of China; Australian government; and Eco-Schools USA). This school-based concepts also conforms to those expressed in studies of Canada (Arroyo, 2017), Spain (León-Fernández et al., 2017), and Portugal (Disterheft et al., 2015). However, differences in policy and management are apparent: countries establish their assessment tools based on their unique needs. For example, countries with temperate climates and those with frigid climates focus on the indoor environment (i.e., MECSST of Japan and Eco-Schools USA). The assessment tools for green buildings in Taiwan also include indoor air quality; however, the indicators for a sustainable campus do not include indoor air quality. This is because Taiwan is located in a subtropical area; thus, the climate is relatively comfortable and air-conditioning is not a requirement in high schools and elementary schools. Instead, they rely on natural ventilation and electric fans in classrooms. Moreover, some of the higher level theses, such as those on forming an eco committee or leader institution (i.e., UNEP; MEP of China) and integrating climate change solutions into education (i.e, Eco-Schools USA; UNEP) were not promoted in the present study. The indicators in Taiwan place more emphasis on executing policies that are more specific and easy for schools to perform; for example, in energy saving and resource recycling activities and participation, it is easy to perform and transform the content involved into sustainable campus-related training courses. Through this process, teachers and students are encouraged to participate in maintaining a sustainable campus and establishing values and concepts that cherish the environment. Although the indicators in the present study have basic and regional features, they essentially emerge from local characteristics. Thus, this study compared green procurement, management policies, and daily life behaviour between various countries. Because Taiwan is an island country and lacks resources, energy saving is a greater priority than in other countries. Moreover, in geographically compact countries, implementing top-down policies is relatively simple.

Policy formulation should broadly include academic research and the wide range of opinions from basic level units; optimistic anticipation of the implementation results is only possible after a consensus is reached. Campus sustainability policies should pay attention to quality, energy saving, and economic considerations, in particular the life cycle of buildings and equipment, instead of focusing on pursuing the quickest solution at the lowest cost. Policy promotion should be comprehensive, in-depth, and effective, and sometimes should be performed in conjunction with appropriate and substantive incentives to increase the implementation willingness of elementary and secondary schools. If these schools desire to establish a sustainable campus that recycles resources and energy, they must account for both policy management and introduce related concepts in learning activities. In particular, schools’ sustainable education curriculum development should be integrated with activity promotion, and teachers and students should be encouraged to participate in maintaining their sustainable campus, establishing the values and concept of cherishing the environment. This study combined the perspectives of academic researchers and campus use representatives; established initial indicators through reviewing the international literature; and determined the appropriate index groups for Taiwan through logical deduction based on the local characteristics and needs, thus serving as a reference for Taiwan to formulate or develop sustainable campus strategies.

Declaration of interest

None.

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