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Planning Wetland Ecology-Based Outdoor Education Courses in Taiwanese Junior High Schools

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ABSTRACT

Education does more than give students facts; it develops their potential and trains them to adapt to and improve their living environment. Through education, students formulate informed ideas about the interactions between people, things, and the environment. In an era of global environmental change, students must understand environmental problems and develop the knowledge and skills to help mitigate or solve them. The key concepts students learn and the ideas that influence students during wetland ecology-based outdoor education courses are thus worthy of investigation. This study summarized several key indicators through a literature review and an analysis of expert interviews. The literature review revealed nine indicators: ecological conservation, natural environment, biological habitat, individual development, environmental education, learning through practice, social culture, economy, and environmental quality. An expert questionnaire was used to apply interpretive structural modeling and integrate correlations among the indicators. Subsequently, the analytic network process was employed to establish the weights of assessing indicators. This study defined key indicators and provided analysis of the weighted results. These findings give teachers an academic basis for enhancing the design of related teaching curricula to achieve their teaching goals effectively.

Keywords: analytic network process, outdoor education course, wetland

INTRODUCTION

Taiwan is an island surrounded by coastal wetlands and ocean. Its inland areas have various types of freshwater wetlands such as lakes, streams, ponds, and rice paddies. The diverse wetland ecologies are attractive as tourist and recreational sites, but are also resting places for migratory birds. Consequently, Taiwanese wetlands are often damaged because of the careless discharge of wastewater and the inappropriate disposal of waste products. This damage affects the ecology of the wetlands, reduces the quality of the environment, and causes environmental hazards. Through wetland ecotourism programs for junior high school students, this study expected to improve students' environmental knowledge, strengthen their understanding of environmental conservation, and enable them to put these ideas into practice

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State of the literature

- Natural environments, habitats, and ecology require conservation. Overprotecting students during outdoor educational activities prevents them from getting close to nature, and lack of variety in courses prevents the desired experiential effects. Therefore, the activities should be lively yet properly controlled for students to improve their idea of environmental quality through education, personal experience, individual development, and economics.
- We integrated relevant concepts and determined the key factors that affect teaching. An ideal teaching-related structurally hierarchical digraph was then applied to assist teaching units arrange outdoor courses and design the most satisfactory learning process for students according to their learning situations.

Contribution of this paper to the literature

- In the course design assessment system established in this study, interpretive structural modeling (ISM) was adopted to analyze the key factors for wetland ecology-based outdoor education in junior high schools. ISM was used to explain the interaction and connection between each teaching-related key factor and construct students' learning paths.
- Weights established in the course design assessment system can be applied to select appropriate wetland ecology-based education elements and design follow-up courses. By doing so, students can progressively obtain satisfactory learning effects during outdoor environmental education of wetland ecologies.

in their daily lives. When organizing outdoor education trips, curricula, instructional methods, and teaching venues or environments should be chosen according to students' learning requirements. Moreover, these trips should focus on motivating students to learn, and thus enhance their understanding of the topics involved.

The United Nations (UN) Agenda 21 states that education plays a central role in sustainable development for the future (UNCED, 1998).The Environmental Protection Administration of the Executive Yuan, Taiwan implemented the Environmental Education Act in 2010 to promote environmental education, improve national environmental ethics, and improve understanding of the interdependency among individuals, society, and the environment. Maintaining ecological balance, respecting life, fostering social justice, cultivating environmentally aware citizens and environmental study communities, and achieving sustainable development were emphasized by the act. Schools at the junior high level and below are required to organize school outings at appropriate facilities and sites for environmental education.

Fennell reported that ecotourism increases knowledge about natural resources, promotes nonconsumptive travel that has small impact on local environments and citizens, and utilizes local resources for the purposes of conservation and protection (Fennell, 2014; Shieh, Hsueh, & Chang, 2014). Through education, students develop socially acceptable values and skills with an awareness of how their actions affect the environment. Teaching students about wetland ecology is crucial, and scholars have suggested that environmental learning begins at an early age (Iozzi, 1989).

Since 2001, environmental education has been emphasized in the nine-year Taiwanese curriculum reform. By becoming aware of their responsibilities for environmental problems, individuals will then actively participate in environmental actions to understand and facilitate personal development (Education, 2008). In recent years, scholars have conducted numerous studies on wetland ecotourism and outdoor teaching.

We integrated relevant concepts from these studies and identified the key factors that affect teaching of environmental issues. An ideal teaching-related structurally hierarchical digraph was used to assist teaching units in arranging and designing outdoor courses that enabled students to learn most effectively. Teachers can focus on concepts that are relatively unfamiliar or select diverse wetlands from which can be learned a range of things. This fulfills the needs of students and increases their learning interest, thus improving their knowledge of wetland environments and ensuring the success of environmental educational.

LITERATURE REVIEW

Taşar and Gough, long dedicated to environmental education, mentioned in their conversation (2009) that "The cliché around what marked the beginning of environmental consciousness, most people put it down as Rachel Carson and Silent Spring, Garrett Hardin and the Tragedy of the Commons, Paul Ehrlich's book on the Population Bomb and so on. They were all scientists in the 1960s who were concerned about the state of the environment: increasing levels of pollution—air pollution, water pollution—and destruction of forests and wetlands. In 1970 in the US and soon after in Australia we had the Clean Air and Clean Water Acts and the US Environmental Education Act in 1970 also" (Taşar, 2009). The concept of education for sustainable development was subsequently established. This concept has since been the source of constant debate with respect to its objectives, terminology, and implications (Eilks, 2015; Sjöström, Rauch, & Eilks, 2015).

Secondary school syllabi in Taiwan

Outline of grade 1–9 curriculum guidelines

The modern grade 1–9 curriculum encourages the development of healthy humanist citizens. The basic content is as follows (Education, 2003): (1) humanistic aspects; (2) integration capability aspects; (3) democratic literacy aspects; (4) local and international awareness aspects; and (5) life-long learning aspects.

Environmental education

Environmental education involves the three dimensions of self, society, and nature. The purpose of environmental education is to promote active and positive attitudes as well as proactive participation in environmental actions. This is achieved by improving awareness of personal responsibility toward environmental problems, thus facilitating personal understanding and growth. The interaction between society and the natural environment is also explored. The discussion and resolution of daily concerns helps students develop life skills.

The goals of the environmental education curricula are as follows (Education, 2008): (1) awareness of and sensitivity toward the environment; (2) conceptual knowledge regarding the environment; (3) suitable values and attitudes toward the environment; (4) environmental action skills; and (5) environmental action experiences.

Proper educational strategies can promote the urban development of cultural and creative industries. The perceived benefits to urban habitants are imperative for successful sustainable urban development (Kuo & Perng, 2016). The Environmental Education Act passed in 2010 specified that the presence of environmental ethics in citizens requires education to enhance knowledge, skills, attitudes, and values related to environmental protection. Citizens are then encouraged to pay attention to the environment and take necessary actions to achieve sustainable development (Environmental Protection Administration, 2010).

Other areas for further consideration are: building on the initial professional development support some schools have received; further consideration of the role of curriculum integration with respect to environmental education; identification of specific areas in which schools need resources; coordination in the development and delivery of programs and resources to support environmental education in schools; and consideration of the visibility and status of environmental education (Bolstad et al., 2004).

Article 14 of the Environmental Education Act of Taiwan stipulates that administrative authorities at all levels and competent authorities in central industry must integrate and propose plans for environmental education facilities and resources. Priority choices for such facilities are unused spaces and buildings as well as privately established facilities, and resources that have received government funding are a priority. The goal of the Act is to create comprehensive and professional services, information, and resources for environmental education (Administration, 2010).

Wetland ecology

Wetlands

Wetlands are border areas between water and land that have been submerged by water in the past or are currently submerged in less than 6 m of water. Wetlands are defined and categorized primarily according to water conditions, specific soil conditions, and the humidity-resistant plants present. The most representative definition of wetlands was outlined at the International Wetland Convention, or Ramsar Convention, held in 1971 (Matthews, 1993; Secretariat, 2013).

Ecotourism

In 1965, Hetzer claimed that ecotourism must be considered from perspectives of culture, education, and tourism, and the author promoted the possibilities of ecological tourism (Hetzer, 1965). In 1980, the International Union for the Conservation of Nature, the UN Environment Programme, and the World Wildlife Fund developed the World Conservation Strategy, proposing direct links between environmental conservation and economic development to achieve the goal of "conservation that promotes development and development that strengthens conservation" (IUCN, 1991).

Outdoor teaching

The value of outdoor teaching lies in its direct contact experiences that are impractical in regular teaching and that facilitate an experiential learning process. As written by Sharp in 1943, "that which ought and can best be taught inside the classroom should there be taught, and that which can best be learned through experience dealing directly with native materials and real-life situations outside the school should there be learned." Outdoor teaching is the most widely implemented and effective method for enabling students to directly interact with their environment and acquire direct experience, which develops their attitude toward and values regarding the environment (Sharp, 1952).

The National Audubon Society Manual of Outdoor Interpretation (Shomon, 1968) promotes the following conservation education goals: (1) obtainment of related knowledge from nature; (2) an understanding of conservation, and a development of outdoor skills on the basis of knowledge acquired from nature; (3) stimulation of interest in and understanding of nature; (4) shaping of appropriate attitudes on the basis of first-hand outdoor learning experiences (i.e., environmental ethics); (5) determination to engage in environmental conservation; and (6) performance of judicious conservation actions as required.

Wetland ecology–based outdoor education course

This study examined the key indicators of secondary school outdoor wetland ecology education through in-depth interviews with experts and a literature review to summarize suitable key indicator factors. Codes and explanations for key indicators are shown in **Table 1**.

APPLICATION OF THE INTERPRETATIVE STRUCTURAL MODELING METHOD TO STRUCTURE AND SYSTEMIZE COURSE PLANNING

Multiple-criteria decision-making is widely used within educational evaluations (Hsieh, 2016). Related techniques include the Delphi method, analytic hierarchy process (AHP), and analytic network process (ANP), which determine order preference using similarity to the ideal solution, and laboratory decision-making trials and evaluations.

Table 1. Explanatory Features and Descriptions of Key Indicators

Dimension	Key Indicators	Explanatory features and descriptions of assessment indicators.
D1 Resources	S1 Ecological conservation	Ecological concepts, ecological sustainability, environmental protection, and cultural preservation.
	S2 Natural environment	Grassroots resources, biological resources, natural resources, undisturbedness, and natural ecology.
	S3 Biological habitat	Advantaged aquatic plants, organisms adapted to humid environments, fish and crustaceans, birds, wildlife habitats, foraging, and drinking water.
D2 Education	S4 Individual development	Inspiration, satisfaction, environmental awareness, environmental action, awareness of cultural preservation, motivation to learn, environmental attitudes and values, communication skills, and fun activities.
	S5 Environmental education	Interpretation services, education, natural sciences, specific topics, opportunistic education, and knowledge of nature.
	S6 Learning through practice	Observing, appreciating, or experiencing wildlife scenery; concern for cultural content, ecological content, learning, exploration, and research.
D3 Socioeconomy	S7 Social culture	Local cultural activities, natural history, traditional culture, cultural exchange, and local taboos.
	S8 Economy	Earnings, welfare, well-being, employment opportunities, tourism revenue, community feedback, commercial activities, seawater erosion, protection against wind, protection against typhoons, and reduction of salt damage.
	S9 Environmental quality	Positive and negative effects.

This study involved a review of the literature relating to wetland ecology and outdoor education, and the collection of course outlines used in secondary schools and environmental education. The collected literature was then organized and analyzed to establish the key indicators of secondary school outdoor wetland ecology education, which can assist teachers to define systematic, relevant, and effective teaching and learning objectives. This study built upon previous research and was intended to contribute to the formulation of a decision-making system. This system is a multicriteria group decision-making model based on the combination of the decision tree model and the cloud model, which can provide a reliable basis for qualitative and quantitative conversion for college teacher evaluation (Chang & Wang, 2016).

This study recruited 12 experts and scholars to complete a questionnaire, with one recruited from the public sector, three from educational institutions, and five from industries related to environmental planning, with the remaining three being academics with backgrounds in tourism, environmental landscapes, and regional development. Each of the 12 experts was familiar to some degree with the measurement methods employed in this study, and completed the questionnaire during focus groups and in-depth interviews. Correlation between elements was determined by individual experiences, opinions, and the results of brainstorming.

ISM definition

ISM is a structural modeling technique that analyzes the relational order of each selected element to yield a comprehensive and concrete hierarchical chart portraying the relational structure of the elements. ISM was first proposed by Warfield as a type of structural modeling for analyzing complex social system engineering. A feature of this technique is its decomposition of complex systems into multiple subsystem elements and the application of experts' practical experience and knowledge in combination with computer-based explanations to automatically generate a complete multilevel structural hierarchy. Warfield (1974) reported that when system structure and complexity increases, ISM produces objective and scientific hierarchical structure charts. Initial ISM procedures employ an individual or group psychological model to calculate a two-element matrix, an incidence matrix, using element values to represent the relationship between each element (Warfield, 1974). Recent research applications of key factor analysis in project management have been extensive (Lee, Shiau, & Hsu, 2015; Wu & Bian, 2012).

ISM analysis procedures

(a) Establish an element relationship diagram or adjacency matrix:

Result (Influenced)

Cause (Influencer) D =

$$\begin{array}{c} \\ e_1 \\ e_2 \\ \vdots \\ \vdots \\ e_i \end{array} \begin{array}{c} \begin{matrix} e_1 & e_2 & \cdots & \cdots & e_j \end{matrix} \\ \begin{bmatrix} 0 & S_{12} & S_{13} & \cdots & S_{1j} \\ S_{21} & 0 & \cdots & \cdots & S_{2j} \\ S_{31} & S_{32} & 0 & \cdots & S_{3j} \\ \vdots & \vdots & \vdots & 0 & \vdots \\ S_{i1} & S_{i2} & \cdots & \cdots & 0 \end{bmatrix} \end{array} \quad (1)$$

(b) Calculate the reachability matrix.

The incidence matrix was established according to

$$B = D + I \quad (2)$$

The Boolean algebra was established according to **Table 2**.

Table 2. Boolean algebra calculation

Boolean Algebra	Equals	Boolean Algebra	Equals
1 × 0	0	0 + 0	0
1 × 1	1	0 + 1	1
0 × 0	0	1 + 0	1
0 × 1	0	1 + 1	1

This study used Excel to sequentially determine the exponentiation of B, obtaining B^*, calculated until $B^k = B^{k+1}$. The reachability matrix is represented by M. Given Equation 2, the exponentiation calculation is performed for B more than $k - 1$ times, until it does not change. k is the dimension of D, which indicates that

$$B^* = B^k = B^{k+1} \tag{3}$$

The reachability matrix M and the element relationship matrix B are transitively related. If $M(S_i, S_j) = 1$, a path exists between nodes S_i and S_j. If $M(Si, Sj) = 0$, no path exists between nodes S_i and S_j. When $B^{k-1} = B^k = B^{k+1}$ (i.e., $B^3 = B^4 = B^5$) is obtained, the matrix values have converged.

(c) Convert the reachability matrix into a hierarchy matrix.

The reachability matrix includes the concepts of the reachability set $R(t_i)$ and the priority set $A(t_i)$. $R(t_i)$ refers to the i^{th} element within the reachability matrix M^* and the elements with a relational value of 1 after vertical calculations are extracted. $A(t_i)$ refers to the ith element within the reachability matrix M^* and the elements with a relational value of 1 after horizontal calculations are extracted, as shown in Equation (4).

$$R(s_i) \cap A(s_i) = R(s_i) \tag{4}$$

ISM is suitable for creating, deducting, and correcting larger models. Graph theory can be applied as a basis for determining the interrelation between each element (Warfield & Ayiku, 1989). ISM can convert abstract thoughts and views into a structural relationship model and enable the analysis of each element through the use of a matrix. Furthermore, this method enables experts to express a greater volume of opinions, after which the definition of each element can be identified and integrated with the subjective ideas of the experts according to their recommendations. Ultimately, this method expands and completes the model and enables the establishment of a hierarchical structure diagram (Sage, 1977). In this study, an adjacency matrix was incorporated into an identity matrix, and repeated calculation and convergence were conducted through ISM to generate a reachability matrix (**Figure 1**).

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	1	0	0	1	1	1	0	1	0
S2	0	1	0	1	1	1	0	1	1
S3	0	0	1	1	1	1	0	1	0
S4	0	0	0	1	1	1	0	1	0
S5	0	0	0	1	1	1	0	1	0
S6	0	0	0	1	1	1	0	1	0
S7	0	0	0	0	0	0	1	0	1
S8	0	0	0	1	1	1	0	1	0
S9	0	0	0	0	0	0	0	0	1

Figure 1. Reachability matrix

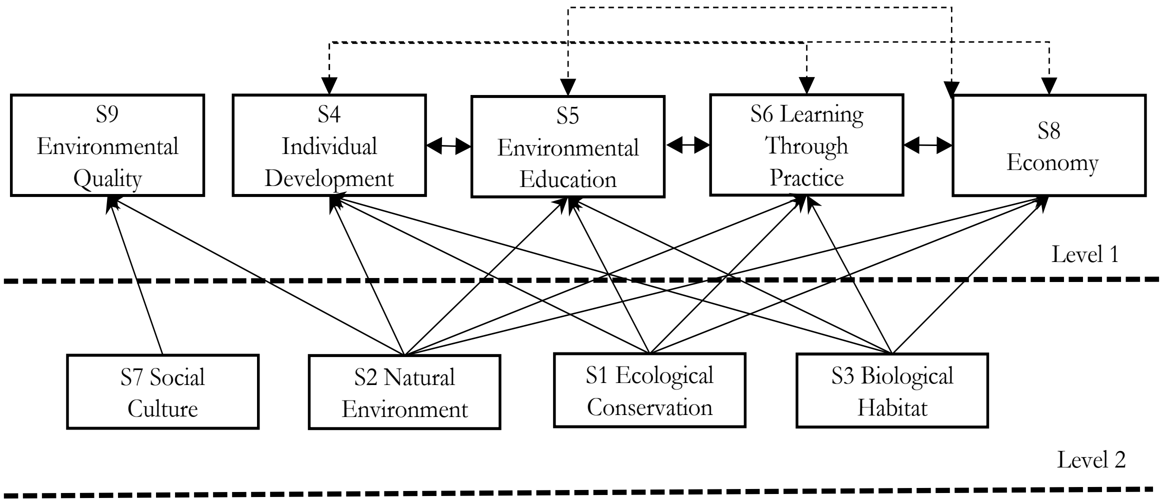

Figure 2. Structured relationship diagram discovered using ISM analysis

Application of structured analysis to course planning

The first-level factor set [S4, S5, S6, S8, S9] was obtained from Equation (4), and the rows and columns corresponding to [S4, S5, S6, S8, S9] in the reachability matrix were excluded. The second-level factor set [S1, S2, S3, S7] was obtained according to the same principle. The aforementioned analysis process converted the hierarchy matrix into a hierarchical transitive relationship diagram, as presented in **Figure 2**.

Regarding learning paths in course planning, according to **Figure 2**, the key indicators of secondary school outdoor wetland ecology education constitute a two-level transitive structural model. S4 (individual development), S5 (environmental education), S6 (learning through practice), S8 (economy), and S9 (environmental quality) were at the first level. S1 (ecological conservation), S2 (natural environment), S3 (biological habitat), and S7 (social culture) were at the second factor set level. These findings can be used to enhance student learning during outdoor wetland ecology programs. Furthermore, they can be used to comprehensively analyze key factors and allocate the successive transitive effects of wetland ecology teaching. The interaction between the key factors is further presented in **Table 3**.

ANP

In 1996, Saaty proposed the ANP, which is based on networks and is structured nonlinearly. The ANP is grounded in the AHP, to which a feedback mechanism is added to overcome the possible interdependence between criteria or levels and the feedback problem in the hierarchy of the conventional AHP (Saaty, 1996). The conventional AHP presumes that level criteria are independent from one another or from other alternatives (Saaty, 1980). The method adapts a complex multiple-criteria decision-making problem into a hierarchical

Table 3. Interdependence between assessment factors, constructed using ISM

Assessment dimension	Assessment factors	Assessment factors affected
D1 Resources	S1 Ecological conservation	Independent factor
	S2 Natural environment	Independent factor
	S3 Biological habitat	Independent factor
D2 Education	S4 Individual development	S1, S2, S3, S5, S6, and S8.
	S5 Environmental education	S1, S2, S3, S4, S6, and S8.
	S6 Learning through practice	S1, S2, S3, S4, S5, and S8.
D3 Socioeconomy	S7 Social culture	Independent factor
	S8 Economy	S1, S2, S3, S4, S5, and S6.
	S9 Environmental quality	S2 and S7.

system, wherein each level is a cluster of nodes composed of different elements. In this system, multiple qualitative factors are processed through systematic matrix computation, and the objectively quantified results can then serve as a reference for decision-makers, who then refer to the ANP for the measurement of intangibles, along with their dependence and feedback, to weight the criteria (Sagir & Saaty, 2015).

Although the AHP is a simplified and specialized version of the ANP, both methods systematically establish decision-making models (Saaty, 1996). When evaluating the priorities of all criteria, the ANP method incorporates the correlation and feedback between each criterion into the decision-making assessment model (Saaty, 1999), and even systematically resolves all mathematical theories related to the criteria (Saaty, 2003). In the ANP, problem structures can be constructed differently according to the problem type, and network systems can be broken down into multiple groups to form a complex network (Momoh & Zhu, 2003).

Procedure for implementing the ANP

The ANP is implemented in three stages: (1) construct the problem hierarchy and interdependence model; (2) establish paired comparison matrices and calculate eigenvalues and eigenvectors; (3) construct supermatrices and calculate the weights of criteria according to their priorities (Chang & Wang, 2016; Lin & Wu, 2008; Saaty, 1996). The procedure is further described as follows.

Constructing problem hierarchy and interdependence model

Goals are determined according to problem characteristics, decision-making criteria as well as subcriteria in each criterion group are sought, and the interactions between criteria are further identified. The existence of an interaction indicates external interdependence, whereas interactions between subcriteria in each criterion group reveal internal interdependence. Finally, the overall structure of the decision-making problem is formulated according to all the interactions found. This study adopted the ISM method described in the preceding section to determine the interdependence between assessment factors and establish the problem hierarchy and an interdependence model.

Establishing paired comparison matrices and calculating eigenvalues and eigenvectors

(a) Using the AHP to construct paired comparison matrices and test for consistency

The AHP has numerous advantages over other analysis methods. It streamlines complex decision-making problems by decomposing them into hierarchies, and is simple enough to be understood by nonprofessionals. Therefore, we examined the validity of the AHP in evaluating the sustainability of international hot spring tourist hotels in indigenous regions. Generating priorities through an organized decision-making process entails breaking down a decision into several hierarchies according to the following steps (R. W. Saaty, 2003):

(1) Define the decision-making problem.
(2) Identify the factors involved.
(3) Establish a hierarchical framework.
(4) Design a questionnaire to obtain a paired comparison matrix A.

If n factors are compared, then the number of paired comparisons that must be conducted is $n(n-1)/2$. Because of the reciprocal property of paired comparisons, if the ratio between elements i and j is a_{ij}, then the ratio between elements j and i is $1/a_{ij}$. Similarly, the lower triangular matrix of the paired comparison matrix A is the reciprocal of the upper triangular matrix:

$$A=\left[a_{ij}\right]=\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array}\begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & 1 & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \end{array}=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_1 \\ \vdots & \vdots & \cdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \tag{5}$$

where W_i represents the element weight of i, $i = 1, 2,\ldots,n$, and a_{ij} represents the relative importance ratio between elements, $i = 1\ldots n$; $j = 1\ldots n$.

(5) Calculate the eigenvalue and eigenvector.

The geometric mean can be obtained by multiplying elements in every row and then normalizing the value:

$$W_i=\frac{\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}},\quad i,\ j,\ =1,2,\ldots..,n \tag{6}$$

Table 4. Average random consistency index

n	1	2	3	4	5	6	7
RI	0.0	0.0	0.58	0.90	1.12	1.24	1.32

The new eigenvector, W_i, is derived by multiplying the paired comparison matrix A with the obtained eigenvector W_i. λ_{max} is obtained by dividing every vector of W_i by the corresponding original vector W_i, and then calculating the arithmetic mean of every derived value:

$$\lambda_{\max} = \frac{1}{n}\left(\frac{W_1^{'}}{W_1} + \frac{W_2^{'}}{W_2} + \ldots \frac{W_n^{'}}{W_n}\right) \quad (7)$$

(6) Execute a consistency test.

This step determines the consistency index (*CI*). Saaty suggested that the most satisfactory *CI* is <0.1, and that the highest allowable bias is 0.2; if the *CI* falls within this range, consistency is ensured. This is expressed as follows:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \quad (8)$$

where λ_{max} is the highest eigenvalue of matrix A, and n is the number of assessment elements.

In matrices of the same order, the ratio of *CI* to random index (*RI*) is referred to as a consistency ratio (*CR*):

$$C.R. = \frac{C.I.}{R.I.} \quad (9)$$

If $CR < 0.1$, then matrix consistency is satisfactory. All assessment criteria at the same level were evaluated using paired comparisons based on an assessment of the elements from the level above and rated using a scale from 1 to 9. The positive reciprocal matrices produced from assessment scales 1–9 led to different *CI* under different orders, and are referred to as the *RI*. Here, each *RI* is an average random consistency indicator. The *RI* of each order is as shown by the average random consistency index in **Table 4** (Saaty & Vargas, 2012).

Additionally, when the importance of each order differs, the consistency of the entire level structure may need to be tested. When a level structure possesses more than two levels, therefore, the consistency ratio of the hierarchy (*CRH*) must be considered. This step may be omitted if a weighting system is established. Because this study does not require the consideration of relative importance between different levels, *CRH* testing is omitted.

(b) Calculating results based on an assessment dimension questionnaire completed by experts

Both qualitative and quantitative methods were employed in this study. Regarding the quantitative methods, data were obtained through an expert questionnaire and then analyzed using different decision-making methods. The AHP was performed to determine the

To test the questionnaires completed by individual experts, the assessment dimensions were compared in pairs. For example, one expert considered D1 (resources) to be more crucial than D2 (education) and thus scored D1 at 3. The expert then considered D1 to be more crucial than D3 (socioeconomy), and scored D1 at 5. In the paired comparison of D1 and D4 (policies), D1 was considered slightly more crucial than D4 and was thus scored at 3. Finally, the expert regarded D2 as relatively more crucial than D3 and scored D2 at 3. This expert's paired comparison of the assessment dimensions is presented as a paired comparison matrix in **Hata! Başvuru kaynağı bulunamadı.** **Table 5.** Paired comparison matrix derived from assessment dimension comparison performed by one expert

Assessment dimension	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1

Table 6. Homogenization and column totals of the paired comparison matrix derived from one expert's comparison of assessment dimensions

Assessment dimension	D1	D2	D3
D1	1	3	5
D2	1/3	1	3
D3	1/5	1/3	1
Column total	1.53	4.33	9.00

questionnaire results and distribution of weights among assessment factors in each of the four assessment dimensions. An assessment dimension questionnaire completed by one expert from the decision-making group in this study was selected to demonstrate the calculation of the results, as is next described.

Step 1: Establish a paired comparison matrix

Step 2: Calculate eigenvalues and eigenvectors

This matrix exhibited a reciprocal relationship because the values in the lower left corner are reciprocal to the corresponding values in the upper right corner (product = 1). The paired comparison matrix was then homogenized, and column totals were calculated as shown in **Hata! Başvuru kaynağı bulunamadı.**

Each element of the matrix was then divided by the corresponding column total to obtain a normalized matrix (**Table 7**).

Next, the formula for normalizing vector means was used with the total and average values in each row to derive the weight of each factor or assessment dimension according to the expert's comparison (**Table 8**).

Table 7. Normalization of the paired comparison matrix derived from one expert's comparison of assessment dimensions

$$\begin{bmatrix} 0.65 & 0.69 & 0.56 \\ 0.22 & 0.23 & 0.33 \\ 0.13 & 0.08 & 0.11 \end{bmatrix}$$

Table 8. Weight of each assessment dimension according to the expert's comparison

Assessment dimension	Row average	Weight
D1	(0.65+0.69+0.56) /3=	0.63
D2	(0.22+0.23+0.33) /3=	0.26
D3	(0.13+0.08+0.11) /3=	0.11

After the weights were obtained, the problem of consistency (through the consistency index *CI*) required consideration. Before performing a consistency test, consistency vectors needed to be calculated by multiplying the weight of each dimension by the corresponding element in the homogenized matrix, totaling row vectors, and dividing the sums by each weight:

$$\begin{bmatrix} 0.63\times1 + & 0.26\times3 + & 0.11\times5 \\ 0.63\times\frac{1}{3} + & 0.26\times1 + & 0.11\times3 \\ 0.63\times\frac{1}{5} + & 0.26\times\frac{1}{3} + & 0.11\times1 \end{bmatrix} = \begin{bmatrix} 1.96 \\ 0.80 \\ 0.32 \end{bmatrix}$$

$$\text{Consistency vector} = \begin{bmatrix} 1.96/0.63 \\ 0.80/0.26 \\ 0.32/0.11 \end{bmatrix} = \begin{bmatrix} 3.11 \\ 3.08 \\ 2.93 \end{bmatrix}$$

Thus, $\lambda_{max} = \frac{3.11+3.08+2.93}{3} = 3.04$

Step 3: Consistency test

According to the consistency test in the conventional AHP proposed by Saaty (1980), the ANP can be inferred to exhibit consistency when $A = |a_{ij}|$ satisfies the requirement of the consistency test ($CI < 0.1$).

To ensure that the calculated weights were consistent and valid, *CI* had to be calculated, which was done by deducting the number of assessment dimensions n from λ and dividing the resultant difference by $n - 1$.

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{3.04 - 3}{3 - 1} = 0.02$$

After the *CI* was obtained, *RIs* were selected from the *RI* table according to the number of n in the table, and *CI* was divided by *RI* to obtain *CR*:

$$CR = \frac{0.02}{0.58} = 0.03$$

The resultant *CR* was smaller than 0.1, and the consistency was thus acceptable.

(c) Aggregating group assessments

When alternatives are selected through group decision-making, group members' preferences are aggregated. This aggregation of judgments is a critical part of the AHP. On the basis of certain reasonable assumptions, Saaty used the geometric mean rather than arithmetic mean as the function for judgment aggregation. If a decision-making group's judgment value is a, and the judgment value of the other members is $1/a$, the mean should be 1 rather than $(a + 1/a)/2$. Therefore, the geometric mean is the superior for calculating the mean of n decision-making members' judgment values $X_1, X_2, \ldots, X_n$. The geometric mean is calculated as follows:

$$G = \sqrt[n]{X_1 \times X_2 \times \cdots \times X_n} = \sqrt[n]{\prod_{i=1}^{N} X_i} \tag{10}$$

The aforementioned procedure was performed to test the consistency of the assessment factor–paired comparison of the dimensions in the expert questionnaire, and the *CI* of the expert group questionnaire met Saaty's suggested standard of <0.1, indicating that the expert questionnaire exhibited superior consistency. In addition, the *RI* value was smaller than 0.1, which demonstrated the superiority of the expert questionnaire.

Constructing supermatrices and calculating the weights of criteria according to their priorities

The ANP calculation used the unweighted, weighted, and limit supermatrices. The expert consensuses derived from the aggregation of expert judgments in the preceding subsection were adopted to establish an unweighted supermatrix, and subsequent calculation was performed using the Super Decisions software. Developed by the research team led by Saaty, this software is primarily used to calculate decision-making problems involving interdependence and feedback. It can be applied to AHP operations in addition to the ANP. When the AHP is employed, it is frequently limited by the assumption that decision-making criteria (or variables) are mutually independent and do not interact. This assumption is often questioned by scholars, and is incompatible with the processes by which humans make decisions. Saaty improved the method in 1996 to form the ANP, which incorporates (both intra- and intercluster) interdependence and feedback effects and computes the effect of interdependence through supermatrices. After Saaty developed this method, which is compatible with human decision-making processes, Super Decisions became the optimal tool for realizing complex relationships through the ANP method. The software is Microsoft-compatible. Super Decisions is presented through interactive dialog boxes and graphics, and is capable of importing graphic data and exporting results into Excel files for further analysis, thus effectively saving the time required for statistical operations (Chang, 2008).

The convergence data calculated using Super Decisions were exported to the ANP assessment model as a weighted supermatrix and limit matrix, then exported to an Excel file for compilation.

Table 9. Employing Super Decisions to test the weights derived from judgment aggregation

	G	D1	D2	D3	S01	S02	S03	S04	S05	S06	S07	S08	S09
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.60	0.00	0.85	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.30	0.81	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.10	0.19	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S01	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.18	0.19	0.19	0.00	0.17	0.00
S02	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.31	0.33	0.36	0.00	0.31	0.85
S03	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.25	0.00	0.28	0.00
S04	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.08	0.00
S05	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.12	0.00	0.09	0.00	0.10	0.00
S06	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.06	0.08	0.00	0.00	0.06	0.00
S07	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
S08	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.03	0.04	0.03	0.00	0.00	0.00
S09	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Employing Super Decisions to calculate the weighted supermatrix in the ANP

	G	D1	D2	D3	S01	S02	S03	S04	S05	S06	S07	S08	S09
G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1	0.60	0.00	0.42	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D2	0.30	0.41	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D3	0.10	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S01	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.18	0.19	0.19	0.00	0.17	0.00
S02	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.31	0.33	0.36	0.00	0.31	0.85
S03	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.25	0.00	0.28	0.00
S04	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.08	0.00
S05	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.12	0.00	0.09	0.00	0.10	0.00
S06	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.06	0.08	0.00	0.00	0.06	0.00
S07	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
S08	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.03	0.04	0.03	0.00	0.00	0.00
S09	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Analysis of results

The assessment levels of wetland ecology-based outdoor education can be divided into the three dimensions: resources, education, and socioeconomy. Nine key assessment factors were selected. Subsequently, ISM was performed to determine the interdependence and feedback among decision-making criteria. The resultant reachability matrix of the assessment factors indicated that the all three dimensions in the assessment level were related, and the assessment factors that interacted with one another were S4 (individual development), S5 (environmental education), S6 (learning through practice), S8 (economy) and S9 (environmental quality). Different levels of interdependence existed between all the assessment factors. After determining decision-making criteria and their mutual relationships, the ANP structure for the assessment levels of wetland ecology-based outdoor education was

Table 11. Employing Super Decisions to calculate the limit matrix in the ANP

	G	D1	D2	D3
G	0.0000	0.0000	0.0000	0.0000
D1	0.1205	0.1205	0.1205	0.1205
D2	0.1147	0.1147	0.1147	0.1147
D3	0.0400	0.0400	0.0400	0.0400
S01	0.1225	0.1225	0.1225	0.1225
S02	0.2136	0.2136	0.2136	0.2136
S03	0.1441	0.1441	0.1441	0.1441
S04	0.0506	0.0506	0.0506	0.0506
S05	0.0874	0.0874	0.0874	0.0874
S06	0.0480	0.0480	0.0480	0.0480
S07	0.0198	0.0198	0.0198	0.0198
S08	0.0182	0.0182	0.0182	0.0182
S09	0.0206	0.0206	0.0206	0.0206

Table 12. Employing Super Decisions to calculate the convergence of the limit matrix in the ANP

Name	Normalized By Cluster	Limiting
G	0	0
D1	0.43784	0.12052
D2	0.41669	0.11469
D3	0.14546	0.04004
S01	0.16899	0.12248
S02	0.29469	0.21358
S03	0.19883	0.14411
S04	0.06981	0.05059
S05	0.12063	0.08743
S06	0.06621	0.04799
S07	0.02737	0.01984
S08	0.02506	0.01816
S09	0.02840	0.02058

established to analyze and identify, through weight convergence and distribution among various dimensions and factors, the weights of crucial decision-making factors that must be addressed during the level assessment. According to the weight analysis of the assessment model performed using the ANP (**Table 13**), the assessment dimension D1 had the highest priority, with an aggregated weight of 0.43784, followed by D2 (0.41669) and D3 (0.14546). Accordingly, consideration of local natural environments should be the first priority when designing wetland ecology-based education courses. Regarding the level of assessment factors, S2 had the greatest aggregated weight (0.29469), followed by S3 (0.19883) and S1 (0.16899). These three factors accounted for a weight of 0.6625 among all the most critical assessment factors for designing wetland ecology-based outdoor education courses. The weight distribution of the other factors is presented in **Table 13**.

Table 13. Weights in the assessment system established using the ANP

Level	Item	Limiting	Normalized By Cluster	Order
Assessment dimension	D1 Resources	0.12052	0.43784	1
	D2 Education	0.11469	0.41669	2
	D3 Socioeconomy	0.04004	0.14546	3
Assessment factor	S1 Ecological conservation	0.12248	0.16899	3
	S2 Natural environment	0.21358	0.29469	1
	S3 Biological habitat	0.14411	0.19883	2
	S4 Individual development	0.05059	0.06981	5
	S5 Environmental education	0.08743	0.12063	4
	S6 Learning through practice	0.04799	0.06621	6
	S7 Social culture	0.01984	0.02737	8
	S8 Economy	0.01816	0.02506	9
	S9 Environmental quality	0.02058	0.02840	7

CONCLUSION

In the course assessment design system established in this study, ISM was employed to analyze the key factors for wetland ecology-based outdoor education for junior high schools. ISM was used to analyze and explain the interaction and relationships among critical teaching factors, as well as to construct the learning path. Courses should be designed on the basis of S1, S2, S3, and S7. According to the ANP weight analysis performed on the course assessment and design, resources and education are more crucial than socioeconomy. Weight analysis of the factors for course design agreed with the ISM results in determining S2 as the most crucial factor, followed by S3 and S1. The learning path and weights in the course design assessment system established in this study can be applied in the selection of suitable follow-up wetland ecology-based courses. By doing so, students can achieve satisfactory learning outcomes at each step of their wetland ecology-based environmental education. The effects, importance, and assistance of the factors in the implementation of wetland ecology-based education in junior high schools can be determined and used as a crucial reference for research and educational institutes in the future.

Suggestions regarding outdoor teaching activities for students

Natural environments and habitats require conservation. Overprotecting students during outdoor educational activities prevents them from getting close to nature, and a lack of variety in courses does not create the desired experiential effects or a deep-rooted understanding of ecological sustainability. Therefore, explanations provided during such activities should be lively and combine teaching with entertainment, and interesting, simple, and explicit methods should be adopted to enable students to understand concepts. If activities are lively yet properly controlled, students' comprehension of environmental quality will be improved through their environmental education, personal experience, individual development, and economy. Learning by doing makes wetland ecology-based outdoor education more interesting, and students interested and concerned about the protection and sustainable development of wetlands will be likely to effect change in the future.

Suggestions for schools

Hierarchical transitive relationship diagrams for key factors and course weight distributions enable teaching units to arrange interesting and effective courses and activities. Courses should be arranged according to students' learning levels, without strictly following the curricula specified in school textbooks. Accessible teaching content that corresponds with the key factors should be adopted. Moreover, when course activities are designed for students with different levels of knowledge, a useful connection can be formed between academic coursework and experience acquired outside the classroom. This transforms what is learned into environmental concepts relevant to real-life situations, rather than unrealistic and boring textbook scenarios. Teaching content then becomes easier to understand, and the quality of learning is enhanced by interesting and lively learning experiences that consolidate the concept of ecological sustainability. Changes in outdoor teaching methods and the learning of concepts enable students to easily engage in activities and identify with the topics. The concept of conservation is then easily portrayed, and the idea of ecological sustainability can exert an implicit influence on student behavior. This study did not include empirical research. The inclusion of fieldwork involving on-site comparison and analysis would render the assessment of key factors at different sites more objective and thus enable course planners to more accurately determine and arrange the required outdoor teaching activities. Fieldwork would be conducive to teaching units during the design of lively courses that implicitly improve students' learning outcomes.

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