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APPLYING INTERPRETIVE STRUCTURAL MODELING IN ANALYZING KEY INDICATORS OF SECONDARY SCHOOL OUTDOOR WETLAND ECOLOGY TEACHING

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Abstract. *Wetland ecosystems are among the most diverse in the world. Wetland ecology is closely related to the human environment, the global economy, and life in general. Wetland ecology teaching should be employed to assist students in understanding the importance of wetlands for human beings. Conclusions were drawn regarding nine indicators: (1) individual development, (2) social culture, (3) natural environment, (4) economy, (5) the biological habitat, (6) environmental quality, (7) ecological conservation, (8) environmental education, and (9) learning through practice. We applied interpretive structural modeling to determining the correlations among the indicators. The findings can provide teachers with an academic basis for enhancing outdoor teaching curricula to achieve effective related teaching goals.*

Keywords: Interpretive structural modeling, Outdoor education, Wetland ecosystems

1. **Introduction.** United Nations (UN) Agenda 21 states that education plays a central role in sustainable development for the future [1]. Furthermore, 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 advance citizens' understanding of the interdependent relationships among individuals, society, and the environment. Thus, the following goals can be achieved: maintaining the ecological balance of the environment, respecting life, fostering social justice, cultivating environmentally aware citizens and environmental study communities, and achieving sustainable development. This act requires junior high schools and lower to organize school outings at environmental education facilities and sites for environmental education. Education develops student potential and enables students to adapt to and improve their environment. Students develop socially acceptable values in their interactions with people, objects, and the environment through education, thus gaining sufficient knowledge and problem solving skills regarding environmental concerns. The effect of outdoor wetland ecological teaching on students is a crucial topic; scholars promoting environmental education have suggested beginning environmental learning at an early age [4]. Wetlands purify water, possess diverse ecosystems, and provide habitats for biological communities including endangered species; thus, wetlands are highly productive locations with a high degree of biodiversity. Wetlands are valuable and present substantial

economic benefits because of their ability to provide humans and animals with food, as well as their potential as tourist, recreational, and educational sites. However, water pollution and intensive man-made development have affected wetland ecosystems. This study incorporated related concepts to determine key influencing factors and applied interpretive structural modeling (ISM) to analyzing the transitively related structural hierarchy of the key indicators of secondary school outdoor wetland teaching to assist teachers in designing wetland ecology curricula that correspond with student understanding. By applying this method, this study aimed to improve the effectiveness and quality of student learning to provide effective teaching objectives. In this paper, Section 2 summarizes key factor indicators, Section 3 outlines the research method and the ISM analysis procedures, Section 4 offers an analysis of the research results, and Section 5 provides the conclusion and explains the contribution of this study.

2. **Literature Review.**

2.1. **Secondary school Syllabi in Taiwan.**

2.1.1. *Content outline of Grade 1-9 Curriculum guidelines.* The new Grade 1-9 Curriculum facilitates the development of healthy citizens that possess humanistic sentiments, integration capability, democratic literacy, local and international awareness, and the ability to engage in life-long learning. The basic content of the curriculum is as follows [5]: (1) aspects relating to humanistic sentiments; (2) aspects relating to integration capability; (3) aspects relating to democratic literacy; (4) aspects relating to local and international awareness; (5) aspects relating to life-long learning.

2.1.2. *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 by improving awareness of personal responsibilities toward environmental problems, thus facilitating personal understanding and growth. The interaction between society and the natural environment is also explored in environmental education. The discussion and resolution of daily concerns assist the practice and implementation of life skills. The goals of environmental education curricula are as follows [6]: (1) awareness and sensitivity toward the environment; (2) conceptual knowledge regarding the environment; (3) values and attitudes toward the environment; (4) environmental action skills; (5) environmental action experiences.

2.2. **Wetland ecology.**

2.2.1. *Wetlands.* Wetlands refer to borders between water and land, land that has been submerged by water in the past, or areas that are currently submerged less than 6 meters under water. Wetlands are defined and categorized primarily according to water conditions, specific soil conditions, and humidity-resistant plants. The most representative definition of wetlands was outlined at the international Wetland Convention, or Ramsar Convention, held in 1971 [7,8].

2.2.2. *Ecotourism.* In 1965, Hetzer claimed that the implications of ecotourism called for the extensive consideration of culture, education, and tourism, promoting a type of ecological tourism [9]. In 1980, the International Union for Conservation of Nature, the UN Environment Programme, and the World Wildlife Fund developed the World Conservation Strategy, which proposed direct links between environmental conservation and economic development to achieve the goal of "conservation that promotes development and development that strengthens conservation" [10].

2.3. **Outdoor teaching.** The value of outdoor teaching lies in its provision of direct contact experiences that are absent in regular teaching and that facilitate an experiential learning process. As proposed 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 most effective method for enabling students to directly interact with their environment and acquire direct experiences to develop their attitudes and values toward the environment [11]. The National Audubon Society's Manual of Outdoor Interpretation [12] promotes the following outdoor conservation education goals: (1) obtain outdoor-related knowledge from nature; (2) develop an understanding of conservation and outdoor skills on the basis of the knowledge acquired from nature; (3) stimulate interest in and understanding of nature; (4) shape appropriate attitudes on the basis of personal outdoor learning experiences (i.e., environmental ethics); (5) establish a determination to engage in environmental conservation; (6) facilitate judicious conservation actions at any time and location as required. In brief, this study examined the key indicators of secondary school outdoor wetland ecology teaching through in-depth interviews with experts and literature review to summarize suitable key indicator factors. The key indicators were coded as shown in Table 1, with explanations for key indicators S1-S9.

Table 1. Explanatory features and descriptions of key indicators

Dimension	Explanatory features and descriptions of assessment indicators
S1 Individual development	Inspiration, satisfaction, environmental awareness, environmental action, awareness of cultural preservation, learning motivation and interest, environmental attitudes, values, communication skills, and fun activities.
S2 Social culture	Local cultural activities, natural history, traditional culture, cultural exchange, and local taboos.
S3 Natural environment	Grassroots resources, biological resources, natural resources, undisturbedness, and natural ecology.
S4 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.
S5 Biological habitat	Advantaged aquatic plants, organisms adapted to humid environments, fish and crustaceans, birds, wildlife habitats, foraging, and drinking water.
S6 Environmental quality	Positive and negative effects, negative impact, productivity, heat island effect, and toxic chemicals.
S7 Ecological conservation	Ecological concepts, ecological sustainability, environmental protection, and cultural preservation.
S8 Environmental education	Interpretation services, education, natural sciences, specific topics, opportunistic education, and knowledge of nature.
S9 Learning through practice	Observing, appreciating, or experiencing wildlife scenery, concern for cultural content, ecological beauty, learning, exploration, and research.

3. **Methods.** In this study a review of literature related to wetland ecology and outdoor education was conducted and course outlines used in secondary schools and environmental education were collected. Subsequently, the collected literature was organized and

analyzed to establish the key indicators of secondary school outdoor wetland ecology education to assist teachers in achieving systematic, relevant, and effective teaching and learning objectives.

3.1. **Brainstorming.** Brainstorming, or the "BS method," was first mentioned by Osborn in 1953 and involves group discussion and creativity development. Brainstorming is defined as "each person utilizing his or her own intellect to perform creative thinking in order to generate solutions for a specific problem". Group members engaging in brainstorming for a specific topic produce a high volume of different ideas through collective thinking and the interactions resulting from ideas. The high volume of different ideas is then organized to determine the highest-quality ideas and optimal solutions [13].

3.2. **ISM.**

3.2.1. *Definition.* ISM is a structural modeling technique that analyzes the relational order of each selected element to yield a comprehensive and concrete hierarchical chart that portrays 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 human practical experience and knowledge in combination with computer-based explanations to automatically generate a complete multilevel structural hierarchy. Warfield indicated that when system structure and complexity increase, ISM can produce objective and scientific hierarchical structure charts in 1974. The beginning procedures of ISM employ an individual or group psychological model to calculate a two-element matrix, or an incidence matrix, using element values to represent the relationship between each element [14]. Recent research applications of key factor analysis in project management have been extensive [15,16].

3.2.2. *Analysis procedures.*
(a) Establish an element relationship diagram or adjacency matrix:

$$\text{Cause (Influencer) } D = \begin{array}{c} \\ \\ e_1 \\ e_2 \\ e_3 \\ \vdots \\ e_i \end{array} \begin{array}{c} \text{Result (Influenced)} \\ \begin{array}{cccc} e_1 & e_2 & \cdots & e_j \end{array} \\ \begin{bmatrix} 0 & S_{12} & \cdots & S_{1j} \\ S_{21} & 0 & \cdots & S_{2j} \\ S_{31} & S_{32} & \cdots & S_{3j} \\ \vdots & \vdots & \ddots & \vdots \\ S_{i1} & S_{i2} & \cdots & 0 \end{bmatrix} \end{array}$$

(b) Calculate the reachability matrix:

The incidence matrix was established as follows:

$$B = D + I \tag{1}$$

The Boolean algebra was established as Table 2.

For the reachability matrix calculation, this study applied Excel to sequentially determining the exponentiation of B, obtaining the reachability matrix B^*, calculated until $B^k = B^{k+1}$. The reachability matrix is the content represented by M. When $B = D + I$,

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

the exponentiation calculation is conducted on B more than $k-1$ times, and its result does not change. Furthermore, k refers to the dimension of D, which indicates that $B^{k-1} = B^k = B^{k+1}$.

$$B^* = B^k = B^{k+1} \tag{2}$$

M refers to the reachability matrix. This matrix 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 $M(S_i, S_j) = 0$, 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 are converged.

$$M = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

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

The reachability matrix involves the concepts of the reachability set $R(t_i)$ and the priority set $A(t_i)$. The reachability set $R(t_i)$ refers to the ith element within the reachability matrix M^*, and the elements with a relational value of 1 after vertical calculation are extracted. The priority set $A(t_i)$ refers to the ith element within the reachability matrix M^*, and the elements with a relational value of 1 after horizontal calculation are extracted.

$$R(S_i) \cap A(S_i) = R(S_i) \tag{3}$$

ISM is suitable for creating, deducting, and correcting larger models. Graph theory can be applied as the basis for determining the interrelation between each element [17]. ISM can convert abstract thoughts and views into a structural relationship model and analyze each element by using 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 [18].

4. **Results and Analyses.** This study recruited 12 experts and scholars for the questionnaire survey, with one recruited from the public sector, three from educational institutions, and five from industries related to environmental planning; the remaining three were academics with backgrounds mainly in tourism, environmental landscapes, and regional development. Each of the 12 experts possessed a degree of familiarity with the measurement methods employed in this study and completed the questionnaire in focus groups and in-depth interviews. The correlation between each element was determined by the individual experiences, opinions, and brainstorming results of the interviewed experts. This study incorporated an adjacency matrix into an identity matrix and conducted ISM repeated calculation and convergence to generate a reachability matrix (Table 3); Tables 4 and 5 show the hierarchy extraction results.

The first-level factor set $\{S1, S4, S6, S8, S9\}$ was obtained from $R(S_i) \cap A(S_i) = R(S_i)$, and the rows and columns corresponding to $\{S1, S4, S6, S8, S9\}$ in the reachability matrix were excluded. Similarly, the second-level factor set $\{S2, S3, S5, S7\}$ was obtained according to the same principle. The aforementioned analysis process converted the hierarchy matrix into a hierarchical transitive relationship diagram. The relationship between the factors is presented in Figure 1.

Table 3. Reachability matrix

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

Table 4. Hierarchy extraction 1

Dimension	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S1	**1, 4, 8, 9**	**1, 3, 4, 5, 7, 8, 9**	**1, 4, 8, 9**
S2	2, 6	2	2
S3	1, 3, 4, 6, 8, 9	3	3
S4	**1, 4, 8, 9**	**1, 3, 4, 5, 7, 8, 9**	**1, 4, 8, 9**
S5	1, 4, 5, 8, 9	5	5
S6	**6**	**2, 3, 6**	**6**
S7	1, 4, 7, 8, 9	7	7
S8	**1, 4, 8, 9**	**1, 3, 4, 5, 7, 8, 9**	**1, 4, 8, 9**
S9	**1, 4, 8, 9**	**1, 3, 4, 5, 7, 8, 9**	**1, 4, 8, 9**

Table 5. Hierarchy extraction 2

Dimension	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S2	2	2	2
S3	3	3	3
S5	5	5	5
S7	7	7	7

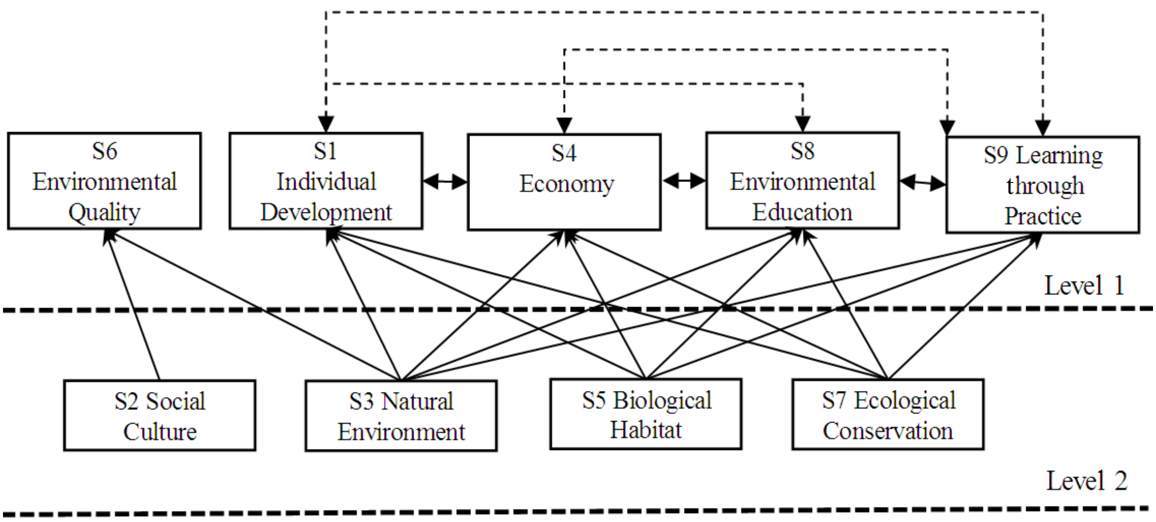

Figure 1. Hierarchical structure diagram

According to Figure 1, the key indicators of secondary school outdoor wetland ecology teaching constitute a two-level transitive structural model. S1 (Individual Development), S4 (Economy), S6 (Environmental Quality), S8 (Environmental Education), and S9 (Learning through Practice) were at the first level. S2 (Social Culture), S3 (Natural Environment), S5 (Biological Habitat), and S7 (Ecological Conservation) were at the second factor set level. These results can be applied in enhancing student knowledge during outdoor wetland ecology teaching. Furthermore, these results can be used to comprehensively analyze key factors and allocate the successive transitive effects of wetland ecology teaching.

5. **Conclusion.** The purpose of this study was to establish the hierarchical transitive effects of the key indicators of secondary school outdoor wetland ecology teaching and investigate structured key indicators. Environmental quality was found to be affected by social culture and the natural environment. Individual development, economy, environmental education, and learning through practice were correlated. The natural environment, biological habitat, and ecological conservation were determined to be related to individual development, economy, environmental education, and learning through practice. Thus, teachers arranging teaching venues must consider the factors of natural environment, biological habitat, and ecological conservation. Furthermore, the addition of experiential courses, environmental education, and economic factors should facilitate a high degree of systemization in students' learning process, thus gradually assisting students in gaining appropriate and complete knowledge of and concern for the sustainable development of wetland habitats. This study analyzed the key indicators by using ISM to produce hierarchical structure diagrams. However, ISM showed a number of disadvantages. For example, the division of factors into different levels for analysis facilitated the analysis process but did not account for the reverse effect. This suggested that other relevant analysis methods may be applied. This study supports the use of an analytic network process method in the future to establish weights for indicating the mutual influence between key indicators, facilitating more favorable planning of course curricula and activities.

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