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Creating the aspired intelligent assessment systems for teaching materials

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ABSTRACT

The core objective of the Nine-Year Integrated Curriculum for primary schools is to "enable students to demonstrate their talents instead of just scoring high on exams" around the world. The determining factor in education reform is to declare the competence indicators of necessary educational behavior in primary and junior high school. In the reform process, for all domains, the enriched rate of competence indicators for educational materials and methods is very meaningful. Because educational materials and methods in different domains have their own style, we should evaluate these teaching materials separately. Thus, in this research we propose a novel MCDM (Multiple Criteria Decision Making) framework for evaluating, comparing, and improving the effectiveness of competence indicators in the various publications for teaching materials in primary school based on different viewpoints. The ANP (Analysis Network Process) weights are based on the DEMATEL technique with the MCDM method for resolving the problems of dependence and feedback among criteria. Then, a VIKOR technique with ANP weights is proposed for addressing and reducing the performance gaps for each criterion, thus hopefully improving, re-configuring and selecting the aspired Intelligent Assessment Systems (IAS) for teaching materials. An empirical study of Mandarin Chinese based on this system design of three publishers is illustrated to verify the effectiveness of the proposed method. The results can improve the efficiency and quality of the authored Mandarin Chinese teaching materials and may extend to other Learning Areas.

1. Introduction

Every country has made the cultivation of human talent a priority in the 21st century. As other advanced countries propose education reform in different forms throughout the world, Taiwan also recognizes education as the bedrock of national development, implementing various education reforms such as pre-school education reform, grade 1–9 curriculum reform, the restructuring of secondary education, the enhancement of higher education, and lifelong learning projects (MOE, 2008). Therefore, the purpose of this research is to propose a novel technique and evaluation method that can improve, re-configure and select the aspired Intelligent Assessment Systems (IAS) for teaching materials to promote education levels.

Since 1990, the four British educational reform contexts have been: (a) the right to national centralization reform; (b) the priority of compulsory education; (c) vocational education mainstreaming; and (d) the ability to pursue educational evaluation (DfE, 1991). The report of the Mayer Committee proposed to advise the Australian Education Council (AEC) and the Ministers for Vocational Education, Employment and Training (MOVEET) on employment-related key competencies for post-compulsory education and training (Mayer, 1992). The Education Commission of Hong Kong proposed the following: "Learning is the key to one's future, and education is the gateway to our society's tomorrow". Education enables individuals to develop their potential, construct knowledge and enhance the quality of their personal lives (EC, 2000).

In general, no matter what style of education reform is used, the key competencies are the major concern for national education reform at the beginning of the 21st century.

The core objective of Nine-Year Integrated Curriculum for primary schools in Taiwan is to "enable students to demonstrate their talents instead of just scoring high on exams". The determining factor in education reform is to declare the competence indicators for necessary educational behavior in primary school (MOE, 2002). In the reform process, for all domains, the enriched rate of competence indicators for educational materials and methods is very meaningful. Because educational materials and methods in different domains have their own style, we should evaluate these teaching materials separately.

Thus, in this research we propose a novel MCDM (Multiple Criteria Decision Making) framework based on the DEMATEL

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(Decision Making Trial and Evaluation Laboratory) technique for evaluating, comparing, and improving the effectiveness of competence indicators in the various publications for teaching materials in primary school based on different viewpoints. The ANP (Analysis Network Process) weights are based on the DEMATEL technique with the novel MCDM method for resolving the problems of dependence and feedback among criteria. Then, a VIKOR technique with ANP weights is proposed for addressing and reducing the performance gaps for each criterion, thus hopefully improving, re-configuring and selecting the aspired Intelligent Assessment Systems for teaching materials. An empirical study of Mandarin Chinese teaching materials in Grade 1 of primary school based on this system design of three publishers is illustrated to verify the effectiveness of the proposed method. The results can improve the efficiency and quality of the authored Mandarin Chinese teaching materials and may extend to other Learning Areas.

The remainder of this paper is organized as follows. In Section 2, the aspired intelligent assessment systems for teaching materials with MCDM are introduced. In Section 3, a novel MCDM method based on the DEMATEL technique is proposed. In Section 4, an empirical study for the aspired IAS for Mandarin Chinese teaching materials is presented to show the process that our proposed method entails, and discussions are conducted. Finally, in Section 5, concluding remarks are presented.

2. Intelligent assessment systems for teaching materials with MCDM method

In recent decades, competence-based education has become the mega trend impacting the education reform strategies of the majority number of governments throughout the world. In the following section, the literatures related to core competence (CC), the intertwined effects of an assessment system for teaching materials, will be reviewed as a foundation for the development of the theoretical framework of this paper. We also give an example of Taiwan to explain the basic concepts of Educational Reform for teaching materials.

2.1. Educational reform of Taiwan (MOE, 2002)

In keeping with the progress of the 21st century and the global trends of educational reform, Taiwan must engage in educational reform in order to foster national competitiveness and boost the overall quality of our citizen's lives.

The Ministry of Education (MOE) of Taiwan, therefore, has initiated curricular and instructional reforms in primary and junior high school education. These reforms have been based on the Action Plan for Educational Reform approved by the Executive Yuan of Taiwan. Because the curriculum is not only the core of schooling but also the foundation on which teachers plan learning activities, the MOE places top priority on the development and implementation of the Grade 1–9 Curriculum. Curricular reforms are necessary and will be timely for the following reasons: (a) meeting national development needs; and (b) meeting public expectations.

2.2. Assessment system for mandarin chinese teaching materials

Mandarin Chinese is one of the curricula included in the Language Arts. It is divided into 3 stages: Grades 1–3, Grades 4–6, and Grades 7–9.

2.2.1. Mandarin Chinese's curriculum goal

Based on the Curriculum Goals and CCs of the Grade 1–9 Curriculum, a more detailed description is given in sub Sections 4.1.2 and 4.1.3, with the Mandarin Chinese Curriculum Goal defined as follows: (1) to utilize language to inspire individual potential and to cultivate learning; (2) to cultivate interest in writing and enhance ability to appreciate literature; (3) to equip with the self-learning ability for language learning and lay the foundation for lifelong learning; (4) to utilize language and words for expressions of emotion, experience-sharing and communications; (5) to utilize language expression to adapt to one's environment and to demonstrate appropriate behavior; (6) to understand and recognize the Chinese, Taiwanese and foreign cultures and rituals through language learning; (7) to utilize the power of language to develop and implement plans effectively; (8) to combine the information of language and technology to enhance learning and to expand fields of study; (9) to cultivate an interest in language exploration and a proactive attitude towards language-learning; (10) to utilize language for independent thinking and problem-solving.

2.2.2. Competence indicators of Mandarin Chinese's curriculum of grade 1–9 curriculum

Based on the requirements for children's intellectual development, the numbers for the competence indicators of the Mandarin Chinese Curriculum for each stage are defined (see Table 1).

In general, this includes listening, speaking, reading and writing of languages, and developing basic communication competencies. From the academic point of view, six terms were developed as follows: (1) phonetic symbol applications; (2) listening skills; (3) the ability to speak; (4) literacy and writing ability; (5) reading skills; and (6) writing skills.

Table 1
Numbers for competence indicators for the mandarin Chinese curriculum for each stage.

Criterion of CC	Stage1	Stage2	Stage3	Sum
$\boldsymbol{D}_1$: Physical, mental, and spiritual mold				
$\boldsymbol{C}_1$: Self-understanding and exploration of potential	24	19	18	61
$\boldsymbol{C}_2$: Appreciation, representation, and creativity	20	17	17	54
$\boldsymbol{C}_3$: Career planning and lifelong learning	9	13	10	32
$\boldsymbol{D}_2$: Interpersonal and social relations				
$\boldsymbol{C}_4$: Expression, communication, and sharing	8	9	12	29
$\boldsymbol{C}_5$: Respect, care and teamwork	9	9	13	31
$\boldsymbol{C}_6$: Cultural learning and international understanding	6	8	6	20
$\boldsymbol{C}_7$: Planning, organizing and putting plans into practice	7	7	6	20
$\boldsymbol{D}_3$: The use of Life Science and Technology				
$\boldsymbol{C}_8$: Utilization of technology and information	4	11	8	23
$\boldsymbol{D}_4$: Logical thinking and reasoning				
$\boldsymbol{C}_9$: Active exploration and study	8	7	9	24
$\boldsymbol{C}_{10}$: Independent thinking and problem-solving	9	8	7	24
Sum	104	108	106	318

Sources: (MOE, 2002)

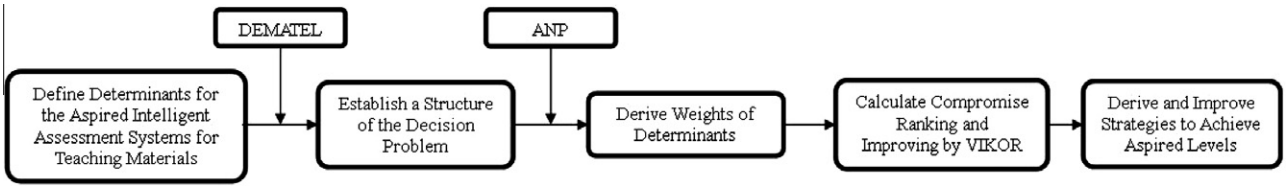


Fig. 1. An analytical framework for aspired assessment system for teaching materials.

3. A novel MCDM method based on the DEMATEL technique with ANP

The structure of the MCDM problem will be derived using the DEMATEL method. The priorities of every determinant are based on the structure derived by using the ANP. The VIKOR technique will be leveraged to calculate the compromise ranking of the alternatives. Finally, the assessment system for Mandarin Chinese teaching materials will be derived. In summary, this evaluation framework consists of five main phases: (1) establishing determinants using the questionnaire survey method; (2) building the structure of network relation map (NRM) for the determinants by using DEMATEL; (3) calculating the priorities of every determinant using the ANP based on the structure of NRM derived by using DEMATEL in (2); (4) ranking the priorities of the assessment system for teaching materials using the VIKOR technique; and finally (5) establishing the assessment system for teaching materials and achieving the aspired levels (see Fig. 1).

3.1. DEMATEL Technique with ANP

The DEMATEL technique was developed by the Battelle Geneva Institute: (1) to analyze complex 'world problems' dealing mainly with interactive man-model techniques; and (2) to evaluate qualitative and factor-linked aspects of societal problems (Gabus & Fontela, 1972). The applicability of the method is widespread, with applications ranging from industrial planning and decision-making to urban planning and design, regional environmental assessment, the analysis of world problems, and so forth. It has also been successfully applied in many situations and fields, such as those of marketing strategies, control systems, safety problems, developing the competencies of global managers, group decision-making and so on (Chen, Lien, & Tzeng, 2010; Chiu, Chen, Tzeng, & Shyu, 2006; Huang, Shyu, & Tzeng, 2007; Lee, Tzeng, Hsu, & Huang, 2009; Li & Tzeng, 2009a, 2009b; Lin & Tzeng, 2009; Lin & Wu, 2008; Liou, Tzeng, & Chang, 2007; Ou Yang, Leu, & Tzeng, 2009; Ou Yang, Shieh, Leu, & Tzeng, 2008; Tzeng, Chen, Yu, & Shih, 2010; Wu & Lee, 2007). Furthermore, a hybrid model combining the two methods has been widely used in various fields – for example, e-learning evaluation (Tzeng, Chiang, & Li, 2007), teaching materials assessment (Chen and Tzeng, 2009), airline safety measurement (Liou et al., 2007), and innovation policy portfolios for Taiwan's SIP Mall (Huang et al., 2007). Therefore, in this paper we use DEMATEL not only to detect complex relationships and build a NRM for the criteria but also to obtain the influence levels of each element over others; we then adopt these influence level values as the basis of the normalization supermatrix for determining ANP weights to obtain the information about relative importance. To apply the DEMATEL method smoothly, the authors refined the definitions based on the above authors and produced the essential definitions indicated below. The DEMATEL method is based upon graph theory, enabling us to plan and solve problems visually, so that we may divide multiple criteria into a relationship of cause and effect to better understand causal relationships. Directed graphs (also called digraphs) are more useful than directionless graphs because digraphs will demonstrate the directed relationships of sub-systems. A digraph typically represents a communication network or a domination relationship between individuals. Suppose a system contains a set of elements, $S = \{s_1, s_2, \ldots, s_n\}$, and particular pair-wise relationships are determined for modeling with respect to a mathematical relationship, MR. Next, portray the relationship MR as a direct-relation matrix that is indexed equally in both dimensions by elements from the set S. Then, extract the case for which the number 0 appears in the cell (i,j) if the entry is a positive integral that has the following meaning: the ordered pair (s_i, s_j) is in the relationship MR; and has the kind of relationship regarding that element such that s_i causes element s_j. The digraph portrays a contextual relationship between the elements of the system, in which a numeral represents the strength of influence (Fig. 2). The number between factors is the influence or influenced degree. For example, an arrow from s_1 to s_2 represents the fact that s_1 influences s_2 and that its influenced degree is two. The DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system (Chiu et al., 2006)..

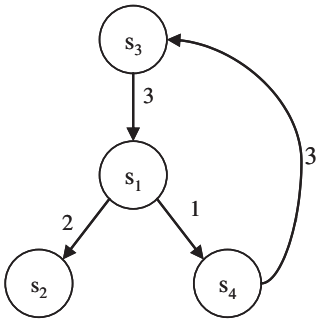


Fig. 2. An example of the directed graph.

Definition 1. The pair-wise comparison scale may be designated as five levels, where the scores $0, 1, 2, \ldots, 4$ represent the range from 'no influence' to 'very high influence'.

Definition 2. The initial direct relation/influence matrix $\boldsymbol{A}$ is an $n \times n$ matrix obtained by pair-wise comparisons in terms of influences and directions of influence between the determinants, in which a_{ij} is denoted as the degree to which the ith determinant affects the jth determinant.

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Definition 3. The normalized direct relation/influence matrix $\boldsymbol{N}$ can be obtained through Eqs. (1) and (2), in which all principal diagonal elements are equal to zero.

$$\boldsymbol{N} = z\boldsymbol{A} \tag{1}$$

where

$$z = 1 \Big/ \max\left(\max_{1\leqslant i\leqslant n}\sum_{j=1}^{n} a_{ij}, \max_{1\leqslant j\leqslant n}\sum_{i=1}^{n} a_{ij}\right). \tag{2}$$

In this case, N is called the normalized matrix. Because

$\lim_{q\to\infty}\boldsymbol{N}^q = [0]_{n\times n}$

Definition 4. Then, the total relationship matrix T can be obtained using Eq. (3), where I stands for the identity matrix.

$$\boldsymbol{T} = \boldsymbol{N} + \boldsymbol{N}^2 + \cdots + \boldsymbol{N}^q = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1} \tag{3}$$

[Explain]

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{N} + \boldsymbol{N}^2 + \cdots + \boldsymbol{N}^q \\ &= \boldsymbol{N}(\boldsymbol{I} + \boldsymbol{N} + \boldsymbol{N}^2 + \cdots + \boldsymbol{N}^{q-1})(\boldsymbol{I} - \boldsymbol{N})(\boldsymbol{I} - \boldsymbol{N})^{-1} \\ &= \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N}^q)(\boldsymbol{I} - \boldsymbol{N})^{-1} \\ &= \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1}, \text{ when } \lim_{q\to\infty}\boldsymbol{N}^q = [0]_{n\times n}\end{aligned}$$

where $q \to \infty$ and $\boldsymbol{T}$ is a total influence-related matrix; $\boldsymbol{N}$ is a direct influence matrix and $\boldsymbol{N} = [x_{ij}]_{n\times n}$;$\lim_{q\to\infty}(\boldsymbol{N}^2 + \cdots + \boldsymbol{N}^q)$ stands for a indirect influence matrix, $0 \leqslant \sum_{j=1}^{n} x_{ij} < 1$ and $0 \leqslant \sum_{i=1}^{n} x_{ij} < 1$, and only one $\sum_{j=1}^{n} x_{ij}$ *or* $\sum_{i=1}^{n} x_{ij}$ is equal to 1 for $\forall i,j$, but not all. So, $\lim_{q\to\infty}\boldsymbol{N}^q = [0]_{n\times n}$. The (i,j) element t_{ij} of matrix $\boldsymbol{T}$ denotes the direct and indirect influences of factor i on factor j.

Definition 5. The row and column sums are separately denoted as r and c within the total-relation matrix T through Eqs. (4) and (5).

$$\boldsymbol{T} = [t_{ij}] \quad i,j \in \{1, 2, \ldots, n\} \tag{4}$$

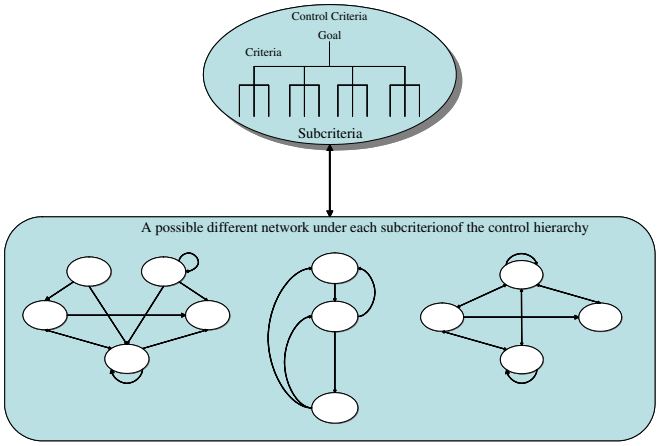
$$\boldsymbol{r} = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \quad \text{and} \quad \boldsymbol{c} = [c_j]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} \tag{5}$$

where the vectors $\boldsymbol{r}$ and $\boldsymbol{c}$ denote the sums of the rows and columns, respectively.

Definition 6. Suppose that r_i denotes the row sum of the ith row of matrix $\boldsymbol{T}$. Then, r_i is the sum of the influences of factor i on the other factors, both directly and indirectly. Suppose that c_j denotes the column sum of the jth column of matrix $\boldsymbol{T}$. Then, c_j is the sum of the influences that factor j is receiving from the other factors. Furthermore, when $i = j$ (i.e., the sum of the row sum and the column sum $(r_i + c_i)$ represents the index indicating the strength of the influence, both dispatching and receiving), $(r_i - c_i)$ is the degree of the central role that factor i plays in the problem. If $(r_i - c_i)$ is positive, then factor i primarily is influencing the strength of the other factors; and if $(r_i - c_i)$ is negative, then factor i primarily is receiving influence from other factors (Huang et al., 2007; Liou et al., 2007; Tamura, Nagata, & Akazawa, 2002).

3.2. The ANP method

The ANP method, a multi-criteria theory of measurement developed by Saaty (1996), provides a general framework for dealing with decisions without making assumptions about the independence of higher-level elements from lower-level elements and about the independence of the elements within a level as in a hierarchy. Compared with traditional MCDM methods (Saaty, 2005) – e.g. AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), ELECTRE (ELimination Et Choix Traduisant la REalité), etc. (Lee et al., 2007) – which usually assume independence between criteria, ANP, a new theory that extends AHP to deal with dependence in feedback and utilizes the supermatrix approach (Saaty, 2003), is a more reasonable tool for dealing with complex MCDM problems in the real world. In this section, the concepts of the ANP are summarized based on Saaty's earlier works (Saaty, 1996, 1999, 2005).



Source: (Saaty, 1996)

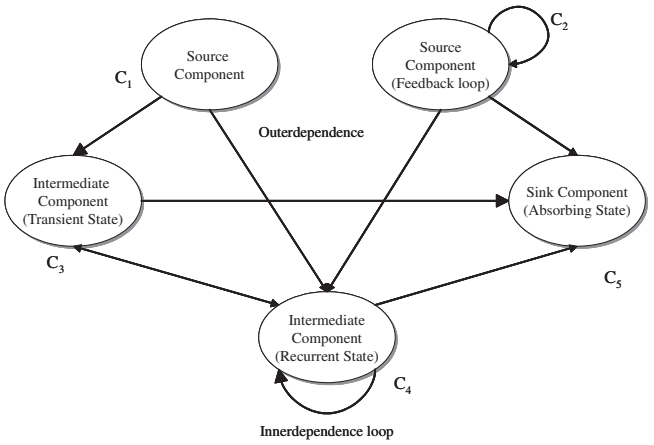
Fig. 3. The control hierarchy.

The ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and subcriteria that control the interactions. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion, and a different supermatrix of limiting influence is computed for each control criterion. Finally, each of these supermatrices is weighted based on the priority of its control criterion, and the results are synthesized through addition for all the control criteria (Saaty, 2004). A control hierarchy is a hierarchy of criteria and subcriteria for which priorities are derived in the usual way with respect to the goal of the system being considered.

The criteria are used to compare the components of a system, and the subcriteria are used to compare the elements. The criteria with respect to which influence is presented in individual supermatrices are called control criteria. Because all such influences obtained from the limits of the several supermatrices will be combined to obtain a measure of the priority of overall influence, the control criteria should be grouped in a structure to be used to derive priorities for them. These priorities will be used to weight the corresponding individual supermatrix limits and sum up. The analysis of priorities in a system can be thought of in terms of a control hierarchy with dependence among its bottom-level alternatives arranged as a network as shown in Fig. 3. Dependence can occur within the components and between them.

A control hierarchy at the top may be replaced by a control network with dependence among its components, which are collections of elements whose functions derive from the synergy of their interaction and that hence have a higher-order function not found in any single element. The criteria in the control hierarchy that are used for comparing the components are usually the major parent criteria whose subcriteria used to compare the elements need to be more general than those of the elements because of the greater complexity of the components.

A network connects the components of a decision system. According to size, there will be a system made up of subsystems, with each subsystem made up of components and each component made up of elements. The elements in each component interact or have an influence on some or all of the elements of another component with respect to a property governing the interactions of the entire system, such as energy, capital, or political influence. Fig. 4 demonstrates a typical network. Those components that no



Source: (Satty, 1996)

Fig. 4. Connections in a network.

arrow enters are known as source components, such as C_1 and C_2. Those from which no arrow leaves are known as sink components, such as C_5. Those components which arrows both enter and exit leave are known as transient components such as C_3 and C_4. In addition, C_3 and C_4 form a cycle of two components because they feed back and forth into each other. C_2 and C_4 have loops that connect them to themselves and are inner-dependent. All other connections represent dependence between components, which are thus known to be outer-dependent.

A component (dimension) of a decision network that was derived by the DEMATEL method in sub Section 3.1 will be denoted by C_h, $h = 1,\ldots,m$; assume that it has n_h elements (determinants), which we denote by $e_{h1}, e_{h2}, \ldots, e_{hn_h}$. The influence of a given set of elements (determinants) in a component (dimension) on any element in the decision system is represented by a ratio scale priority vector derived from paired comparisons of the comparative importance of one criterion and another criterion with respect to the interests or preferences of the decision-makers. This relative importance value can be determined using a scale of 1–9 to represent equal importance to extreme importance (Saaty, 1996). The influence of elements (determinants) in the network on other elements (determinants) in that network can be represented using the following supermatrix:

$$W = \begin{array}{c} \\ \\ C_1 \\ \\ \\ C_2 \\ \\ \vdots \\ C_m \\ \end{array} \begin{array}{c} \begin{array}{cccccccccc} C_1 & & & C_2 & & & \cdots & C_m & & \\ e_{11} & \cdots & e_{1n_1} & e_{21} & \cdots & e_{2n_2} & \cdots & e_{m1} & \cdots & e_{mn_m} \end{array} \\ \begin{bmatrix} e_{11} & & & & & & & & & \\ \vdots & W_{11} & & W_{12} & & & \cdots & W_{1m} & & \\ e_{1n_1} & & & & & & & & & \\ e_{21} & & & & & & & & & \\ \vdots & W_{21} & & W_{22} & & & \cdots & W_{2m} & & \\ e_{2n_2} & & & & & & & & & \\ \vdots & \vdots & & \vdots & & & \ddots & \vdots & & \\ e_{m1} & & & & & & & & & \\ \vdots & W_{m1} & & W_{m2} & & & \cdots & W_{mm} & & \\ e_{mn_m} & & & & & & & & & \end{bmatrix} \end{array}$$

A typical entry W_{ij} in the supermatrix is called a block of the supermatrix in the following form, where each column of W_{ij} is a principal eigenvector of the influence of the elements (determinants) of the ith component of the network on an element (determinant) in the jth component. Some of its entries may be zero corresponding to those elements (determinants) that have no influence.

$$W_{ij} = \begin{bmatrix} w_{i_1 j_1} & w_{i_1 j_2} & \cdots & w_{i_1 j_{n_j}} \\ w_{i_2 j_2} & w_{i_2 j_2} & \cdots & w_{i_2 j_{n_j}} \\ \vdots & \vdots & \ddots & \vdots \\ w_{i_{n_i} j_1} & w_{i_{n_i} j_2} & \cdots & w_{i_{n_i} j_{n_j}} \end{bmatrix}$$

After forming the supermatrix, the weighted supermatrix is derived by transforming all columns sum to unity exactly. This step is very much similar to the concept of the Markov chain in terms of ensuring that the sum of these probabilities of all states equals 1. Next, the weighted supermatrix is raised to limiting powers, such as $\lim_{\theta\to\infty} W^{\theta}$ to get the global priority vector or called weights (Huang, Tzeng, & Ong, 2005).

3.3. VIKOR

The compromise ranking method (VIKOR) was proposed by Opricovic (Opricovic, 1998) as one applicable technique to implement within MCDM. We assume that the alternatives are denoted as $A_1, A_2, \ldots, A_k, \ldots, A_m$. The rating (performance score) of the jth criterion is denoted by f_{kj} for alternative A_k, w_j is the weight of the jth criterion, expressing the relative importance of the criteria, where $j = 1,2,\ldots,n$, and n is the number of criteria. The VIKOR method began with the following form of the $L_p - metric$:

$$L_k^p = \left\{ \sum_{j=1}^{n} \left[w_j \left(\left| f_j^* - f_{kj} \right| \right) \Big/ \left(\left| f_j^* - f_j^- \right| \right) \right]^p \right\}^{1/p}$$

where $1 \leqslant p \leqslant \infty$, $k = 1,2,\ldots,m$; weight w_j is derived using the ANP according to the NRM based on the DEMATEL method. The VIKOR method also uses $L_k^{p=1}$ (as S_k) and $L_k^{p=\infty}$ (as Q_k) to formulate the ranking measure (Opricovic, 1998; Opricovic & Tzeng, 2002, 2004, 2007; Tzeng, Teng, Chen, & Opricovic, 2002, 2005).

$$S_k = L_k^{p=1} = \sum_{j=1}^{n} \left[w_j \left(\left| f_j^* - f_{kj} \right| \right) \Big/ \left(\left| f_j^* - f_j^- \right| \right) \right]$$

$$Q_k = L_k^{p=\infty} = \max_j \left\{ w_j \left(\left| f_j^* - f_{kj} \right| \right) \Big/ \left(\left| f_j^* - f_j^- \right| \right) \middle| j = 1,2,\ldots,n \right\}$$

The compromise solution $\min_k L_k^p$ will be chosen because its value is closest to the ideal/aspired level. In addition, when p is small, group utility is emphasized (such as $p = 1$), and as p increases to $p = \infty$, the individual maximal regrets/gaps receive more importance, as shown by Yu (Freimer & Yu, 1976; Yu, 1973). Therefore, $\min_i S_i$ emphasizes the maximum group utility, whereas $\min_i Q_i$ emphasizes selecting the minimum of the maximum individual regrets. Based on the above concepts, the compromise ranking algorithm VIKOR has the following steps.

Step 1. *Normalize the original rating matrix.* In this step, we determine the best f_j^* and the worst f_j^- values of all criterion functions, $j = 1,2,\ldots,n$. If we assume that the jth function represents a benefit, $f_j^* = \max_i f_{kj}$ (or setting an aspired level) and $f_j^- = \min_i f_{kj}$ (or setting a tolerable level). Alternatively, if we assume that the jth function represents a cost, $f_j^* = \min_i f_{kj}$ (or setting an aspired level) and $f_j^- = \max_i f_{kj}$ (or setting a tolerable level). Moreover, an original rating matrix is transformed into a normalized weight-rating matrix with the following formula:

$$r_{kj} = \left(\left| f_j^* - f_{kj} \right| \right) \Big/ \left(\left| f_j^* - f_j^- \right| \right)$$

Step 2. *Compute the values S_k, Q_k, when $k = 1,2,\ldots,m$,* using the relations (Ou Yang et al., 2008, Ou Yang, Leu, & Tzeng, 2009)

$$S_k = \sum_{j=1}^{n} w_j r_{kj}$$

and

$$Q_k = \max_j\{r_k | j = 1, 2, \ldots, n\}$$

where S_k and Q_k show the mean of group utility and maximal regret, respectively. Using the traditional VIKOR method, Q_k is represented as $\max_j\{w_j r_{kj} | j = 1,2,\ldots,n\}$, which implies that group utility is more important than maximal regret. Because Q_k is only a part of S_k, S_k is unquestionably more than Q_k. Therefore, S_k is emphasized more than Q_k using the traditional VIKOR method. However, maximal regret is also very important in practice and is usually taken into account to improve it. Therefore, to balance S_k and Q_k, $Q_k = \max_j\{r_{kj} | j = 1,2,\ldots,n\}$ is used instead of the traditional VIKOR Q_k.

Step 3. *Compute the index values* R_k, $i = 1,2,\ldots,m$,using the relation

$$R_k = v(S_k - S^*)/(S^- - S^*) + (1 - v)(Q_k - Q^*)/(Q^- - Q^*)$$

where

$$S^* = \min_k S_k, \quad S^- = \max_k S_k, \quad Q^* = \min_k Q_k, \quad Q^- = \max_k Q_k;$$

(here, we can also set the best value to 0 and the worst value to 1) and $0 \leqslant v \leqslant 1$, where v is introduced as a weight for the strategy of maximum group utility, whereas $1 - v$ is the weight of the individual regret.

Step 4. *Rank the alternatives, sorting by the value of* S_k, Q_k, and R_k, for $k = 1,2,\ldots,m$, *in decreasing order*. Propose as a compromise the alternative ($\boldsymbol{A}^{(1)}$), which is ranked first by the measure $\min\{R_k | k = 1,2,\ldots,m\}$ if the following two conditions are satisfied:

- **C1.** *Acceptable advantage:* $R(A^{(2)}) - R(A^{(1)}) \geqslant 1/(m-1)$, where $\boldsymbol{A}^{(2)}$ is the alternative with the second position on the ranking list by R; m is the number of alternatives.
- **C2.** *Acceptable stability in decision making*: Alternative $\boldsymbol{A}^{(1)}$ must also be the best ranked by S_k or/and Q_k, $k = 1,2,\ldots,m$.

A set of compromise solutions is proposed if one of the conditions is not satisfied. The set of compromise solutions consists of the following: (1) alternatives $\boldsymbol{A}^{(1)}$ and $A^{(2)}$ if only condition **C2** is not satisfied; (2) alternatives $\boldsymbol{A}^{(1)}, \boldsymbol{A}^{(2)}, \ldots, \boldsymbol{A}^{(M)}$ if condition **C1** is not satisfied. $\boldsymbol{A}^{(M)}$ is determined by the relation $R(\boldsymbol{A}^{(M)}) - R(\boldsymbol{A}^{(1)}) < 1/(m-1)$ for maximum M (the positions of these alternatives are close).

The compromise-ranking method (VIKOR method) determines the compromise solution; the obtained compromise solution is acceptable to the decision-makers because it provides the maximum group utility of the majority (represented by min$S$) and a minimum of individual maximal regret for the opponent (represented by min$Q$). The model uses the DEMATEL and ANP procedures in sub Sections 3.1 and 3.2 to obtain the weights of the criteria with dependence and feedback; it uses the VIKOR method to obtain the compromise solution.

4. An empirical study of the aspired assessment systems for mandarin chinese teaching materials

In this section, an example being modified from a real case will be presented to demonstrate the effectiveness of the proposed novel MCDM framework using the DEMATEL technique. One empirical study example will be based on an example modified from three leading publishers.

In this case study, Mandarin Chinese teaching materials (six books) for Grade 1 in primary school in Taiwan are selected; these materials were edited by those publishers.

4.1. Background description

In the twenty-first century, major changes have taken place around the world in social, political, economic and cultural arenas. These changes are not only global but also national. In a drastic change, the most countries have become aware of the importance of education and culture. Education reform in these countries has been carried out to stimulate personal potential, to overtake the fine culture, and to promote social progress.

After six decades of postwar development, Taiwan has transitioned from a traditional agricultural society into a modern industrial society. Political, economic, and cultural environments are faced with modernization, industrialization and the technological influences of structural adjustment and reconstruction. The impact of education reform is one of the most far-reaching and extensive implications of a major reform. It affects national self-positioning, slushing the social consciousness, establishing a new culture and developing national competitiveness for the new century.

The effectiveness of economic development and of the development of democracy in Taiwan have aroused praise from more developed countries. It is a fact that the main contributing factor is the spread of education and enhancement of people's quality of life. Taiwan is becoming an educational community. However, in the development of education over the years, many problems have emerged, and delays in solving the problems have made them even more complicated.

In light of this, the Council on Education Reform was established in September, 1994. It was responsible for educational reform and the educational development of research and consideration, the Commission "Education overall reform Consultation Report" was presented in December of 1996.

Taiwan should actively engage in reform. Issues that need to be addressed include the following: establishing a life-long learning society; enhancing equal opportunities in education; guiding examination biased towards intellectual culture; improving course materials and assessments; improve the multi-teacher education system; and improving the efficiency of the use of educational resources. The influence of education reform on the social and personal is significant. We must ponder social change movements and carefully consider how the value of benchmarks of socio-cultural development is determined, when they occur in the context of education reform, rather than acting rashly.

The Council has developed a comprehensive education reform proposal. It is divided into five dimensions as follows: (1) education deregulation, (2) good educational care for every student, (3) smoother avenues to higher education, (4) improved education quality, and (5) developing a life-long learning society.

Speaking of the need to provide proper educational care for every student, it is clear that schools have not given adequate attention to students, especially disadvantaged students. This has been mainly due to the rigidity of primary school and junior high school education (compulsory education) in Taiwan, with a uniform system and curriculum, coupled with a lack of long-term investment in resources, the unusual effect of teaching, and a single mode for entrance writing examinations at senior high schools and universities. Early on in the education of those disadvantaged students, they were not able to develop a good foundation for learning, and they were then exposed to large class size and a lack of timely and adequate care in general, so that their performance was different from that of the other students and were relatively vulnerable at their schools.

The Council proposed the following specific recommendations: (1) to reform the curriculum and instruction; (2) to reduce school size and class size; (3) to open autonomous schools; (4) to stimulate schools to use the inner strength of their own power; (5) to assist each student with basic competence; (6) to establish a remedial teaching system; (7) to strengthen career counseling and provide multiple approaches; (8) to renew a system of student behavioral counseling; (9) to weaken the physical and psychological barriers to education; (10) to attach importance to aboriginal education; (11) to implement gender equality in education; and (12) to protect the quality of early childhood education.

In the meantime, the Education Reform Committee, Taiwan, MOE proposed the curricular reforms for the Grades 1–9 (compulsory education) Curricula.

The current Curriculum Frameworks for Primary Schools and Junior High Schools were revised and promulgated in 1993 and 1994, respectively. Although the current Curriculum Frameworks have been gradually and properly implemented, the MOE believes that innovative thinking and practice in education are the prerequisites for success in the new century. Therefore, the MOE has launched plans for another curricular reform to build up consensus and integrate efforts at education reform to create a new and better environment for school education. The development of a new curriculum was divided into three stages. The duration and major tasks for each stage are shown in detail as follows: (1) Stage 1 (from April 1997 to September 1998): Establishing the Special Panel on the Development of Primary and Junior High Schools' Curricula; (2) Stage 2 (from October 1998 to November 1999): Establishing the Panel on Researching and Formulating the Guidelines of Each Learning Area in the Grade 1–9 Curriculum, which covered the primary school and junior high school levels of education; and (3) Stage 3 (from December 1999 to August 2002): Establishing the Review Committee on the Revision and Formulation of Elementary and Junior High School Curricula.

4.1.1. Core rationale

The aim of education is to foster sound minds and character in students. Students should be taught democratic values, the Rule of Law, and humanitarian ideals; they should develop strong and healthy physiques, learn how to think for themselves and be creative. Every government hopes that the school system will produce outstanding citizens with a sense of patriotism and the ability to adopt a global perspective. In essence, education is a learning process to help students explore their potential and develop their capacity to adapt and make the necessary efforts to improve their living environment. Given that, the following five basic aspects are emphasized and included in Grade 1–9 Curricula designed for the new century: developing humanitarian attitudes, enhancing the ability to integrate, cultivating democratic literacy, fostering both indigenous awareness and a global perspective, and building up the capacity for lifelong learning. The core components of each aspect are as follows: (A) humanitarian attitude; (B) integration ability; (C) democratic literacy; (D) native awareness and a global perspective; and (E) capacity for lifelong learning.

4.1.2. Curriculum goals

The curricula for primary and junior high schools will adopt the following principles: (A) to involve all aspects of daily life that are related to students' mental and physical development; (B) to encourage the development of individuality and the exploration of one's potential; (C) to foster democratic literacy and respect for different cultures; and (D) to develop scientific understanding and competencies to meet the needs of modern life.

The aim of national education is to teach students to obtain basic knowledge and to develop the capacity for lifelong learning, thus cultivating able citizens who are mentally and physically healthy, vigorous and optimistic, gregarious and helpful to the community, intellectually curious and reflective, tolerant, and creative, with a positive attitude and a global perspective. Schools will achieve such ideals through the promotion of educational learning activities that emphasize humanity, practicality, individuality, comprehensiveness, and modernity. Such activities include interactions between oneself and others, individuals and the community, and humans and nature. Regarding this aspect of national education, we must guide our students to achieve the following curriculum goals: (A) to enhance their self-understanding and explore their individual potential; (B) to develop creativity and the ability to appreciate beauty and present their own talents; (C) to promote abilities related to career planning and lifelong learning; (D) to cultivate knowledge and skills related to expression, communication, and sharing; (E) to learn to respect others, care for the community, and facilitate teamwork; (F) to promote further cultural learning and international understanding; (G) to strengthen knowledge and skills related to planning, organizing, and implementation; (H) to acquire the ability to utilize technology and information; (I) to encourage an attitude of active learning and studying; and (J) to develop abilities related to independent thinking and problem-solving.

4.1.3. Core competencies

To achieve the aforementioned goals, the curricular design of primary and junior high school education shall focus on the needs and experiences of students and aim to develop the core competencies that a modern citizen should possess. Such CCs (core competencies) refer to the key competencies, which defined by the Mayer Committee are: (A) collect, analyze and organize information; (B) communicate ideas and information; (C) plan and organize activities; (D) co-operate with others and help sustain the group's ability to work; (E) use mathematical concepts and technologies; (F) solve problems; (G) use technology (Mayer, 1992).

Thus, the CCs for the Grade 1–9 curriculum reform in Taiwan may be categorized as follows (MOE, 2002): (A) self-understanding and exploration of potential; (B) appreciation, representation, and creativity; (C) career planning and lifelong learning; (D) expression, communication, and sharing; (E) respect, care and teamwork; (F) cultural learning and international understanding; (G) planning, organizing and putting plans into practice; (H) utilization of technology and information; (I) active exploration and study; and (J) independent thinking and problem-solving.

With reference to curricular principles (see Section 4.1.2), the CCs may be divided into 4 dimensions: (1) the physical, mental, and spiritual mold (A-C); (2) interpersonal and social relations (D-G); (3) the use of Life Sciences and Technology (H); and (4) logical thinking and reasoning (I-J).

4.1.4. Learning areas

To foster the CCs in citizens, the curricula for primary and junior high school education should emphasize three dimensions: individual development, community and culture, and natural environment. Thus, the Grade 1–9 Curriculum encompasses seven major learning areas: (A) Language Arts, including Mandarin and English; (B) Health and Physical Education; (C) Social Studies, including history and culture, geography, social institutions, morals and norms, etc., and the incorporation of the aforementioned subjects into one's daily life; (D) Arts and Humanities, including music instruction and instruction in the visual and performing arts; (E) Science and Technology, including learning about substances and energy, nature, the environment, ecological conservation, and information technology; (F) Mathematics, including acquiring the basic concepts of figures, shapes, and quantity; the ability to calculate and organize; and the ability to apply such knowledge and skills to daily life; and (G) Integrative Activities, referring to activities that may

Table 2
Rating the CCs relationships/influences for grades 1–3 mandarin curricula.

		D_1			D_2				D_3	D_4	
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
D_1	C_1	0.000	3.500	3.375	3.625	3.250	2.250	2.750	2.375	2.875	3.000
	C_2	3.250	0.000	2.875	3.000	2.625	2.875	2.750	2.250	2.500	2.375
	C_3	3.750	2.375	0.000	2.875	2.625	2.500	3.000	2.750	3.000	3.125
D_2	C_4	3.750	3.250	3.000	0.000	3.250	3.125	3.250	2.750	3.125	3.250
	C_5	2.375	3.000	2.125	3.500	0.000	3.500	3.375	2.375	2.750	3.000
	C_6	2.625	3.000	2.500	3.250	3.125	0.000	2.875	2.375	2.625	2.625
	C_7	2.625	2.625	3.375	3.375	3.375	2.875	0.000	2.750	3.000	3.125
D_3	C_8	2.375	2.500	2.875	3.125	2.375	2.500	3.000	0.000	3.250	3.250
D_4	C_9	3.000	3.000	3.375	3.250	3.000	2.875	3.500	3.125	0.000	3.750
	C_{10}	3.375	3.375	3.125	3.000	2.875	2.625	3.250	2.875	3.875	0.000

Remark: Surveyed based on the opinions of teacher(s) who are editing Mandarin Chinese teaching materials or have been teaching Mandarin Chinese teaching in primary school, Taiwan. Core Competencies (CCs) D_1: Physical, mental, and spiritual mold D_2: Interpersonal and social relations D_3: The use of Life Science and Technology D_4: Logical thinking and reasoning C_1: Self-understanding and exploration of potential; C_2: Appreciation, representation, and creativity; C_3: Career planning and lifelong learning; C_4: Expression, communication, and sharing; C_5: Respect, care and teamwork; C_6: Cultural learning and international understanding; C_7: Planning, organizing and putting plans into practice; C_8: Utilization of technology and information; C_9: Active exploration and study; C_{10}: Independent thinking and problem-solving.

guide learners to practice, experience, and reflect upon the learning process as well as to testify to and apply what they have learned in real situations.

Based on the analytical frame for expanding them, CCs were first selected as determinants. Then, the structure of the assessment system for the Mandarin Chinese teaching materials definition problem was established using DEMATEL. After that, the weight of each determinant for the decision structure would be decided by using the ANP. The determinants are CCs. The criteria were confirmed as Competence Indicators and as determinants for editing Mandarin Chinese teaching material. Meanwhile, the relationships between the determinants and the ANP derivations of the weights of each determinant would also be derived for the case study.

The relationships between the determinants for the assessment system for Mandarin Chinese teaching materials were surveyed based on the opinions of teacher(s) who are editing Mandarin Chinese teaching materials or have been teaching Mandarin Chinese in primary school, Taiwan. The teachers are familiar with the assessment of Mandarin Chinese teaching materials.

With the understanding of the determinants of the assessment system for Mandarin Chinese teaching materials, appropriate assessment strategies will also be proposed to shorten the gap between the level of the selected current teaching material and the aspired levels of the determinants. Meanwhile, the proposed assessment system for Mandarin Chinese teaching materials will assist the publishers in surpassing the publisher leaders. Detailed procedures and results are illustrated below.

4.2. Decision problem network relation map structuring by DEMATEL

The inter-relationships between the ten determinants will be deduced using the DEMATEL method introduced in sub Section 3.1. First, the direct relation/influence matrix $\boldsymbol{A}$ is introduced (see Table 2). After that, the direct relation/influence matrix $\boldsymbol{A}$ is normalized based on Eq. (1). Then, the total relationship matrix is deduced based on Eq. (3) (see Table 3). Finally, the strength of the influence for each determinant is deduced based on Eq. (5) (see Table 4) (see Fig. 6).

The sequence for the strength of the influence of the determinants is as follows: (1) the use of Life Science and Technology (D_3), which includes the utilization of technology and information (C_8); (2) logical thinking and reasoning (D_4), which is sequent as (a) independent thinking and problem-solving (C_{10}) and (b) active exploration and study (C_9); (3) physical, mental, and spiritual mold (D_1), which is sequent as (a) career planning and lifelong learning (C_3). (b) self-understanding and exploration of potential (C_1) and (c) appreciation, representation, and creativity (C_2); (4) interpersonal

Table 3
Result of the DEMATEL analysis of CC Relationships/Influences for Grades 1–3 Mandarin Curricula.

		D_1			D_2				D_3	D_4	
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
D_1	C_1	1.1989	1.2839	1.2798	1.3786	1.2721	1.1868	1.3055	1.1287	1.2787	1.3022
	C_2	1.1962	1.0744	1.1645	1.2523	1.1539	1.1083	1.2002	1.0342	1.1654	1.1802
	C_3	1.2752	1.2146	1.1384	1.3175	1.2173	1.1574	1.2736	1.1063	1.2450	1.2678
D_2	C_4	1.3819	1.3446	1.3369	1.3402	1.3398	1.2754	1.3896	1.1999	1.3542	1.3787
	C_5	1.2329	1.2298	1.2038	1.3322	1.1317	1.1851	1.2818	1.0928	1.2346	1.2607
	C_6	1.1988	1.1890	1.1737	1.2813	1.1885	1.0379	1.2253	1.0562	1.1897	1.2083
	C_7	1.2867	1.2638	1.2847	1.3773	1.2810	1.2097	1.2242	1.1445	1.2880	1.3116
D_3	C_8	1.2067	1.1886	1.1998	1.2927	1.1809	1.1305	1.2441	0.9939	1.2232	1.2419
D_4	C_9	1.3678	1.3436	1.3544	1.4480	1.3390	1.2745	1.4038	1.2172	1.2641	1.4001
	C_{10}	1.3587	1.3351	1.3284	1.4204	1.3162	1.2490	1.3767	1.1927	1.3628	1.2651

Remark: Core Competencies (CCs) D_1: Physical, mental, and spiritual mold D_2: Interpersonal and social relations D_3: The use of Life Science and Technology D_4: Logical thinking and reasoning C_1: Self-understanding and exploration of potential; C_2: Appreciation, representation, and creativity; C_3: Career planning and lifelong learning; C_5: Respect, care and teamwork; C_6: Cultural learning and international understanding; C_7: Planning, organizing and putting plans into practice; C_8: Utilization of technology and information; C_9: Active exploration and study; C_{10}: Independent thinking and problem-solving.

Table 4
$r_i + c_i$ and $r_i - c_i$ of the DEMATEL analysis of CC Relationships/Influences for Grades 1–3 Mandarin Curricula.

CC	$r_i + c_i$		$r_i - c_i$	
D_1: Physical, mental, and spiritual mold				
C_1: Self-understanding and exploration of potential	25.3189	(5)	−0.0886	(5)
C_2: Appreciation, representation, and creativity	23.9970	(8)	−0.9377	(10)
C_3: Career planning and lifelong learning	24.6777	(6)	−0.2515	(8)
D_2: Interpersonal and social relations				
C_4: Expression, communication, and sharing	26.7817	(1)	−0.0992	(6)
C_5: Respect, care and teamwork	24.6058	(7)	−0.2351	(7)
C_6: Cultural learning and international understanding	23.5633	(9)	−0.0659	(4)
C_7: Planning, organizing and putting plans into practice	25.5963	(4)	−0.2534	(9)
D_3: The use of Life Science and Technology				
C_8: Utilization of technology and information	23.0685	(10)	0.7357	(2)
D_4: Logical thinking and reasoning				
C_9: Active exploration and study	26.0180	(3)	0.8069	(1)
C_{10}: Independent thinking and problem-solving	26.0219	(2)	0.3886	(3)

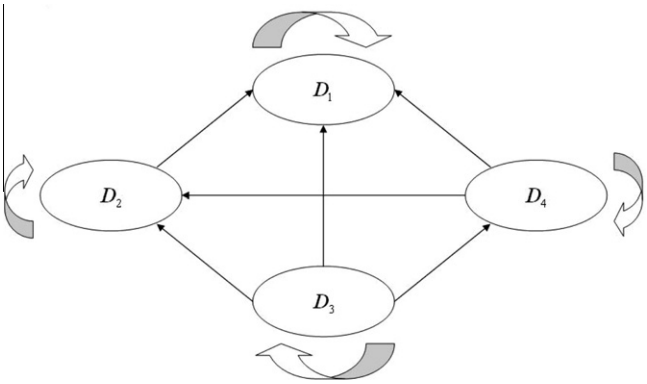


Fig. 5. The analytic network based on the casual diagram of total relationships.

and social relations (D_2), which are sequent as (a) respect, caring and teamwork (C_5), (b) cultural learning and international understanding (C_6), (c) expression, communication, and sharing (C_4) and (d) planning, organizing and putting plans into practice (C_7).

4.3. Calculating the weights of determinants by ANP

Setting an appropriate assessment system as the goal, pairwise comparisons of the determinants were executed based on the total relationship matrix as deduced by DEMATEL. The inter-relationships between the goal and the dimensions of determinants of an assessment system are illustrated in Fig. 5 where the direction of the arrows indicates the direction of the influences. Finally, the total relationship matrix serves as inputs for the ANP. By implementing the ANP, the limit super matrix W is calculated. Weights corresponding to each determinant (Table 5) are derived accordingly that will be used for the calculation of weighted averages and VIKOR scores.

4.4. Compromise ranking by VIKOR

The VIKOR technique being introduced for compromise ranking was applied after the determinants' weight calculations by ANP in sub Section 4.3. Meanwhile, the weighted averages for the Mandarin Chinese teaching materials (six books) for Grade 1 in primary school, which were edited by three leading publishers, are also calculated for comparison. In general, the calculation results (Table 6–8) demonstrate that both global and local reached the same conclusions: publisher A $\succ$ publisher C $\succ$ publisher B.

4.5. Discussions and implications

Authoring teaching material is not an easy task. Meanwhile, there are no straightforward answers to the question of how teaching material should be authored to meet particular criteria. Not only criteria but also determinant, how teaching material should be authoring by considering factors being related to the authored curriculum. Also, from the perspective of MCDM, very little research has addressed the assessment system for teaching material, not to mention Mandarin Chinese teaching materials. In this research, a novel MCDM framework combining the DEMATEL technique, ANP and VIKOR was proposed to address the above-mentioned problems; using this technique yielded satisfactory results.

The novel MCDM model consisting of DEMATEL, ANP and VIKOR was formed as follows: (1) overcome the issue of defining the assessment system for teaching material; (2) use innovative traditional MCDM approaches to resolve the problem of defining the assessment system for teaching material; (3) clarify the vague correlations between the determinants of teaching material; and (4) create the aspired priorities for the authored teaching material.

For the assessment system for teaching materials, CCs were selected as determinants of the assessment, and categorized into 4 groups as the criteria of the assessment. These groups were as follows;

D_1: Physical, mental, and spiritual mold
- C_1: Self-understanding and exploration of potential;
- C_2: Appreciation, representation, and creativity;
- C_3: Career planning and lifelong learning;

D_2: Interpersonal and social relations
- C_4: Expression, communication, and sharing;
- C_5: Respect, care and teamwork;
- C_6: Cultural learning and international understanding;
- C_7: Planning, organizing and putting plans into practice;

D_3: The use of Life Science and Technology
- C_8: Utilization of technology and information;

D_4: Logical thinking and reasoning
- C_9: Active exploration and study;
- C_{10}: Independent thinking and problem-solving.

Through application studies, we found the novel MCDM model to be applicable. DEMATEL establishes a reasonable assessment structure for dealing with criteria influence. Basically, the influence relationships of the results (see Fig. 6) were quite reasonable:

Table 5
Weights of the determinants being derived by ANP.

CC	Local weights	Globe weights (ANP)
D_1: Physical, mental, and spiritual mold	0.3014	
C_1: Self-understanding and exploration of potential	0.3377	0.1018
C_2: Appreciation, representation, and creativity	0.3312	0.0998
C_3: Career planning and lifelong learning	0.3312	0.0998
D_2: Interpersonal and social relations	0.4054	
C_4: Expression, communication, and sharing	0.2656	0.1077
C_5: Respect, care and teamwork	0.2455	0.0995
C_6: Cultural learning and international understanding	0.2335	0.0947
C_7: Planning, organizing and putting plans into practice	0.2554	0.1035
D_3: The use of Life Science and Technology	0.0895	
C_8: Utilization of technology and information	1.0000	0.0895
D_4: Logical thinking and reasoning	0.2037	
C_9: Active exploration and study	0.4959	0.1010
C_{10}: Independent thinking and problem-solving	0.5041	0.1027

Table 6
Satisfaction of Grade 1 Curriculum.

CC	A Publisher		B Publisher		C Publisher	
	11	12	11	12	11	12
D_1: Physical, mental, and spiritual mold						
C_1: Self-understanding and exploration of potential	6.0000	5.7500	5.5000	5.2500	6.2500	6.2500
C_2: Appreciation, representation, and creativity	6.5000	6.7500	5.5000	7.0000	5.7500	7.2500
C_3: Career planning and lifelong learning	5.7500	4.7500	4.2500	4.5000	6.2500	4.7500
D_2: Interpersonal and social relations						
C_4: Expression, communication, and sharing	6.7500	7.5000	6.0000	6.5000	6.2500	7.2500
C_5: Respect, care and teamwork	6.7500	6.2500	6.2500	6.5000	6.5000	6.5000
C_6: Cultural learning and international understanding	5.2500	4.0000	4.2500	4.2500	4.0000	4.0000
C_7: Planning, organizing and putting plans into practice	5.0000	5.0000	4.5000	4.7500	4.5000	4.2500
D_3: The use of Life Science and Technology						
C_8: Utilization of technology and information	3.7500	3.7500	4.0000	4.7500	4.5000	4.5000
D_4: Logical thinking and reasoning						
C_9: Active exploration and study	5.0000	5.2500	4.2500	4.2500	4.7500	4.5000
C_{10}: Independent thinking and problem-solving	5.2500	4.7500	4.7500	4.5000	5.0000	6.0000

Remark: 11: the 1st Semester of Grade 1; 12: the 2nd Semester of Grade 1.

Table 7
Aspired level for Grade 1 Curriculum.

Criterion of CC	Local weights	Global weights (ANP)	A Publisher		B Publisher		C Publisher	
			11	12	11	12	11	12
D_1: Physical, mental, and spiritual mold	**0.3014**	S_i	**0.3917**	**0.4250**	**0.4914**	**0.4419**	**0.3916**	**0.3916**
		Q_i	**0.4250**	**0.5250**	**0.5750**	**0.5500**	**0.4250**	**0.5250**
C_1: Self-understanding and exploration of potential	0.3377	0.1018	0.4000	0.4250	0.4500	0.4750	0.3750	0.3750
C_2: Appreciation, representation, and creativity	0.3312	0.0998	0.3500	0.3250	0.4500	0.3000	0.4250	0.2750
C_3: Career planning and lifelong learning	0.3312	0.0998	0.4250	0.5250	0.5750	0.5500	0.3750	0.5250
D_2: Interpersonal and social relations	**0.4054**	S_i	**0.4047**	**0.4263**	**0.4730**	**0.4472**	**0.4661**	**0.4459**
		Q_i	**0.5000**	**0.6000**	**0.5750**	**0.5750**	**0.6000**	**0.6000**
C_4: Expression, communication, and sharing	0.2656	0.1077	0.3250	0.2500	0.4000	0.3500	0.3750	0.2750
C_5: Respect, care and teamwork	0.2455	0.0995	0.3250	0.3750	0.3750	0.3500	0.3500	0.3500
C_6: Cultural learning and international understanding	0.2335	0.0947	0.4750	0.6000	0.5750	0.5750	0.6000	0.6000
C_7: Planning, organizing and putting plans into practice	0.2554	0.1035	0.5000	0.5000	0.5500	0.5250	0.5500	0.5750
D_3: The use of Life Science and Technology	**0.0895**	S_i	**0.6250**	**0.6250**	**0.6000**	**0.5250**	**0.5500**	**0.5500**
		Q_i	**0.6250**	**0.6250**	**0.6000**	**0.5250**	**0.5500**	**0.5500**
C_8: Utilization of technology and information	1.0000	0.0895	0.6250	0.6250	0.6000	0.5250	0.5500	0.5500
D_4: Logical thinking and reasoning	**0.2037**	S_i	**0.4874**	**0.5002**	**0.5498**	**0.5624**	**0.5124**	**0.4744**
		Q_i	**0.5000**	**0.5250**	**0.5750**	**0.5750**	**0.5250**	**0.5500**
C_9: Active exploration and study	0.4959	0.1010	0.5000	0.4750	0.5750	0.5750	0.5250	0.5500
C_{10}: Independent thinking and problem-solving	0.5041	0.1027	0.4750	0.5250	0.5250	0.5500	0.5000	0.4000
Integration	**1.0000**	S_i	**0.4374**	**0.4587**	**0.5056**	**0.4760**	**0.4606**	**0.4446**
		Q_i	**0.6250**	**0.6250**	**0.6000**	**0.5750**	**0.6000**	**0.6000**

Remark: 11: the 1st Semester of Grade 1; 12: the 2nd Semester of Grade 1.

(a) The aim of education is to foster students' sound mind and character – first, enhancing "D_3: The use of Life Science and Technology" may strengthen "D_4: Logical thinking and reasoning" for students; then, improving "D_2: Interpersonal and social relations" becomes the goal; finally, the curriculum goal gives students a "D_1: Physical, mental, and spiritual mold".

Table 8
VIKOR versus weighted average results.

	v	A Publisher		B Publisher		C Publisher	
		11	12	11	12	11	12
D_1 Physical, mental, and spiritual mold	(S_i) v = 1	0.0016(4)	0.3350(3)	1.0000(1)	0.5041(2)	0.0000(6)	0.0001(5)
	v = 0.5	0.0008(5)	0.5008(3)	1.0000(1)	0.6687(2)	0.0000(6)	0.3334(4)
	(Q_i) v = 0	0.0000(5)	0.6667(3)	1.0000(1)	0.8333(2)	0.0000(5)	0.6667(3)
D_2 Interpersonal and social relations	(S_i) v = 1	0.0000(6)	0.3153(5)	1.0000(1)	0.6223(3)	0.8984(2)	0.6031(4)
	v = 0.5	0.0000(6)	0.6577(5)	0.8750(2)	0.6862(4)	0.9492(1)	0.8015(3)
	(Q_i) v = 0	0.0000(6)	1.0000(1)	0.7500(4)	0.7500(4)	1.0000(1)	1.0000(1)
D_3The use of Life Science and Technology	(S_i) v = 1						
	v = 0.5	1.0000(1)	1.0000(1)	0.7500(3)	0.0000(6)	0.2500(4)	0.2500(4)
	(Q_i) v = 0						
D_4 Logical thinking and reasoning	(S_i) v = 1	0.1478(5)	0.2933(4)	0.8568(2)	1.000(1)	0.4319(3)	0.0000(6)
	v = 0.5	0.0739(6)	0.3133(5)	0.9284(2)	1.0000(1)	0.3826(3)	0.3333(4)
	(Q_i) v = 0	0.0000(6)	0.3333(4)	1.0000(1)	1.0000(1)	0.3333(4)	0.6667(3)
Integration	(S_i) v = 1	0.0000(6)	0.3133(4)	1.0000(1)	0.5671(2)	0.3403(3)	0.1069(5)
	v = 0.5	0.5000(3)	0.6567(2)	0.7500(1)	0.2836(6)	0.4201(4)	0.3034(5)
	(Q_i) v = 0	1.0000(1)	1.0000(1)	0.5000(3)	0.0000(6)	0.5000(3)	0.5000(3)

Remark: 11: the 1st Semester of Grade 1; 12: the 2nd Semester of Grade 1.

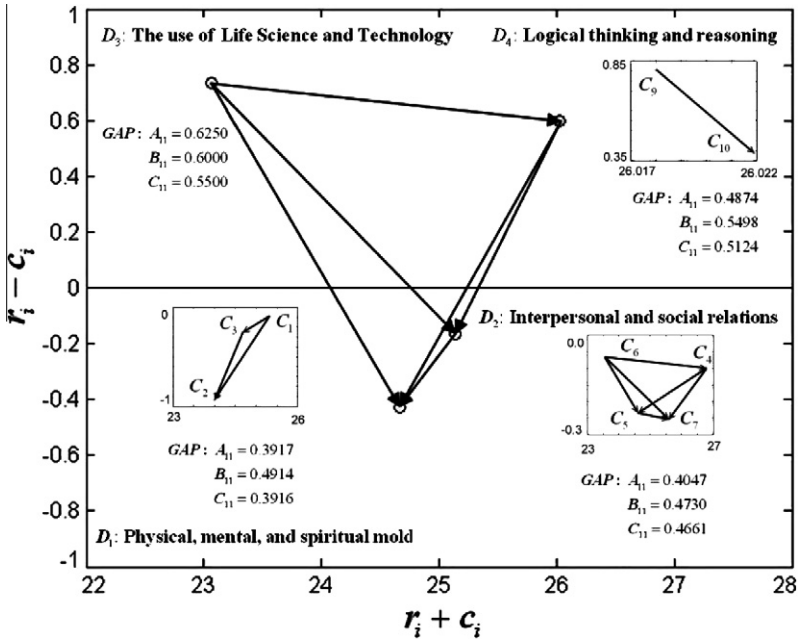


Fig. 6. The causal diagram of total relationship.

(b) For "D_4: Logical thinking and reasoning", "C_9: Active exploration and study" is better than "C_{10}: Independent thinking and problem-solving" from the well-known Knowledge Management point of view.
(c) For "D_2: Interpersonal and social relations", starting from "C_6: Cultural learning and international understanding" may shorten the spiritual distance of the individual; then, there will be improvement in "C_4: Expression, communication, and sharing"; naturally, "C_5: Respect, care and teamwork" will be consolidated; and "C_7: Planning, organizing and putting plans into practice" will be thoroughly considered.
(d) For "D_1: Physical, mental, and spiritual mold", "C_2: Appreciation, representation, and creativity" are the benchmark of "C_1: Self-understanding and exploration of potential"; in particular, "C_3: Career planning and lifelong learning" is bright and healthy.

ANP provides a general framework for dealing with decisions without making assumptions about the independence of higher-level elements from lower-level elements and about the independence of the elements within a level as in a typical hierarchy (Saaty, 2005). Thus, in defining the assessment system for teaching material illustrated in the paper, ANP is apparently a more reasonable tool for analysing the network structure with feedback. Indeed, the weighting sequence for the CCs (see Table 5) is seemingly the priority in the practice of CCs. It is contracted with the influence relationships mentioned above using the DEMATEL technique. For long-term concerns, who is responsible for assessing teaching materials is a serious concern.

The VIKOR method uses an aggregating function R representing "closeness to the ideal". In comparison with the TOPSIS, which determines a solution with the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution (Chen & Hwang, 1992; Tzeng, Shiau, & Teng, 1994), VIKOR can se-

lect the real "closest to the ideal" solution. On the other hand, a solution by TOPSIS is not always the closest to the ideal. A detailed comparison of TOPSIS and VIKOR has already been presented in the article by Opricovic and Tzeng (Opricovic & Tzeng, 2004, 2007).

Furthermore, the L_p-*metric* of VIKOR represents the grouping level in power p; in other words, $p = 1$ is the most emphasized group utility; $p = \infty$ represents the most emphasized individuals. For example (see Table 8), regarding Book 11 from A Publisher, one can say that when $v = 1, R_{D_1} = 0.0016, R_{D_2} = 0.0000, R_{D_3} = 1.0000, R_{D_4} = 0.1478, R_{A_{11}} = 0.0000$, and the sequences are, respectively, 4, 6, 1, 5, and 6. However, when $v = 0$, $R_{D_1} = 0.0000, R_{D_2} = 0.0000, R_{D_3} = 1.0000, R_{D_4} = 0.0000, R_{A_{11}} = 1.0000$, and the sequences are, respectively, 5, 6, 1, 6, and 1. In this case, Book 11 from A Publisher has good behavior on average, but D_3 is the worst. Thus, when $v = 0.5$, the integration sequence is 3. This means that improving D_3 will achieve higher performance. In contrast, Book 12 from B Publisher may indicate the reverse conclusion.

5. Concluding remarks

Based on effective concern, begin from Mandarin Chinese. This paper would have mainly advanced work in the field of the assessment system for teaching materials.

First, a novel MCDM framework was proposed to define the determinants of teaching materials (not exclusively for Mandarin Chinese).

Second, the traditional problem of the difficulty of defining the assessment system for teaching materials was resolved based on the novel MCDM approach being proposed. An important reasoning conclusion was obtained: the more important determinant, the less influent determinant. The influent sequence of determinants is as follows: The use of Life Science and Technology ($\boldsymbol{D}_3$) $\succ$ Logical thinking and reasoning ($\boldsymbol{D}_4$) $\succ$ Interpersonal and social relations ($\boldsymbol{D}_2$) $\succ$ Physical, mental, and spiritual mold ($\boldsymbol{D}_1$) (see Fig. 5). However, the weighting sequence of determinants is as follows: Interpersonal and social relations ($\boldsymbol{D}_2$,0.4054) $\succ$ Physical, mental, and spiritual mold ($\boldsymbol{D}_1$,0.3014) $\succ$ Logical thinking and reasoning ($\boldsymbol{D}_4$,0.2037) $\succ$ The use of Life Science and Technology ($\boldsymbol{D}_3$,0.0895) (see Table 5).

Finally, the difficulty of the traditional MCDM approach in selecting "rotten apple(s)" was also resolved based on the conceptual advance in achieving the aspired level of criteria.

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