ASSESSMENT MODEL FOR IMPROVING EDUCATIONAL CURRICULUM MATERIALS BASED ON THE DANP TECHNIQUE WITH GREY RELATIONAL ANALYSIS

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Keywords: Teaching curriculum materials, MCDM (multiple criteria decision making), DANP (DEMATEL-based ANP), GRA (grey relational analysis).

Abstract: The core objective of the integrated curriculum of compulsory education is to "enable students to demonstrate their network-talents instead of just scoring high on independent exams." The key to determining education reform strategies in the e-era is to establish network-competence indicators for educational behavior in primary schools. We propose a MCDM means for evaluating, comparing and improving the effectiveness of network-competence indicators in various publications that are used for teaching at the primary school level. The Mandarin Chinese teaching curriculum based on this system is provided to verify the effectiveness of our method, which may extend to other subject areas.

1 INTRODUCTION

Most countries have made the cultivation of human talent a priority in the twenty-first century. As other advanced countries propose education reform, Taiwan also views education as the bedrock of national development. Taiwan has implemented various education reforms, such as preschool education reform, curriculum reforms for grades 1-9, the restructuring of secondary education, the enhancement of higher education, and projects to promote lifelong learning. This study proposes a set of techniques and evaluation methods to improve, reconfigure and select the most appropriate Aspiring Intelligent Grey Relational Assessment System (AIGRAS) for improving the teaching materials in our education system.

Four British educational reform projects have been implemented since 1990 (DfE, 1991). The report of the Mayer Committee advised the Australian Education Council and the Ministers for Vocational Education, Employment and Training on employment-related key competencies for post-compulsory education and training (Mayer, 1992). The Education Commission of Hong Kong proposed "Learning is the key to one's future, and education is the gateway to our society's tomorrow" (EC, 2000).

Regardless of the style of educational reform, key competencies are generally the major concern for national reforms at the beginning of the twenty-first century.

The core objective of the Nine-Year Integrated Curriculum of compulsory education in Taiwan is to "enable students to demonstrate their network-talents instead of just scoring high on independent exams." The key to determining education reform is to establish network-competence indicators of targeted educational standards in primary school and junior high school (MOE, 2002).

Therefore, in this study, we propose a new MCDM (multiple criteria decision making) method for evaluating, comparing and improving the effectiveness of competence indicators in the various publications used for curriculum materials in primary schools. The DANP (DEMATEL-based ANP) (decision making trial and evaluation laboratory, DEMATEL; analytic network process, ANP) influential weights are based on getting the total relationship/influence-related matrix by DEMATEL technique, using an MCDM approach to solve and address the network-relational problems of

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dependence and feedback involving various criteria. Next, a grey relational analysis (GRA) technique with DANP influential weights is proposed to determine and implement the best performance indicator related to each criterion for improving, reconfiguring and selecting AIGRAS for the development of curriculum materials. An empirical study involving three publishers based on this system design is provided to verify the effectiveness of the proposed methods. This design may improve the efficiency and quality of Mandarin Chinese teaching curriculum materials; moreover, our work may also apply to other subject areas.

The remainder of this paper is organized as follows. In Section 2, AIGRAS for teaching curriculum materials with MCDM are introduced. In Section 3, a MCDM method based on the DANP method is proposed. In Section 4, an empirical study involving AIGRAS for Mandarin Chinese teaching materials is presented to demonstrate our proposed method, and we discuss the results. Finally, in Section 5, we offer concluding remarks.

2 AIGRAS FOR TEACHING CURRICULUM MATERIALS WITH MCDM

In recent decades, competency-based education has become a major trend, influencing the educational reform strategies of most governments worldwide. In the following subsection, we review the related literatures describing core competencies (CCs) and the intertwined effects of an assessment system for teaching materials as a foundation for the development of a theoretical framework.

2.1 Educational Reform in Taiwan (MOE, 2002, 2008)

Taiwan must engage in educational reform to meet the needs of the twenty-first century, respond to global education reform trends, foster national competitiveness and boost the overall quality of our citizens' lives.

The Ministry of Education (MOE) of Taiwan has initiated curricular and instructional reforms in primary school and junior high school education. These reforms are based on the Action Plan for Educational Reform approved by the Executive Yuan of Taiwan. Because the curriculum represents not only the core of schooling but also the foundation on which teachers plan learning activities, the MOE places the greatest emphasis on the development and implementation of curriculum reforms for grades 1-9. These timely reforms are necessary to meet: (1) national development needs and (2) public expectations with respect to the next generation.

A major goal of education is to nourish each student's mind and character. Every legitimate government hopes that its school system will produce outstanding citizens with both a sense of patriotism and the ability to adopt a global perspective. In essence, education is a learning process that helps students explore their potential and develop their capacity to adapt and improve their living environments. In this new century, the following five basic aspects are emphasized and included in the curricula for grades 1-9: (1) developing humanitarian attitudes, (2) enhancing the ability to integrate, (3) cultivating democratic literacy, (4) fostering both indigenous awareness and a global perspective, and (5) building a capacity for lifelong learning.

For both primary schools and junior high schools, the aim of national education is to teach students basic networking knowledge and to develop the capacity for lifelong learning. To cultivate able citizens, we hope to engender mental and physical health, vigour and optimism, gregariousness and helpfulness, intellectual curiosity, reflection, tolerance, creativity, a positive attitude and a global perspective. To accomplish this, the curriculum design of primary school and junior high school education should focus on the needs and experiences of students and on developing CCs relevant to modern citizens. Such CCs are referred to as key competencies and, as defined by the Mayer Committee, should: (1) collect, analyze and organize information; (2) communicate ideas and information; (3) plan and organize activities; (4) cooperate with others and help sustain the group's ability to work; (5) use mathematical concepts and technologies; (6) solve problems; and (7) use technology (Mayer, 1992).

In Taiwan, the CCs applicable to curriculum reforms in grades 1-9 (MOE, 2002) can be categorized as follows: (1) self-understanding and exploration of potential; (2) appreciation, representation, and creativity; (3) career planning and lifelong learning; (4) expression, communication, and sharing; (5) respect, care and teamwork; (6) cultural learning and international understanding; (7) planning, organizing, and putting plans into practice; (8) use of technology and information; (9) active exploration and study; and (10) independent thinking and problem solving.

With reference to curricular principles, CCs can be organized into four basic categories: (A) physical, mental and spiritual mold (1-3); (B) interpersonal and social relations (4-7); (C) the use of life science and technology (8); and (D) logical thinking and reasoning (9-10).

To foster CCs in citizens, the curricula for primary school and junior high school education should emphasize three dimensions, including individual development, community and culture, and the natural environment. Thus, curricula in grades 1-9 encompasses include seven major learning areas: (1) Language Arts, (2) Health and Physical Education, (3) Social Studies, (4) Arts and Humanities, (5) Science and Technology, (6) Mathematics, and (7) Integrative Activities.

2.2 AIGRAS with the MCDM Method

"Decision-making is as old as man." The MCDM method may be applied for computer-aided learning (Quaddus, 1997). Most research has concentrated on evaluating the quality of web-based learning by the MCDM method (Hwang et al., 2004; Shee & Wang, 2008; Lin, 2010). A MCDM method based on the DEMATEL technique for evaluating a private university of science and technology in Taiwan has been proposed by Tseng (2010).

A MCDM method based on the DEMATEL technique for assessing Mandarin Chinese teaching curriculum materials was first proposed by the authors. MCDM frameworks exist for teaching curricula so that we can judge the quality of the teaching materials, but these frameworks are vague, even if clear CCs are used as the basis for the criteria. In this paper, we propose an AIGRAS technique in which the grey relational grade is used to rank the indices between the performance ratings of various curriculum materials.

3 A MCDM METHOD BASED ON THE DANP TECHNIQUE

The structure of the MCDM problem will be derived using the DEMATEL technique. The priorities of each determinant are based on the structure derived by using ANP. The GRA technique will be leveraged to calculate the degree of alternatives to be close the aspiring levels. Finally, the assessment system for obtaining the best teaching curriculum materials will be derived. In summary, this evaluation framework consists of four main phases (see Figure 1).

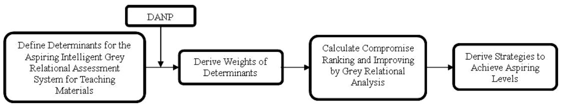


Figure 1: An analytical framework for the aspiring assessment systems of teaching materials.

3.1 DANP Technique

The DEMATEL technique was developed by the Battelle Geneva Institute to analyze complex "world problems" dealing mainly with interactive man-model techniques. A second goal was to evaluate qualitative and factor-linked aspects of societal problems (Gabus & Fontela, 1972). The applicability of the method is broad, with applications ranging from industrial planning and decision-making to urban planning and design, regional environmental assessment, the analysis of global problems, and so forth. This technique has also been successfully applied in many situations and contexts, such as creating marketing strategies, control systems and safety solutions and developing the competencies of global managers and group decision-making (Chen et al., 2010; Chiu et al., 2006; Lee et al., 2009; Li & Tzeng, 2009; Lin & Wu, 2008; Ou Yang et al., 2008; Wu & Lee, 2007). Furthermore, a hybrid model combining the two methods has been widely used in such fields as e-learning evaluation (Tzeng et al., 2007), airline safety measurement (Liou et al., 2007), and innovation policy portfolios for Taiwan's SIP Mall (Huang et al., 2007).

In this paper, we use DEMATEL not only to detect complex relationships and build a network relation map (NRM) of the criteria but also to calculate the inter-relational influence levels of each element. We developed/adopted these influence level values as the basis of the normalization supermatrix for determining ANP influential weights of each criterion. To apply DEMATEL, we refined the definitions based on the above references and produced new essential definitions, as indicated below. We based the DEMATEL technique on graph theory so that we could divide multiple criteria into cause and effect groups. Directed influence graphs (also called digraphs) are more useful than directionless graphs. A digraph typically represents a communication network-relation or a domination relationship between individuals.

Suppose that a system contains a set of elements $S=\{s_1,s_2,\cdots,s_n\}$ and that particular pair-wise relationships are used for modeling with respect to a mathematical relationship (MR). Next, consider the relationship MR as a direct-relation matrix that is indexed equally in both dimensions using elements from set *S*. Then, extract the case for which the number appears in the cell (i,j). If the entry is a positive integral, it means the ordered pair (s_i, s_j) is in the relationship MR; and its relationship is such that s_i has an effect on s_j. The digraph portrays a contextual relationship between the elements of the system in which a numeral represents the strength of influence (Figure 2). The number between factors is the degree of influence. For example, an arrow from s_1 to s_2 represents the fact that s_1 influences s_2 and that its degree of influence is 2. The DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible network-structural model of the system (Chiu et al., 2006).

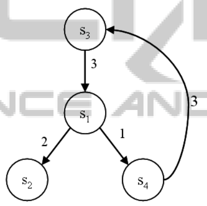


Figure 2: An example of a directed graph.

The pair-wise comparison scale features five levels, where the scores 0, 1, 2, 3 and 4 represent the range from "no influence (0)" to "very high influence (4)" By experts.

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

The initial direct-relation matrix A is the $n \times n$ matrix obtained by pair-wise comparisons in terms of influences and directions between the determinants in which a_{ij} is denoted as the degree to which the i^{th} determinant affects the j^{th} determinant.

The normalized direct-relation matrix N can be calculated from Equation (1) in which all principal diagonal elements are equal to zero.

$$N = zA \tag{1}$$

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

In this case, N is called the normalized matrix. Then, the total relationship / influence-related matrix T can be obtained

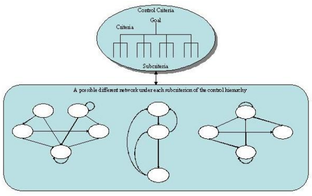
$$T = N + N^2 + \cdots + N^{\infty} = N(I - N)^{-1} \tag{2}$$

where I stands for the identity matrix, N is a direct influence matrix and $N = \left[x_{ij} \right]_{n \times n}$. $N^2 + \cdots + N^{\infty}$ stands for an indirect influence matrix. $0 \le x_{ij} < 1$, $0 < \sum_i x_{ij} \le 1$, $0 < \sum_j x_{ij} \le 1$ and at least one column sum $\sum_j x_{ij}$ or one row sum $\sum_i x_{ij}$ equals 1, but not all; hence, $\lim_{h \to \infty} N^h = [0]_{n \times n}$. The element t_{ij} of matrix T denotes the direct and indirect influences of factor i on factor j.

The row sum $r_i = \sum_{j=1}^{n} t_{ij}$ and column sum $c_j = \sum_{i=1}^{n} t_{ij}$ of the total-relation matrix T are denoted through $T = \left[t_{ij} \right],\ i,j \in \{1,2,\cdots,n\}$, then $r = [r_i]_{n \times 1} = \left[\sum_{j=1}^{n} t_{ij} \right]_{n \times 1}$ and $c = [c_j]_{n \times 1} = \left[\sum_{i=1}^{n} t_{ij} \right]'_{1 \times n}$ where the vectors r and c denote the sums of the rows and columns, respectively.

Suppose that r_i denotes the row sum of the i^{th} row of matrix T, and, c_j denotes the column sum of the j^{th} column of matrix T, when $i = j$, $(r_i + c_i)$ represents the index indicating the strength of both the dispatching and receiving influences. Furthermore, $(r_i - c_i)$ is the degree of the central role that factor i plays in the problem. If $(r_i - c_i)$ is positive, then factor i will primarily exert influence upon the strength of other factors, and if $(r_i - c_i)$ is negative, then factor i will primarily be influenced by other factors (Huang et al., 2007; Liou et al., 2007).

Consequently, the ANP method, a multi-criteria theory of measurement developed by Saaty (1996), provides a general framework to deal with decision-making problems 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. ANP is different from traditional MCDM methods (Saaty, 2005). For example, AHP (Analytic Hierarchy Process), TOPSIS, ELECTRE, et al. usually assume independence between criteria. ANP is a new theory that extends AHP to address dependence in feedback and utilizes the supermatrix approach (Saaty, 2003). ANP is a more reasonable tool for dealing with complex MCDM problems in the real world. ANP features two parts. The first consists of a control hierarchy or network of criteria and sub-criteria that control all interactions. The second is a network of influences among the elements and clusters. A control hierarchy is a hierarchy of criteria and sub-criteria for which priorities are derived in the usual way with respect to the goal of the system being considered. However, we build the hierarchical structure of the network relation map (NRM) with dependency and feedback problems in real situations, as shown in Figure 3.



Source: Saaty 1996

Figure 3: The control hierarchy.

The analysis of priorities in a system can be considered in terms of a control hierarchy, with dependence among its bottom-level alternatives arranged as a network relation, as shown in Figure 3. Dependence can occur both within and between components.

Therefore, a hierarchy structure of NRM for decision-makers (such as Figure 3) can be derived by the DEMATEL technique. Based on NRM, a supermatrix $\boldsymbol{W}$ for ANP as clusters $\boldsymbol{C}_h$, $h=1,\cdots,m$ can be obtained, where cluster $\boldsymbol{C}_h$ resides in the h^{th} dimension; we assume that $\boldsymbol{C}_h$ has n_h elements (determinants), which we denote as $e_{h1}, e_{h2}, \cdots, e_{hn_h}$. The influences of a given set of elements (determinants) in a component (dimension) on any element in the decision system are represented by a ratio scale priority vector derived from pair-wise comparisons of the relative importance of one criterion to 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 supermatrix is as follows:

$$\boldsymbol{W}=\begin{array}{cc} & \begin{array}{ccccccccc} & \boldsymbol{C}_1 & & & \boldsymbol{C}_2 & & \cdots & \boldsymbol{C}_m & \\ e_{11} & \cdots & e_{1n_1} & e_{21} & \cdots & e_{2n_2} & \cdots & e_{m1} & \cdots\ e_{mn_m}\end{array} \\ \begin{array}{c} \boldsymbol{C}_1 \begin{array}{c} e_{11}\\ \vdots \\ e_{1n_1}\end{array} \\ \boldsymbol{C}_2 \begin{array}{c} e_{21}\\ \vdots \\ e_{2n_2}\end{array} \\ \vdots \quad \vdots \\ \boldsymbol{C}_m \begin{array}{c} e_{m1}\\ \vdots \\ e_{mn_m}\end{array} \end{array} & \begin{bmatrix} \boldsymbol{W}_{11} & \boldsymbol{W}_{12} & \cdots & \boldsymbol{W}_{1m} \\ \boldsymbol{W}_{21} & \boldsymbol{W}_{22} & \cdots & \boldsymbol{W}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{W}_{m1} & \boldsymbol{W}_{m2} & \cdots & \boldsymbol{W}_{mm} \end{bmatrix} \end{array}$$

A typical entry $\boldsymbol{W}_{ij}$ in the supermatrix is called a block of the supermatrix in the following form, where each column of $\boldsymbol{W}_{ij}$ is a principal eigenvector of the influence of the elements (determinants) in the i^{th} component of the network on an element (determinants) in the j^{th} component. Some of the entries may be zero, corresponding to those elements (determinants) that have no influence.

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

After forming the supermatrix, the weighted supermatrix is derived by precisely transforming the sum of all columns to unity for normalization. This step is similar to the concept of the Markov chain in terms of ensuring that the sum of the probabilities of all states equals 1. Next, the weighted supermatrix is raised to limiting powers, such as $\lim_{\theta\to\infty}\boldsymbol{W}^{\theta}$, to obtain the constant values of global priority vectors, or so-called weights (Huang et al., 2005).

3.2 Grey Relation for Evaluation

Since Deng (1982) proposed the grey theory, related models have been developed and applied to MCDM problems. Similar to fuzzy set theory, the grey theory is a practical mathematical approach that can be used to deal with systems analysis characterized by inadequate information. Fields covered by the grey theory include systems analysis, data processing, modeling, prediction, decision-making, and control engineering (Deng, 1985, 1988, 1989; Tzeng et al., 2002; Tzeng & Tasur, 1994). In this section, we briefly review the calculation process for the grey relation model. This research modifies the definitions used by Chiou and Tzeng (2001). GRA is used to determine the relationship between two sequences of stochastic data in a grey system. The procedure bears some similarity to pattern recognition technology. One sequence of data is called the "reference pattern" or "reference sequence," and the correlation between the other sequence and the reference sequence remains to be identified (Deng, 1986; Tzeng & Tasur, 1994; Wu et al., 1996). In this study, we use these concepts to determine how to improve the degree of grey relations from the performance values to reach the aspired values for various publishers (called alternatives) who create textbooks for Taiwanese school children.

Let the initial relationship matrix $\boldsymbol{A}$ be a $m\times n$ matrix, where there are m alternatives and n criteria, obtained by surveying the relationships following normalization, such as

$$
\begin{array}{cc}
 & \boxed{\text{Criteria}} \\
\text{Alternatives} & \begin{array}{ccccc} c_1 & \cdots & c_j & \cdots & c_n \\ w_1 & \cdots & w_j & \cdots & w_n \end{array} \\
\begin{array}{c} x_1 \\ \vdots \\ x_k \\ \vdots \\ x_m \end{array} & \begin{bmatrix} x_1(1) & \cdots & x_1(j) & \cdots & x_1(n) \\ \vdots & & \vdots & & \vdots \\ x_k(1) & \cdots & x_k(j) & \cdots & x_k(n) \\ \vdots & & \vdots & & \vdots \\ x_m(1) & \cdots & x_m(j) & \cdots & x_m(n) \end{bmatrix} \\
\text{Aspiring value } x^* & \begin{array}{ccccc} x^*(1) & \cdots & x^*(j) & \cdots & x^*(n) \end{array}
\end{array}
$$

Therefore, coefficients of grey relation for the aspiring values are

$$\gamma(x^*(j),x_k(j)) = \frac{\min_k \min_j |x^*(j)-x_k(j)| + \varsigma \max_k \max_j |x^*(j)-x_k(j)|}{|x^*(j)-x_k(j)| + \varsigma \max_k \max_j |x^*(j)-x_k(j)|} \quad (3)$$

Then, the grade (degree) of the grey relation is obtained so that larger is better:

$$\gamma(x^*,x_k) = \sum_{j=1}^{n} w_j \gamma(x^*(j),x_k(j)) \quad (4)$$

where the weight w_j can be obtained by DANP.

4 AN EMPIRICAL STUDY OF AIGRAS FOR MANDARIN CHINESE TEACHING MATERIALS

In this section, an example modified from a real case will be presented to demonstrate the effectiveness of the proposed MCDM framework with the DANP technique including the grey relational assessment. One empirical example focuses on the experiences of three leading textbook publishers.

In this case study, we look at Mandarin Chinese curriculum materials (six textbooks) for primary school children in grade 1.

4.1 Background (MOE, 2002, 2008)

In the twenty-first century, major changes have taken place in social, political, economic and cultural arenas. These changes are both national and global. Given the drastic changes brought about by the e-era, most countries have become aware of the importance of education and culture. Educational reform in these countries has been carried out to foster personal potential, to modernize, and to promote social progress.

After six decades of post-war development, Taiwan (also called Formosa) has transitioned from a traditional agricultural society into a modern industrial society. Political, economic, and cultural arenas are facing modernization, industrialization and the technological influences of structural adjustment and reconstruction in the e-era. Among the major arenas of reform, the impact of education reform is one of the most far-reaching and has extensive implications. It affects national pride, impacts social consciousness, establishes a new culture and develops the nation's competitiveness in the new century.

With the spread of education and enhancements in quality of life, Taiwan is becoming an educational community. However, many problems have emerged in the development of education over the years, and delays in solving these problems have made them even more complex.

In light of this, the Council on Education Reform of Taiwan was established in September 1994. The Commission's report on educational reform and the development of educational research was presented in December 1996.

In Taiwan, certain issues were addressed to enable reform. The influence of educational reform at both social and personal levels is significant. It is important to ponder the impact of social change and carefully consider how the value of the benchmarks of socio-cultural development may be determined. This is especially true in the context of educational reform.

The Council has proposed a comprehensive proposal for education reform. Given the need to provide proper education for every student, it is clear that schools have not paid adequate attention to disadvantaged students. This has been mainly due to inappropriate compulsory education of Taiwan, where an excessively rigid system and curriculum is coupled with a lack of long-term investment in resources. As a result of weak educational practices, many disadvantaged students fail to build a solid foundation for learning; they are then exposed to large class sizes and a general lack of timely and adequate care. Consequently, their performance falls even further behind that of other students, causing them to feel insecure about school.

At the convening of the Education Reform Committee, the MOE of Taiwan proposed curriculum reforms for grades 1-9 (compulsory education) (MOE, 2002, 2008). A more detailed description is in Subsection 2.1.

The Mandarin Chinese curriculum is one of the curricula included in Language Arts. It is divided into three stages: grades 1-3, grades 4-6, and grades 7-9.

Based on curricular goals and CCs for grades 1-9, the goals of the Mandarin Chinese curriculum included listening, speaking, reading and writing of languages, as well as developing basic communication competencies.

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

Table 1: Competence indicators for the Mandarin Chinese curriculum at each stage.

CCs	Stage 1	Stage 2	Stage 3	Total
D_1: Physical, mental and spiritual mold				
C_1: Self-understanding and exploration of potential	24	19	18	61
C_2: Appreciation, representation, and creativity	20	17	17	54
C_3: Career planning and lifelong learning	9	13	10	32
D_2: Interpersonal and social relations				
C_4: Expression, communication, and sharing	8	9	12	29
C_5: Respect, care and teamwork	9	9	13	31
C_6: Cultural learning and international understanding	6	8	6	20
C_7: Planning, organizing and putting plans into practice	7	7	6	20
D_3: The use of life science and technology				
C_8: Using technology and information	4	11	8	23
D_4: Logical thinking and reasoning				
C_9: Active exploration and study	8	7	9	24
C_{10}: Independent thinking and problem solving	9	8	7	24
Total	104	108	106	318

Data source: MOE, 2002

Based on our chosen analytical framework, CCs were first selected as determinants. The structure of the assessment systems for the Mandarin Chinese teaching materials was then established using DANP. Then, the influential weights of each determinant for the decision structure was identified. The determinants are equivalent to CCs in this research. The criteria were confirmed as competence indicators and as determinants for improving Mandarin Chinese teaching materials. Meanwhile, the relationships between the determinants, the DANP derivations of the weight of each determinant, and the GRA of each determinant were similarly derived for our case study.

4.2 Structuring NRM and Calculating the Influential Weights of Determinants using DANP

The relationships between determinants involving assessment systems for Mandarin Chinese teaching materials were surveyed based on the opinions of teachers in Taiwan who write Mandarin Chinese textbooks (1/3), have taught Mandarin Chinese in primary school (1/3), or have taught other subjects in primary school (1/3). All of the surveyed teachers were familiar with the assessment protocols for Mandarin Chinese in schools.

Our proposed assessment system for Mandarin Chinese will assist publishers in creating better textbooks and will help to determine which assessment strategies can best achieve the aspiring levels of quality of textbooks. Detailed procedures and results are given below.

Table 2: Rating the CCs' relationships matrix ***A*** for grades 1-3: Mandarin Chinese 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

Table 3: Results of the CCs' total relationships matrix ***T*** for grades 1-3: Mandarin Chinese.

		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

The interrelationships between the ten determinants were deduced using the DANP method in Subsection 3.1. First, the direct relation matrix ***A*** was introduced (see Table 2). After that, the direct relation matrix ***A*** was normalized based on Equation (1). The total relationship matrix was then deduced based on Equation (2) (see Table 3). Finally, the strength of the influence for each determinant was deduced (see Table 4 and Figure 4).

Table 4: r_i+c_i and r_i-c_i for the CCs' total relationships for grade 1-3: Mandarin Chinese.

	$r_i + c_i$	$r_i - c_i$
D_1: Physical, mental and spiritual mold	**24.6645(3)**	**-0.4259(4)**
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	**25.1368(2)**	**-0.1634(3)**
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	**23.0685(4)**	**0.7357(1)**
C_8: Using technology and information	23.0685(10)	0.7357(2)
D_4: Logical thinking and reasoning	**26.0200(1)**	**0.5977(2)**
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)

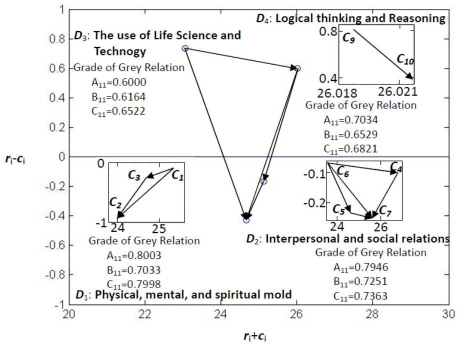


Figure 4: Causal diagram of the total influential relationship.

Table 5: Weights of the determinants derived by DANP.

	Local	Global
***D*₁**: Physical, mental and spiritual mold	**0.3015**	
***C*₁**: Self-understanding and exploration of potential	0.3376	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**: Using 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

With an appropriate assessment system as the goal, pair-wise comparisons of the determinants were calculated based on the total relationship matrix, as deduced by DEMATEL. Note the interrelationships between the goals and the directions of arrows, relationship matrix serves as a set of inputs for ANP. By implementing ANP, the limit supermatrix $\boldsymbol{W}$ can be calculated.

Weights corresponding to each determinant (Table 5) are derived accordingly and may be used to calculate both weighted averages and GRA scores.

4.3 Compromise Rankings Calculated using GRA

After the determinants' weights were calculated using DANP, the GRA technique introduced for compromise ranking was applied. Weighted averages of the six Mandarin Chinese textbooks for grade 1 of primary school, which were edited by three leading publishers (Table 6), were also calculated as comparisons. In general, the calculation results (Table 7) demonstrated that the same conclusions are apparent at both the global and local levels: publisher A ≻ publisher C ≻ publisher B.

Table 6: Satisfaction of grade 1 textbooks.

Dimensions	Criteria	A		B		C	
		11[a]	12[b]	11	12	11	12
D_1	C_1	6.0000	5.7500	5.5000	5.2500	6.2500	6.2500
	C_2	6.5000	6.7500	5.5000	7.0000	5.7500	7.2500
	C_3	5.7500	4.7500	4.2500	4.5000	6.2500	4.7500
D_2	C_4	6.7500	7.5000	6.0000	6.5000	6.2500	7.2500
	C_5	6.7500	6.2500	6.2500	6.5000	6.5000	6.5000
	C_6	5.2500	4.0000	4.2500	4.2500	4.0000	4.0000
	C_7	5.0000	5.0000	4.5000	4.7500	4.5000	4.2500
D_3	C_8	3.7500	3.7500	4.0000	4.7500	4.5000	4.5000
D_4	C_9	5.0000	5.2500	4.2500	4.2500	4.7500	4.5000
	C_{10}	5.2500	4.7500	4.7500	4.5000	5.0000	6.0000

Note: a::11: the 1st Semester of grade 1; b: 12: the 2nd Semester of grade 1

Table 7: Grey relations versus weighted average results.

	Local	Global	A		B		C	
			11[c]	12[d]	11	12	11	12
D_1	**0.3015**		**0.8003(5)**	**0.7722(3)**	**0.7033(1)**	**0.7613(2)**	**0.7998(4)**	**0.8158(6)**
C_1	0.3376	0.1019	0.7895(4)	0.7627(3)	0.7377(2)	0.7143(1)	0.8182(5)	0.8182(5)
C_2	0.3312	0.0998	0.8491(3)	0.8824(4)	0.7377(1)	0.9184(5)	0.7627(2)	0.9574(6)
C_3	0.3312	0.0998	0.7627(5)	0.6716(3)	0.6338(1)	0.6522(2)	0.8182(6)	0.6716(3)
D_2	**0.4054**		**0.7946(6)**	**0.7872(5)**	**0.7251(1)**	**0.7535(3)**	**0.7363(2)**	**0.7686(4)**
C_4	0.2656	0.1077	0.8824(4)	1.0000(6)	0.7895(1)	0.8491(3)	0.8182(2)	0.9574(5)
C_5	0.2455	0.0995	0.8824(6)	0.8182(1)	0.8182(1)	0.8491(3)	0.8491(3)	0.8491(3)
C_6	0.2335	0.0947	0.7143(6)	0.6164(1)	0.6338(4)	0.6338(4)	0.6164(1)	0.6164(1)
C_7	0.2554	0.1035	0.6923(5)	0.6923(5)	0.6522(2)	0.6716(4)	0.6522(2)	0.6338(1)
D_3	**0.0895**		**0.6000(1)**	**0.6000(1)**	**0.6164(3)**	**0.6716(6)**	**0.6522(4)**	**0.6522(4)**
C_8	1.0000	0.0895	0.6000(1)	0.6000(1)	0.6164(3)	0.6716(6)	0.6522(4)	0.6522(4)
D_4	**0.2037**		**0.7034(5)**	**0.6928(4)**	**0.6529(2)**	**0.6431(1)**	**0.6821(3)**	**0.7214(6)**
C_9	0.4959	0.1010	0.6923(5)	0.7143(6)	0.6338(1)	0.6338(1)	0.6716(4)	0.6522(3)
C_{10}	0.5041	0.1027	0.7143(5)	0.6716(2)	0.6716(2)	0.6522(1)	0.6923(4)	0.7895(6)
ζ=0.5			**0.7603(5)**	**0.7467(4)**	**0.6941(1)**	**0.7260(2)**	**0.7368(3)**	**0.7628(6)**

Note: c::11: the 1st Semester of grade 1; d: 12: the 2nd Semester of grade 1.

4.4 Discussions and Implications

Authoring teaching materials is not an easy task. There are no straightforward answers to the question of how teaching materials should be designed to meet particular criteria and determinants, considering that textbooks should generally take into account the relevant curriculum. Very little research addresses assessment systems for Mandarin Chinese teaching materials.

In this study, a MCDM framework that combined the DANP technique and GRA was proposed to address the aforementioned problems. We consider the results satisfactory. This MCDM framework was created to: (a) overcome the issue of defining the assessment system for teaching materials, (b) use innovative but traditional MCDM approaches to resolve the problem of how to define an assessment system for textbooks, (c) explore the vague correlations between the determinants of teaching materials, (d) create target priorities for the resulting teaching materials, and (e) shape vague semantic processing issues, such as defining 'good' and 'very good' assessments.

CCs were selected as determinants for the assessment system. CCs were then categorized into four groups and used as criteria for the assessment. These groups were as follows:

$\boldsymbol{D}_1$: Physical, mental and spiritual mold
- $\boldsymbol{C}_1$: Self-understanding and exploration of potential
- $\boldsymbol{C}_2$: Appreciation, representation, and creativity
- $\boldsymbol{C}_3$: Career planning and lifelong learning

$\boldsymbol{D}_2$: Interpersonal and social relations
- $\boldsymbol{C}_4$: Expression, communication, and sharing
- $\boldsymbol{C}_5$: Respect, care and teamwork
- $\boldsymbol{C}_6$: Cultural learning and international understanding
- $\boldsymbol{C}_7$: Planning, organizing and putting plans into practice

$\boldsymbol{D}_3$: The use of life science and technology
- $\boldsymbol{C}_8$: Using technology and information

$\boldsymbol{D}_4$: Logical thinking and reasoning
- $\boldsymbol{C}_9$: Active exploration and study
- $\boldsymbol{C}_{10}$: Independent thinking and problem solving

Through application studies, we found the MCDM model to be relevant and helpful. DANP establishes a reasonable assessment structure for dealing with the influence of various criteria. The influence relationships pertaining to the results (see Figure 4) were quite reasonable.

(1) The goal of education is to nurture each student's mind and character. First, enhancing "the use of life science and technology" may strengthen "logical thinking and reasoning" for students, which then improves "interpersonal and social relations" and becomes the ultimate goal; finally, this gives students "the physical, mental and spiritual dimensions."

(2) For logical thinking and reasoning, "active exploration and study" is better than "independent thinking and problem solving," consistent with the well-known point of view of knowledge management.

(3) For interpersonal and social relations, starting from "cultural learning and international understanding" may shorten the mental distance for the individual; sharing "expression, communication" should then naturally lead to improvement in "respect, care and teamwork," and "planning, organizing and putting plans into practice" should be thoroughly examined.

(4) For physical, mental and spiritual mold, "self-understanding and exploration of potential" is the benchmark of "career planning and lifelong learning" and "appreciation, representation, and creativity."

DANP suggests 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 typical hierarchy. Therefore, by defining the assessment system for teaching materials as illustrated in the paper, DANP is apparently a more reasonable tool for analyzing network structures with feedback.

The GRA technique uses a grade of the grey relation function $\gamma(x^*, x_k)$ that represents "closeness to the aspiring level." The GRA approach in this paper simply measures the grey relationship of the alternatives with the aspiring level.

In Table 7, globally, the six volumes for $\gamma(x^*, x_k)$ are 0.7603, 0.7467, 0.6941, 0.7260, 0.7368, and 0.7628, and the sequences are 5, 4, 1, 2, 3, and 6, respectively. This means that Book 11 of Publisher B $\prec$ Book 12 of Publisher B $\prec$ Book 11 of Publisher C $\prec$ Book 12 of Publisher A $\prec$ Book 11 of Publisher A $\prec$ Book 12 of Publisher C.

However, if Publisher B were to improve Book 11, for example, the sequences would be (1) the use of life science and technology ($\gamma_{D_3} = 0.6164$), (2) logical thinking and reasoning ($\gamma_{D_4} = 0.6529$), (3) physical, mental and spiritual mold ($\gamma_{D_1} = 0.7033$), then (4) interpersonal and social relationships ($\gamma_{D_2} = 0.7251$).

5 CONCLUDING REMARKS

This paper advances work in the field of teaching material assessment. In response to current concerns, we began with Mandarin Chinese. First, a MCDM framework was proposed to define the determinants of any set of teaching materials (not exclusively for Mandarin Chinese). Second, the traditional problem of the difficulty of defining an assessment system for teaching materials was resolved using the MCDM approach. An important conclusion was that the most important determinants may be the least influential determinants. We concluded that the sequence of influence among 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 Figure 4). However, the weighting sequence of determinants is as follows: interpersonal and social relations ($\boldsymbol{D}_2$, 0.4054) $\succ$ physical, mental and spiritual mold ($\boldsymbol{D}_1$, 0.3015) $\succ$ 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 challenge of selecting "rotten apple(s)" when using the traditional MCDM approach was also addressed based on our conceptual advances in achieving the aspiring level for each of the criteria.

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