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Competency Model for Vocational and Technical Education Based on Analytic Network Process

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Abstract

In order to better carry out targeted instructional design based on technical talent requirements, it is necessary to construct a model suitable for vocational and technical education. Competency Model is a descriptive tool for identifying the competencies required for occupational positions and helps in the scientific evaluation of individual performance. By collecting data through multiple rounds of questionnaire surveys, vocational skills are condensed into competency elements and ratedbyexperts. In response to the complexity among competency elements, the Analytic Network Process (ANP) is adopted to analyze competency elements and determine the weights of competency element indicators. The Competency Model constructed helps to target instructional design.

Keywords

Competency model, Competency indicator system; Analytic Network Process.

1. Introduction

The competency model is mainly used for the management of comprehensive human resources systems. It helps organizations to rationally allocate positions, reasonably evaluate personal performance, and helps to carry out targeted training for vocational education by identifying the key competencies and skills of a position.

Asame and Wakrim [1] provide a review of the research on competency principles and Competency Models. Oroszi [2] and Riversetal[3]examined Competency-based education models. Horvathoraetal [4] studied the Competency Model of industrial organizations using Analytic Hierarchy Process (AHP). Focusing on the development requirements, the competencies of vocational and technical education students are increasingly diversified, and the relationship between the competency elements is more intricate than ever. Aiming at the above characteristics, this paper adopts the Analytic Network Process (ANP) to construct a Competency Model for vocational and technical education: firstly, it adopts multi-round questionnaire survey to sort out the competencies of jobs and occupations; then it adopts the Analytic Network Process to determine the weights of the Competency elements. The Competency Model obtained helps educational institutions to plan the systematic development of vocational skills.

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2. Principles

2.1. Competency

(1) Concept. "Competency", refers to the quality or state of being in which a job is accomplished, and includes a set of explicit knowledge, skills, and behavioral attitudes that an individual needs to complete a task. Of these, knowledge refers to one's mastery of facts, processes, and principles, skills refer to one's learned behaviors, and behavioral attitudes refer to one's personal feelings or perceptions.

"Competency" was first introduced to the field of human resource management in the early 1980's, and was originally developed as an attempt to replace the traditional IQ test with a set of skills associated with job performance. After decades of development, Competency Models have been widely used to improve individual and organizational effectiveness [1].

According to the United Nations Industrial Development Organization (UNIDO), competency consists of three main dimensions: knowledge (recognition), attitude (affective), and skills (psychomotor), which enable the performance of specific tasks through the combination of these competencies, as shown in Figure 1.

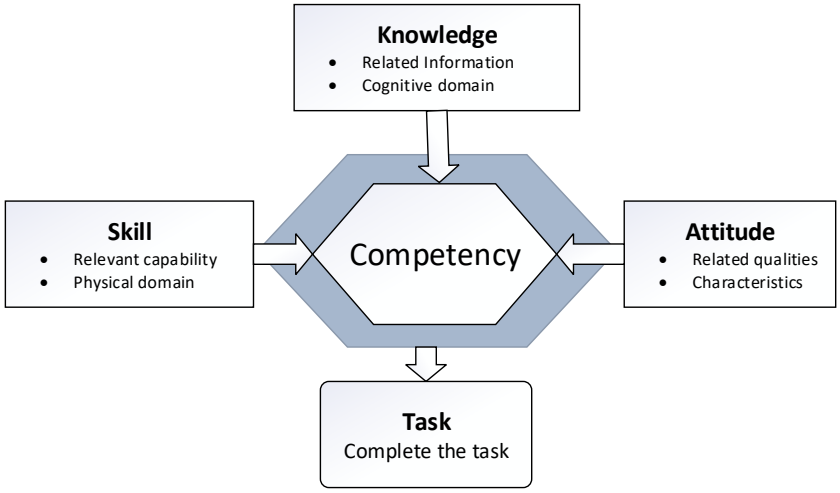

Figure 1. UNIDO Competency ModelAspects

(2) Characteristics of Competency. The key characteristics of Competency include: The subjects of Competency can be individuals, companies, or project teams. Competency is a combination of multiple resources, not only possessing these resources (knowledge, skills, motivation, abilities, expertise, value, etc.), but also the synthesis of the aforementioned resources. Competency is a process of utilizing all necessary resources. Competency is aimed at the effectiveness of specific goals. Competency depends on specific backgrounds, situations, and conditions, therefore person who is competent in one environment may not be competent in another environment.

(3) Competency Model.The competency model is composed of a set of capabilities related to completing specific tasks, usually including technical ability, leadership, interpersonalskill, and personal ability. Traditional management models focus more on an individual's qualifications, personality, and intellectual level, while competency models focus more on vocational competency, centering on an individual's ability to perform specific tasks. Therefore, the Competency Model can concentrate on the focus of the organization and the skills related to the actual work to ensure the performance of the goals.

Analytic Network Process. Analytic Network Process (ANP) isamulticriteria decision making tool proposed by ThomasSatty [5]. Itisanupgrade from Analytic Hierarchy Process

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(AHP).Essentially, ANP is an extension of AHP and AHP is a special case of ANP. The basic principles of the two evaluation methods arethe same: all necessary factors affecting decision-making are constructed into a system of indicators; numerical pairwise comparative judgments are used to express the evaluator's understanding of the importance or degree of influence of the pairwise comparison object; and sensitivity analyses are conducted to determine the stability of the results. In a multi-criteria synthesis judgment, a hierarchical or network structure can combine the impacts of numerous criteria, stakeholders, competitors, environment, multiple scenarios, and so on, into a holistic consideration. The combination of qualitative and quantitative factors with a certain degree of redundancy makes it informative. That is, this approach is more meaningful than the predictive results obtained by simply manipulating measurable data.

The theoretical foundation of both AHP and ANP is based on the relative measurement of quantitative and qualitative indicators on an absolute scale. The difference between the two is mainly in the different construction of the indicator system for evaluation. Theindicator systemofAHPishierarchical, while theindicator system of ANPisaintertwined network.

The use of ANP to solve the problem of comprehensive evaluation allows for a more thorough consideration of the impact of different factors on effectiveness and enables the construction of an effectiveness evaluation index system that is closer to reality than AHP. In addition, ANP takes into account the interactions between the factors affecting the effectiveness and retains the characteristics of the complex system more completely, so the results obtained are more objective. Compared with AHP, the disadvantages of ANP are mainly manifested in the high complexity of constructing and calculating super matrix and the need for computer-aided calculation. In this study, the ANP method is applied to conduct a comprehensive analysis of the Competency Model.

2.2. Competency Elements Condensing

2.2.1. Determine the elements of competency

In order to determine the key elements of the quality of competency, it is necessary to analyze the competency of talents and form an index system accordingly at first. Delphi method, direct observation method, work task decomposition method are used to identify the competency of the position. Considering that the purpose of the study is education and training, and the object of the study is vocational and technical positions, in order to ensure that the competency elements in the competency model can comprehensively and accurately reflect the most critical competencies needs of the positions, this study adopts the questionnaire survey method to collect position-related information.

Multiple rounds of questionnaires were used in thisstudy. The first round of questionnaires is distributed to employers, educational and training institutions, and other stakeholders to collect and summarize the competency elements. After analyzing, the questionnaire survey method is used again, and the experts score the competency elements. Based on the scores returned by the experts, the skill elements are screened and evaluated.

2.2.2. Classification of Competency Elements

Considering the purpose and object of this study, the competency elements obtained are classified into 4 sets, including professional and technical ability, physical and mental adaptability, organization and management ability, and learning and innovation ability. The above four sets of competencies serve as the first-level indicators of the competency model, in which professional and technical competency serves as the core ability of the competency model framework, while physical and mental adaptation competency, organizational management competency, and learning and innovation competency serve as supplements to

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the core competency. Considering the above relevant influencing factors, the influencing factor indicators are shown in Table.1.

Table 1. Indicators of cometency factors

First-level indicators	Second-level indicators
C1 Professional and technical ability	C11 Intellectual ability
	C12Professional ability
	C13Technical ability
C2 Physical and mental adaptability	C21Psychological resilience
	C22Interpersonal skills
	C23 Teamwork skills
C3 Organization and management ability	C31Organizational capacity
	C32Leadership
	C33Coordination capacity
C4 Learning and innovation ability	C41 Learning ability
	C42Innovative thinking ability
	C43 Innovative practical ability

2.2.3. Competency levels for vocational and technical talents

Competency levels can be set for the assessment of specific positions. Positions can be categorized into three levels according to the degree of specialization: senior, intermediate and junior. Further, different competency requirements are constructed for the 3 different levels. Depending on the specific position and purpose, the combination of competencies in the competency Model is determined: For junior levels, competencymodels usually focus on basic and personality competencies, such as basic knowledge and interpersonal skills. For advanced special skills positions, competency models focus on special skills competencies. For intermediate level positions, competency requirements fall somewhere in between.

2.3. Constructing Competency Model based on ANP

2.3.1. Competency evaluation index system of talents

Based on different research purposes, different forms of evaluation index system structure can be established. When constructing the competencymodel, the weights can be determined by using AHPmethod [4]. However, in a system with more complex structure, in which the assessment indicators are dependent on each other, sointer dependentthatit istoo difficult to separate the indicators intoahierarchical structure, or the system assessment model itself has not yet been determined, a network-like evaluation indicator system should be used or partially used.

The primary and secondary indicators in Table.1 are not completely independent from each other, and there is a strong correlation between some of them, for example: There is a strong correlation between professional and technical ability and learning and innovation ability: learning ability affects knowledge ability; innovation and practice ability is closely related to professional skills; knowledge ability is more relevant to professional skills, etc. There is a strong correlation between physical and mental adaptability and organizational and management ability: interpersonal ability affects teamwork ability; there is a positive correlation between coordination ability, organizational ability and interpersonal ability, etc.

In summary, in view of the intricate correlation between the indicators of each level, a certain level of the system can be in a dominant position or in a position of being directly or indirectly

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dominated by other levels, and there is both a hierarchical structure and a dominant structure, which makes it inappropriate to analyze using the traditional hierarchical indicator system. In order to better consider the relevant influencing factors, a network structure indicator system is constructed, as shown in Figure 2.

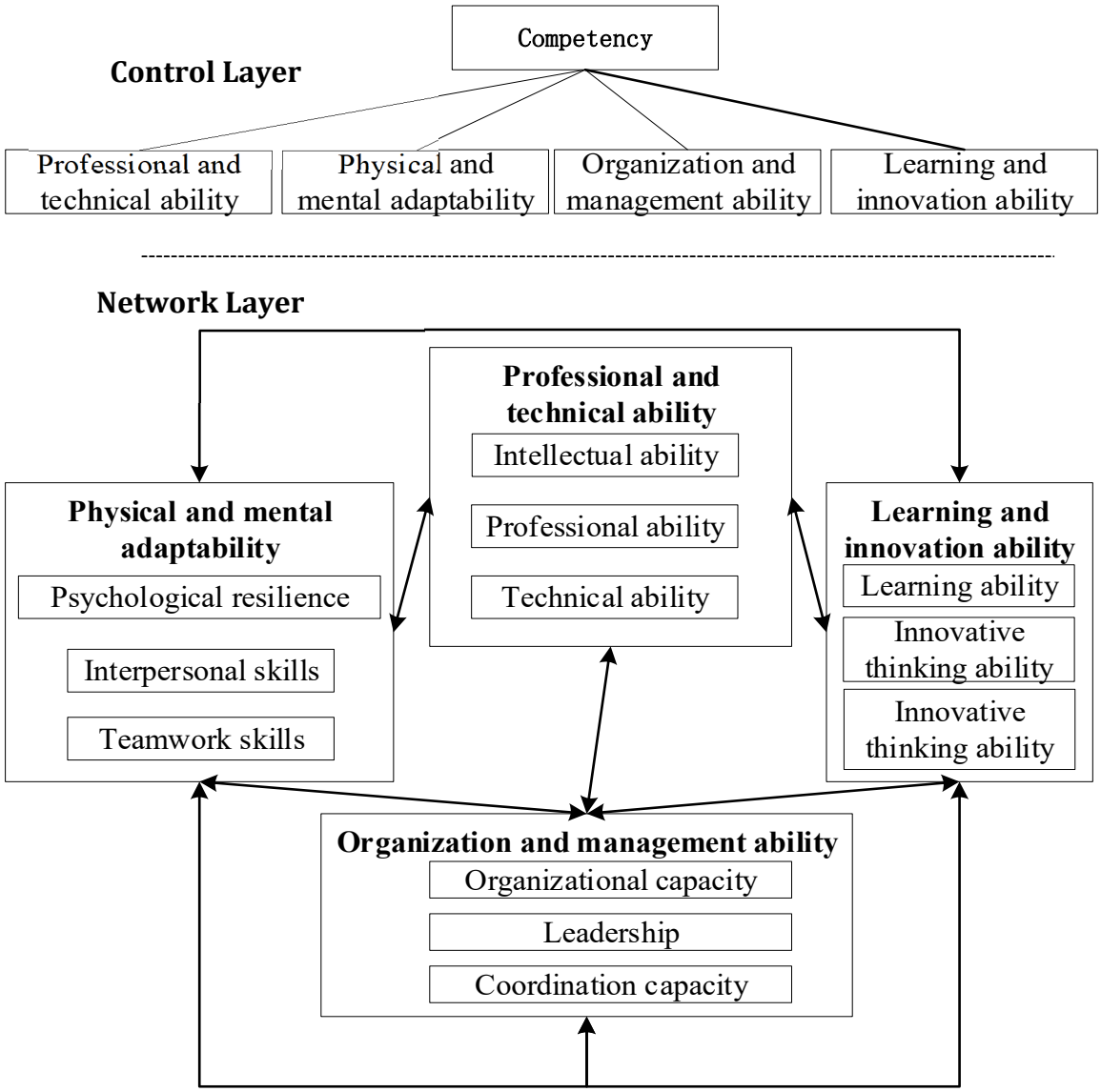

Figure 2. Competency index system of network structure

2.3.2. Determine the weights of competency evaluation indexes by Analytic Network Process

The first step is to analyze the evaluation problem. In the network structure evaluation index system shown in Figure 2, the control layer contains four first-level indicator element groups, and there are influences between the internal elements (second-level indicators) of the element groups (first-level indicators) in the network layer and between the elements of different element groups, which are not independent of each other. Therefore, it is necessary to analyze the network structure evaluation index system in Figure 2, and the analysis includes judging whether the element level is internally independent, whether there is dependence and other correlations. The analysis can be carried out in the form of meeting discussion and experts filling in the table. For the investigation of the correlation of influencing factors in Table.1 is shown in Table.2.

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Table 2. Assessment of the relevance of the indicator elements

Influenced Factor / Factor		Factor (C1)			Factor (C2)			Factor (C3)			Factor (C4)		
		C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43
Factor (C1)	C11		√	√							√	√	√
	C12	√		√							√		√
	C13	√	√				√				√		√
Factor (C2)	C21					√	√		√				
	C22				√		√	√	√	√			
	C23			√	√	√		√	√	√			
Factor (C3)	C31					√	√						
	C32				√	√	√						
	C33					√	√						
Factor (C4)	C41	√	√	√								√	√
	C42	√									√		√
	C43	√	√	√							√	√	

Note: The top element is the factor being influenced, the left column is the factor that may exert influence, and a √ indicates that there is an influence relationship between the elements.

The second step is to construct the ANP model.Construct the ANP model based on the mutual influence relationship between the elements. Through the correlation between the set of indicator factors and the set of programs in Table.2, the ANP model reflecting the dependency and feedback relationship is constructed, as shown in Figure 3.By counting the second-level influencing factors with correlation in Table.2, we can get the correlation situation table, as shown in Table.3.

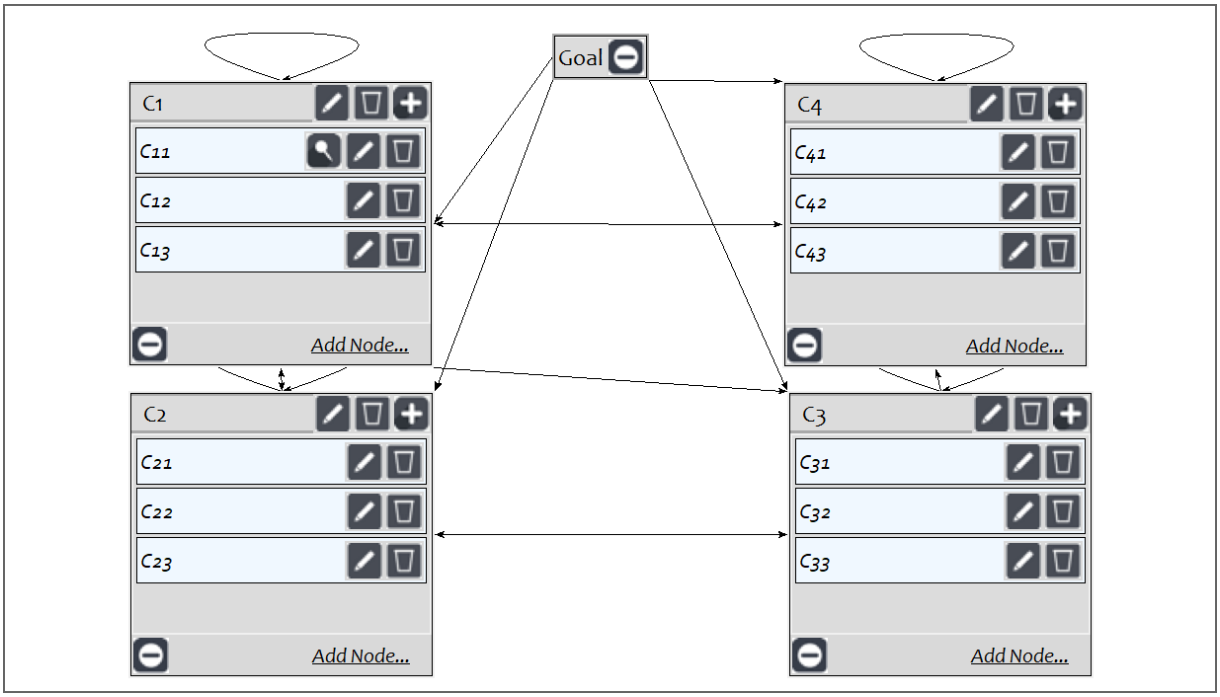

Figure 3. ANP network indicator system

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Table 3. Correlation of secondary indicator elements

Influenced Factor / Factor	Program (A)	Factor (C1)	Factor (C2)	Factor (C3)	Factor (C4)
Program (A)		9	9	9	6
Factor (C1)	9		1	0	7
Factor (C2)	9	1		7	0
Factor (C3)	9	0	7		0
Factor (C4)	6	7	0	0	

Based on the counts of the association situations of the secondary indicators, pairwise comparison matrix of the secondary indicators is constructed.The related factors with association count greater than 0 in Table.3 need to build a pairwise comparison judgment matrix. The pairwise comparison judgment matrix is used to judge the degree of dominance between the elements, indicating the relative importance of the comparison between the relevant factors for the factors in the previous level. Wherever there is a correlation between each other, a pairwise comparison should be made. The judgment matrix is the basic basis for ANP analysis and the basis for relative importance calculation. The judgment matrix of the expert is usually "1 to 9" assignment: by comparing two elements pairwisely, the degree of importance is assigned a value. If the judgment matrix constructed in practice does not have consistency, it is necessary to carry out consistency tests.

In the third step, the ANP supermatrix is constructed and solved.The core work of ANP empowerment is to solve the supermatrix, but the computational process is extremely complex and difficult to calculate by hand. Therefore, computer aided software can be used to solve the supermatrix problem.The unweighted supermatrix is shown in Table.4, weighting the unweighted supermatrix gives the weighted supermatrix as shown in Table.5 and the limit supermatrix is shown in Table.6.

Table 4. The unweighted supermatrix

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43
C11	0.00	0.50	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.41	1.00	0.26
C12	0.50	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.41
C13	0.50	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.33	0.00	0.33
C21	0.00	0.00	0.00	0.00	0.50	0.33	0.00	0.20	0.00	0.00	0.00	0.00
C22	0.00	0.00	0.00	0.50	0.00	0.67	0.50	0.40	0.50	0.00	0.00	0.00
C23	0.00	0.00	1.00	0.50	0.50	0.00	0.50	0.40	0.50	0.00	0.00	0.00
C31	0.00	0.00	0.00	0.00	0.33	0.50	0.00	0.00	0.33	0.00	0.00	0.00
C32	1.00	0.00	0.00	0.00	0.33	0.25	0.00	0.00	0.67	0.00	0.00	0.00
C33	0.00	0.00	0.00	0.00	0.33	0.25	0.00	0.00	0.00	0.00	0.00	0.00
C41	0.55	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
C42	0.21	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	0.00
C43	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00

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Table 5. The weighted supermatrix

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43
C11	0.00	0.38	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.75	0.26
C12	0.27	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.41
C13	0.27	0.38	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.25	0.00	0.33
C21	0.00	0.00	0.00	0.00	0.25	0.11	0.00	0.10	0.00	0.00	0.00	0.00
C22	0.00	0.00	0.00	0.50	0.00	0.22	0.25	0.20	0.25	0.00	0.00	0.00
C23	0.00	0.00	0.19	0.50	0.25	0.00	0.25	0.20	0.25	0.00	0.00	0.00
C31	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.17	0.00	0.00	0.00
C32	0.31	0.00	0.00	0.00	0.17	0.08	0.00	0.00	0.33	0.00	0.00	0.00
C33	0.00	0.00	0.00	0.00	0.17	0.08	0.00	0.00	0.00	0.00	0.00	0.00
C41	0.09	0.24	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
C42	0.03	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.25	0.00	0.00
C43	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00

Table 6. The limit supermatrix

	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43
C11	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
C12	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
C13	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
C21	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
C22	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
C23	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
C31	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
C32	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
C33	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
C41	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
C42	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
C43	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

In summary, the importance of the elements of the Competency Model was analyzed by Analytic Network Process and the weights of the indicators were obtained as shown in Table.7.

Table 7. Indicator weights

First-level indicators	Second-level indicators	Weights
C1 0.483466	C11	0.181861
	C12	0.140336
	C13	0.161269
C2 0.195179	C21	0.035125
	C22	0.066661
	C23	0.093393
C3 0.129546	C31	0.029825
	C32	0.080828
	C33	0.018893
C4 0.191810	C41	0.087328
	C42	0.083416
	C43	0.021066

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The weight distribution of competency is shown in Figure 4 and Figure 5.

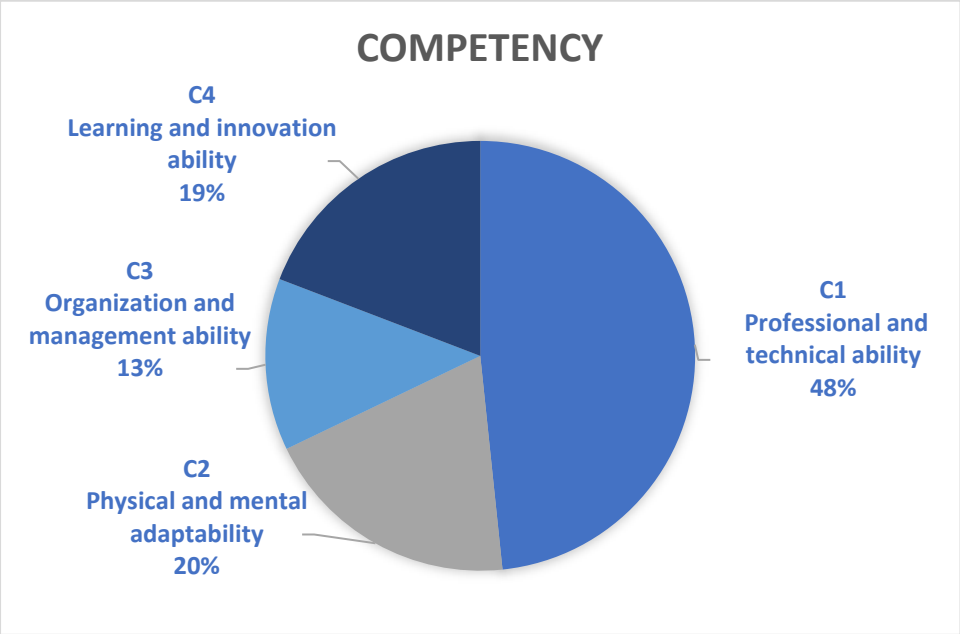

Figure 4. The weight distribution of the first-level indicators

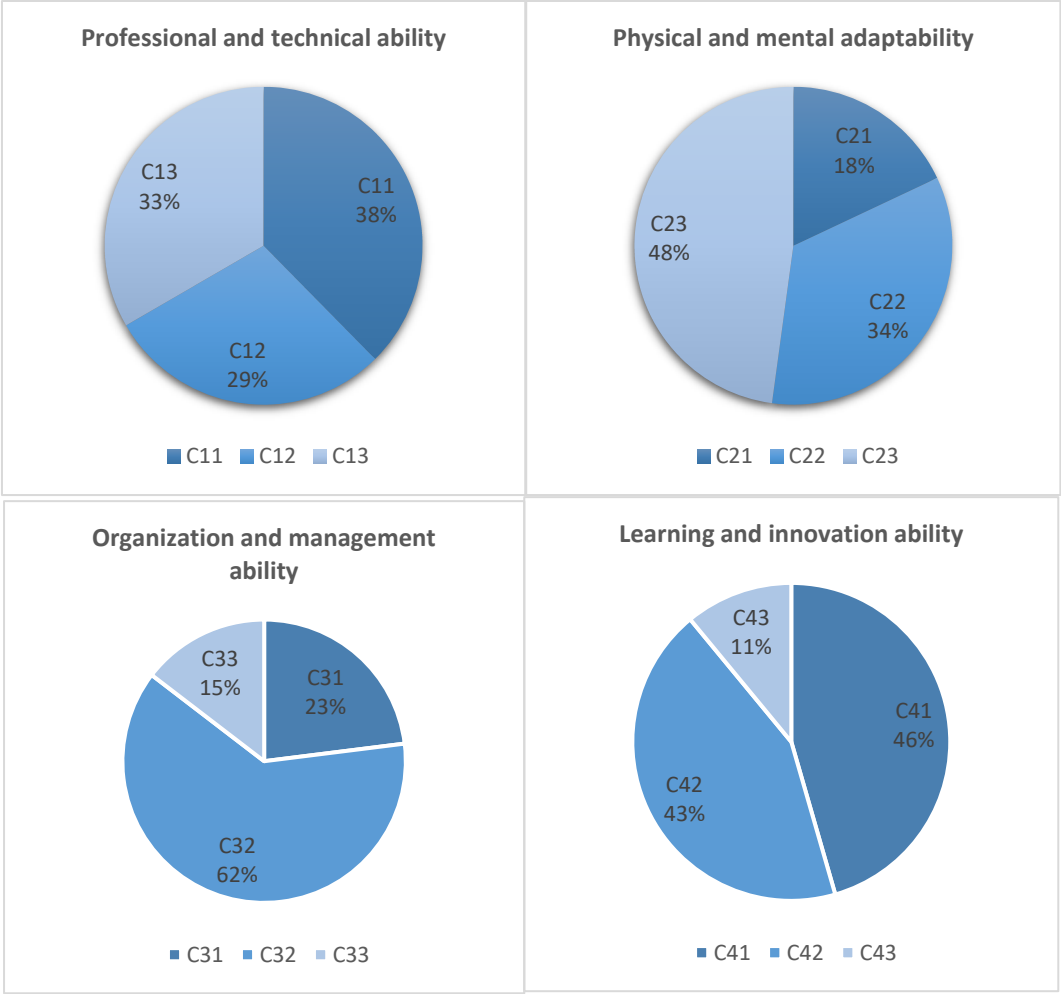

Figure 5. The weight distribution of the second-level indicators

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2.3.3. Conclusion and Prospect

In view of the trend of diversification of technical job competencies, in order to carry out targeted vocational and technical education design, this paper constructs a Competency Model applicable to vocational and technical education based on Analytic Network Process. Firstly, the multi-round questionnaire survey method is used to analyze the competency ability of the position and the competency elementswere filtered according to the talent category skill combination. The competencymodelis constructed, and the set of competency elements includes professional and technical ability, physical and mental adaptation competency, organizational management ability and learning and innovation ability. Aiming at the characteristics of complex correlation between competency elements, this paper adopts the Analytic Network Process (ANP) to determine the weights of competency element indicators, which can better analyze the interrelationship between competency elements. Based on the competency model obtained in this study, the competencycan be scientificallyevaluated. Themodelcanhelpclarify the gap between the existing competency level and the expected competency level, facilitate targeted teaching and training design, formulate competency-based teaching and training programs, as well as many other practical values.

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