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PAPER

A New Evolution Model for Collaborative Management of Knowledge Resources

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ABSTRACT

Collaborative management of knowledge resources is a particularly important issue in the context of collaborative development of vocational education since it can increase utilization of knowledge resources, narrow knowledge gap, promote educational equity, and support the innovation and collaboration of vocational education. However, currently available studies and methods are quite deficient in the aspect of knowledge attribute regulation, such as the difficulty in meeting requirements for different-type knowledge resources, the ignorance of the dynamic feature of knowledge resources, and the insufficient consideration of knowledge attributes. To solve these matters, this study aims to discuss the importance of collaborative management of knowledge resources in a backdrop of the collaborative development of vocational education, with special attention on the key role of knowledge attribute regulation in collaborative management of knowledge resources. In the paper, a collaborative knowledge resource management evolution model was built to reveal the dynamic evolution process of the collaborative management of knowledge resources, so as to provide theoretical evidences for the decision-making of knowledge attribute regulation. On this basis, the paper further proposed a decision-making method of knowledge attribute regulation for the collaborative management of knowledge resources, in the hopes of realizing efficient collaborative management of knowledge resources and promoting the collaborative development of vocational education.

KEYWORDS

knowledge resources, collaborative management, knowledge attribute regulation, evolution model, decision-making

1 INTRODUCTION

The fast-rising knowledge economy makes knowledge resources become increasingly precious these days [1–3], and vocational education is playing a more important role in promoting social economy development as it's a major way for cultivating talents with professional skills and qualities. In this backdrop, the collaborative

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management of knowledge resources is particularly critical in vocational education, as it helps to increase utilization of knowledge resources, narrow knowledge gap, promote educational equity, and support the innovation and collaboration of vocational education [4–11].

Scholars in relevant research fields began to attach importance to the collaborative management of knowledge resources in recent decades and they have carried out a series of studies, most of which focuses on aspects of the classification, integration and sharing of knowledge resources, and a few of them on the role of knowledge attribute regulation [12–15]. In fact, knowledge attribute regulation plays a key role in the collaborative management of knowledge resources, as it helps organizations and individuals better acquire, integrate, and utilize knowledge resources, thereby improving the ability to innovate and apply knowledge [16–18].

Although existing knowledge attribute regulation methods can support collaborative knowledge resource management to a certain extent, they have many defects [19–21]. First, the available methods are not diverse enough to meet the requirements of collaborative management of knowledge resources of different types and forms, such as texts, videos, and audios; second, existing methods have their respective limitations during the decision-making process of knowledge attribute regulation—some ignore the dynamic feature of knowledge resources, and some are not applicable to the complexity and uncertainty of collaborative knowledge resource management. Besides, these methods generally lack a consideration of the attributes of knowledge, such as the usability, value, applicability of a knowledge resource and its correlation with other knowledge resources.

To overcome the shortcomings of existing knowledge attribute regulation methods, this paper attempts to discuss the role of knowledge attribute regulation in collaborative knowledge resource management in a research background of the collaborative development of vocational education. For this reason, a collaborative knowledge resource management evolution model was built to reveal the dynamic evolution process of the collaborative management of knowledge resources, so as to provide theoretical evidences for the decision-making of knowledge attribute regulation. The model takes organizations and individuals as basic units, and focuses on processes such as the acquisition, sharing, integration, and innovation of knowledge resources.

Main contents of this study include the establishment of the collaborative knowledge resource management evolution model, and the proposal of the knowledge attribute regulation decision-making method. The construction of the evolution model fully considered the dynamic and complex features of knowledge resources and the changes in knowledge attributes during the collaborative management process. On this basis, a decision-making method of knowledge attribute regulation was proposed for the collaborative management of knowledge resources, aiming at making up for the defects of existing methods in the decision-making process of knowledge attribute regulation. The proposal of this method comprehensively considered the multiple dimensions of knowledge attributes, such as the importance, scarcity, and applicability scenarios of knowledge, for the purposes of realizing efficient collaborative management of knowledge resources and further promoting the collaborative development of vocational education.

In addition, the proposed model and decision-making method were empirically examined by actual cases to verify their validity and practicality. The research results of this paper could provide new theories and methodologies for the collaborative knowledge resource management in the field of vocational education, thereby promoting high-quality development of vocational education and collaborative innovation.

2 CONSTRUCTION OF COLLABORATIVE KNOWLEDGE RESOURCE MANAGEMENT EVOLUTION MODEL

The study of Synergetics proposed by Hermann Haken is a discipline that studies how multiple elements in a complex system develop in concert with each other, and the order parameter principle is a core concept in the study of Synergetics that is used to describe collaborative behavior and evolutionary process in complex systems. The relaxation coefficient method is a way to describe the interaction between elements in complex systems and can quantify the contribution of each influencing factor to system evolution. In this paper, the order parameter principle and the relaxation coefficient method were adopted to construct the collaborative knowledge resource management evolution model (hereinafter referred to as the "evolution model" for short). By introducing the order parameter principle, the laws of synergistic development in collaborative knowledge resource management could be revealed better, and more theoretical evidences could be provided for knowledge attribute regulation. By applying the relaxation coefficient method, multiple factors that affect knowledge attribute regulation, such as type, source, and application background of knowledge resources, could be taken into consideration to make the model more comprehensive and accurate. The introduction of order parameter and relaxation coefficient makes the evolution model have a stronger decision-making ability. Based on the analysis results of the model, corresponding strategies of knowledge attribute regulation could be formulated to optimize the effect of collaborative knowledge resource management. Besides, the dynamic evolution feature of the model facilitates the continuous optimization of collaborative knowledge resource management, thereby improving the quality and efficiency of vocational education.

Specific steps of the model are given below. Assuming: $Z_u(y)$ represents the u-th state variable in the collaborative knowledge resource management system, and $Z_u(y)$ represents its change rate.

In the context of collaborative development of vocational education, the state variables of the collaborative knowledge resource management system can be the various types of knowledge resources, such as courses, textbooks, cases, or multimedia resources, etc. In this study, the synergistic terms and competing terms within the system, as well as the synergistic competing terms outside the system were described from the following aspects.

The synergy within the system includes internal synergy and external synergy, wherein internal synergy refers to the development status of knowledge resources themselves, such as the knowledge resources' quality, update frequency, and usability, and other factors that influence the collaborative management of knowledge resources; while external synergy refers to the synergy between different knowledge resources, such as the influence of complementation and correlation between knowledge resources on the collaborative management of knowledge resources. Internal competition within a system contains internal competitive effect and external competitive effect, wherein the internal competitive effect is the inhibitory effect produced by knowledge resources themselves, namely the influence on collaborative knowledge resource management caused by negative factors such as excessive redundancy and obsolescence of knowledge resources; and external competitive effect is the inhibitory effect produced by the competition among different knowledge resources, such as the influence on collaborative knowledge resource management caused by duplication and mutual exclusivity among knowledge resources. The synergistic competing terms outside the system refer to those influencing factors coming from the outside environment of the system, and specifically, they include policy factors, technical factors, economic factors, and socio-cultural factors.

Based on the principle of Synergetics, assuming: $s_u z_u(y)$ and $n_{uk}(z_u(y))^2(n_u < 0)$ represent synergistic terms and competitive terms within the collaborative knowledge resource management system, k represents state parameter, u represents state variable, $v_{uk}(z_k(y))^2$ and $n_{uk}(z_u(y))^2$ represent synergistic terms and competitive terms outside the system, $v_{uk}(z_k(y))^2$ represents the synergistic effect of k on u, $n_{uk}(z_u(y))^2$ represents the competitive effect of k on u, then the common evolution model containing b state variables can be expressed as:

$$\frac{dz_u(y)}{dy} = s_u z_u(y) + n_{uu}(z_u(y))^2 + \sum_{k=u,k\neq 1}^{b} n_{uk}(z_u(y))^2 + \sum_{k=u,k\neq 1}^{b} v_{uk} z_u(y) + dd_u(y) \tag{1}$$

Assuming: y represents the value of a state variable at moment y, $dd_u(y)$ represents the disturbance factor, let $n_u(z_u(y))^2 = n_{uu}(z_u(y))^2 + \sum_{k=u,k\neq 1}^{b} n_{uk}(z_u(y))^2$, then there is:

$$\frac{dz_u(y)}{dy} = s_u z_u(y) + n_u(z_u(y))^2 + \sum_{k=u,k\neq 1}^{b} v_{uk} z_k(y) + dd_u(y) \tag{2}$$

Based on the least-square method, let $dd_u(y) = 0$, then the values of s_u, n_u and v_{uk} could be calculated, and the evolution model could be attained.

In the context of collaborative development of vocational education, the order parameter is a state variable that plays a dominant role in describing the evolution of the system. The principle for determining order parameter is mainly based on the absolute values of relaxation coefficient s_u of each state variable. The relaxation coefficient reflects the change rate of state variable over time. In the collaborative knowledge resource management system, it is necessary to determine the state variable that plays the dominant role, that is, the order parameter needs to be determined.

Detailed steps for solving order parameter are introduced below. Since the raw data of each state variable of the collaborative knowledge resource management system are of different dimensions, they must be standardized. Assuming: $z_u(y)$ represents the raw data of the u-th state variable, $z_u^{(0)}(y)$ represents the processed data sequence, $z_u(y_s)$ represents the maximum value of all samples of the u-th state variable, and $z_u(y_n)$ represents the minimum value of all samples of the u-th state variable, then there is:

$$z_u^{(0)}(y) = \frac{z_u(y) - z_u(y_n)}{z_u(y_s) - z_u(y_n)} \tag{3}$$

Since the raw data of each state variable are random and hard to analyze, in this study, data sequence $z_u^{(0)}(y)$ was accumulated, assuming $z_u^{(1)}(y)$ represents the accumulated data sequence, it can be written as:

$$z_u^{(1)}(y) = \sum_{k=1}^{y} z_k^{(0)}(y) \tag{4}$$

Let $dd_u(y) = 0$, then the equation set for describing the synergetic evolution of the collaborative knowledge resource management system is:

$$\begin{cases} \dfrac{dz_1(y)}{fy} = s_1 z_1^{(1)}(y) + n_1\left(z_1^{(1)}(y)\right)^2 + \sum\limits_{k\neq 1}^{b} v_{1k} z_k^{(1)}(y) \\ \dfrac{dz_2(y)}{fy} = s_2 z_2^{(1)}(y) + n_2\left(z_2^{(1)}(y)\right)^2 + \sum\limits_{k\neq 2}^{b} v_{2k} z_k^{(1)}(y) \\ \cdots\cdots \\ \dfrac{dz_n(y)}{fy} = s_n z_n^{(1)}(y) + n_n\left(z_n^{(1)}(y)\right)^2 + \sum\limits_{k\neq n}^{b} v_{nk} z_k^{(1)}(y) \end{cases} \tag{5}$$

Moreover, since $dz_u(y)/dy = z_u^{(1)}(y) - z_u^{(1)}(y-1) = z_u^{(0)}(y)$, namely $z_u^{(0)}(y) = s_u z_u^{(1)}(y) + n_u(z_u^{(1)}(y))^2 + \sum_{k\neq u}^{b} v_{uk} z_k^{(1)}(y)$, when $u = 1$, there is:

$$\begin{cases} z_1^{(0)}(2) = s_1 z_1^{(1)}(2) + n_1(z_1(2))^2 + \sum\limits_{k\neq 1}^{b} v_{1k} z_{1k}^{(1)}(2) \\ z_1^{(0)}(3) = s_1 z_1^{(1)}(3) + n_1(z_1(3))^2 + \sum\limits_{k\neq 1}^{b} v_{1k} z_{1k}^{(1)}(3) \\ \cdots\cdots \\ z_1^{(0)}(y) = s_1 z_1^{(1)}(y) + n_1(z_1(y))^2 + \sum\limits_{k\neq 1}^{b} v_{1k} z_{1k}^{(1)}(y) \end{cases} \tag{6}$$

If there are multiple order parameters, they can be screened further based on the size of the order of magnitude of relaxation coefficients, and one or several state variables with the smallest order of magnitude could be selected as the order parameter(s).

3 DECISION-MAKING OF KNOWLEDGE ATTRIBUTE REGULATION FOR COLLABORATIVE KNOWLEDGE RESOURCE MANAGEMENT

Collaborative knowledge resource management involves many types of knowledge resources, such as courses, textbooks, cases, and multimedia resources. These resources are interrelated and complementary to each other, and they work together to promote the development of vocational education. The decision-making of knowledge attribute regulation is conducive to identifying and deleting redundant and repeated knowledge resources, thereby improving the efficiency of resource utilization. The regulation of the attributes of knowledge resources could ensure orderly resource allocation and avoid the waste of resources. Moreover, decisions of knowledge attribute regulation can also help optimize the structure of knowledge resources to make it better fit the requirements of vocational education, including adjusting the type, quality, and quantity of knowledge resources to meet the requirements of vocational education in different stages and fields. Figure 1 gives a diagram showing the decision-making model of knowledge attribute regulation.

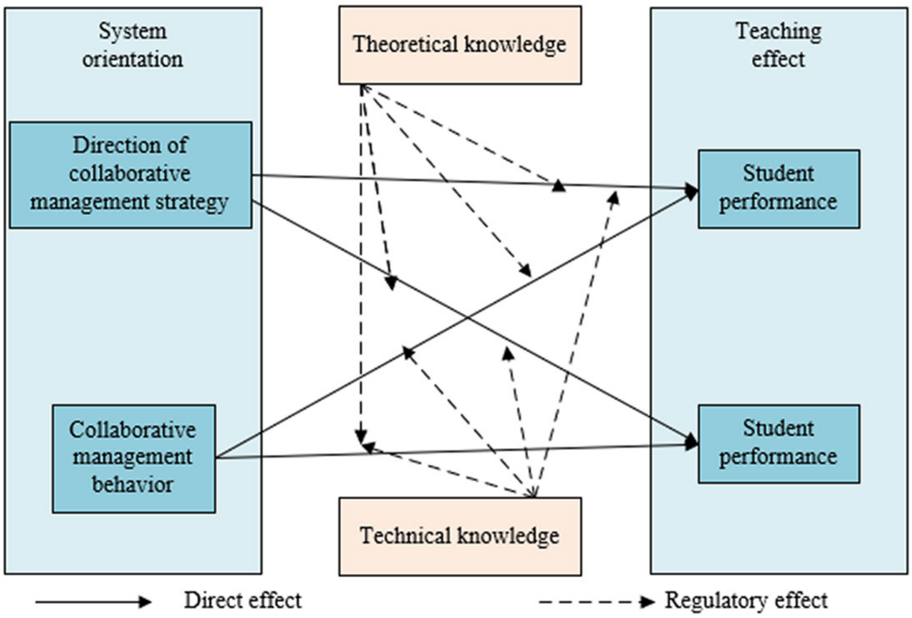

Fig. 1. The decision-making model of knowledge attribute regulation

Here, this study proposes a multi-attribute decision-making method for attributes with real number values and unknown weights, aiming at making decisions of knowledge attribute regulation for collaborative knowledge resource management in the context of collaborative development of vocational education. By screening the attributes according to their values, those attributes that are less contributive to the strategy of collaborative knowledge resource management can be effectively eliminated, thereby reducing computational complexity and improving the efficiency of decision-making. For the strategy of collaborative knowledge resource management, the proposed method fuses attributes one by one from small to large according to their differences, which is conductive to retaining key attributes while reducing redundant information. Such attribute-fusion strategy not only ensures quantity and quality of attributes, but also realizes effective attribute combination, thereby providing more accurate references for the decision-making of collaborative knowledge resource management. The proposed method determines attribute weights through regression, which can avoid the influence of subjective bias on decision results to a certain extent. The regression is data-driven and can discover the intrinsic relationship and degree of influence among attributes, thus providing a more objective weight assignment scheme for the decisions of knowledge attribute regulation.

3.1 Sorting of the multi-attribute collaborative knowledge resource management strategies

Assuming: $(a_{u,k-1}, a_{uk})$ represents the normalized values of knowledge attributes V_{k-1} and $V_k (2 \leq k \leq b)$ of the u-th strategy of collaborative knowledge resource management; the horizontal axis V_{k-1} represents the value of $a_{u,k-1}$, and the vertical axis V_k represents the value of a_{uk}. Since $a_{u,k-1} \in [0,1]$ and $a_{uk} \in [0,1]$, all points of $(a_{u,k-1}, a_{uk})$ are within a rectangle with [0,0], [0,1], [1,0], and [1,1] as vertices. Assuming l_{k-1} and l_k respectively represent the arithmetic mean of the normalized values of knowledge attributes V_{k-1} and V_k, then there is:

$$l_{k-1} = \frac{1}{l}\sum_{u=1}^{l} a_{u,k-1}, l_k = \frac{1}{l}\sum_{u=1}^{l} a_{uk} \tag{7}$$

The line $V_k = l_k$ parallel to the V_k axis and the line $V_{k-1} = l_{k-1}$ parallel to the V_{k-1} axis divided the rectangle with [0,0], [0,1], [1,0], and [1,1] as vertices into four blocks, each of which was assigned with different values $j_u = 0, 1, 2$ and 3. The block in the upper right corner was $j_u = 3$, the block in the lower right corner was $j_u = 2$, the block in the upper left corner was $j_u = 1$, and the block in the lower right corner was $j_u = 0$. A block with a greater j value has more advantageous strategy of collaborative knowledge resource management. Based on the size of j value, the strategy set S of collaborative knowledge resource management could be divided into four sub-sets $S = \{S^3, S^2, S^1, S^0\}$.

$$S^3{:}a_{uk} \in [l_{uk},1],\ a_{uk-1} \in [l_{uk-1},1],\ S^2{:}a_{uk} \in (0,l_{uk}),\ a_{uk-1} \in (l_{uk-1},1)$$

$$S^1{:}a_{uk} \in (l_{uk},1),\ a_{uk-1} \in (0,l_{uk-1}),\ S^0{:}a_{uk} \in [0,l_{uk}],\ a_{uk-1} \in [0,l_{uk-1}]$$

Usually, the strategies of collaborative knowledge resource management within rectangle blocks with different j_u values can be determined by the following formula:

$$j_u = [3 + 2SIGN(a_{u,k-1} - l_{k-1}) + SIGN(a_{uk} - l_k)]/2 \tag{8}$$

Strategies in rectangle blocks with different j_u values can be sorted in descending order according to the distance from the strategy point to the optimal point. Let Ψ be the set of all strategies within a block with the same j_u value, then there is:

$$a_{k-1}^{(j)} = \underset{u\in\Psi}{MAX}(a_{u,k-1}), a_k^{(j)} = \underset{u\in\Psi}{MAX}(a_{uk}) \tag{9}$$

If $(a_{k-1}^{(j)}, a_k^{(j)})$ is the optimal point in the block, then the distance from other points to this optimal point can be defined as follows:

$$f_u^{(j)} = \sqrt{\left(a_{u,k-1} - a_{k-1}^{(j)}\right)^2 + \left(a_{uk} - a_k^{(j)}\right)^2}, j = 0,1,2,3 \tag{10}$$

Based on the above formula, the distance $f_u^{(j)}$ from each strategy point in the four rectangle blocks with different j_u values to the optimal point can be attained. The smaller the value of $f_u^{(j)}$, the closer the distance from a strategy point to the optimal point, indicating that this strategy is better than other strategies. If all strategies are to be sorted from good to bad, then it'll need to fuse the first b-1 strategies to get the knowledge attribute $V_{(2)}$. Then the rectangle determined by $V_{(2)}$ and V_1 needs to be divided into four blocks with different j_u values based on Formula 8, and the distance from each strategy point in each block to the optimal point needs to be calculated based on Formula 10. In this study, the following steps were taken to sort out all strategies of collaborative knowledge resource management from good to bad.

1. Sort out strategies in the $j_u = 3$ rectangle block from good to bad;
2. Sort out strategies in the $j_u = 2$ rectangle block in descending order based on the sorting results of $j_u = 3$;
3. Similarly, sort out strategies in the $j_u = 1$ rectangle block in descending order based on the sorting results of the previous two blocks;

4. At last, sort out strategies in the $j_u = 0$ rectangle block in descending order based on the sorting results of other three blocks to get the rank of all strategies.

Let $E_u^{(k-1)}(2 \le k \le b)$ be the rank of the k-th strategy under the k–1-th and the k-th knowledge attributes, then the estimated value of the comprehensive score under knowledge attributes V_{k-1} and $V_k(2 \le k \le b)$ can be calculated by the following formula:

$$a_u^{(k-1)} = 1 - E_u^{(k-1)} / B \in (0,1) \tag{11}$$

3.2 Comprehensive assessment of collaborative knowledge resource management strategies

After each knowledge attribute was fused, the strategies of knowledge resources were sorted to attain the comprehensive assessment of collaborative knowledge resource management strategies. The comprehensive assessment took the fused multiple knowledge attributes as the overall assessment value of collaborative knowledge resource management strategies to choose or sort out the strategies.

For $\{a_u^{b-1}\text{u}\text{b}-1, 1 \le \text{u} \le l\}$, when $k = 2$, the comprehensive score $a_u^{(1)}$ of the u-th strategy under all knowledge attributes could be attained based on the above formula. Further, through linear regression, the comprehensive score was correlated with the quality of strategies, so as to achieve the comprehensive assessment of collaborative knowledge resource management strategies.

$$G = s_0 + \sum_{k=1}^{b} s_k z_k \tag{12}$$

To determine the value of s_k $(1 \le k \le b)$ in the above formula, in this study, $\{a_u^{(1)}, 1 \le u \le l\}$ was taken as the estimated value of G, $\{z_{uk}\}$ was taken as the estimated value of z_k, then the coefficient values could be attained based on the above formula. If the above formula is adopted to assess the level of collaborative knowledge resource management, then it can be called an effectiveness indicator of collaborative knowledge resource management.

3.3 Determination of knowledge attribute weights

In related fields of this research, the objective weight assignment method has a great advantage in determining the weights of knowledge attributes. The method determines weights based on the discrete degree of knowledge attribute values and does not rely on subjective judgment, the attained weight assignment schemes are fairer and more objective since the influence of subjective factors on decisions has been reduced. Moreover, using such mathematical method to determine weights is conductive to improving the accuracy of decisions. Through data analysis of knowledge attribute values, the intrinsic relationship and importance degree among attributes could be revealed, providing more accurate references for the weight determination of knowledge attribute regulation decisions of collaborative knowledge resource management.

Assuming: a_k represents the value of benefit-type knowledge attributes, let $n_k > 0$, then there is:

$$G = n_0 + \sum_{k=1}^{b} n_k a_k \tag{13}$$

By comparing above two formulas, we have:

$$n_k = \left| s_k \Delta z_k \right| \tag{14}$$

Further, the weights of knowledge attributes can be attained as follows:

$$q_k = n_k / \sum_{k=1}^{b} n_k \tag{15}$$

4 EXPERIMENTAL RESULTS AND ANALYSIS

This study chose to take knowledge importance, knowledge scarcity, knowledge applicability, and knowledge usability as the attributes of knowledge to measure collaborative knowledge resource management. Knowledge importance refers to the value and influence of knowledge in organizations and individuals, which is very important for achieving vocational education goals and promoting synergistic development. Knowledge scarcity indicates the uniqueness of knowledge and the difficulty to acquire it, a knowledge with higher scarcity has a greater value in collaborative management. Knowledge applicability measures the practicality and suitability of knowledge in specific scenarios, a knowledge with a higher applicability is easier to be used and disseminated in collaborative management. Knowledge usability describes whether a knowledge is easy to understand, learn, and apply, a knowledge with a higher usability can reduce the cost and difficulty of collaborative management.

Figure 2 gives several curves showing the variation of knowledge importance with the passing of time period of collaborative knowledge resource management. It's observed that the curves showed an upward concave trend, that is, they rose slower in earlier periods and rose faster in latter periods. Such trend is related to the time and resources required in the process of collaborative knowledge resource management, and the adaptability of participants in the collaboration. In the initial stage of collaborative management, participants need to invest time and resources to adapt to the collaborative working mode, establish trusting relationships. and understand each other's knowledge requirements, so knowledge importance rose slowly in this stage. After that, with the progress of collaborative work, participants become more proficient in tools, skills, and communication methods of collaboration. They can identify, integrate, and share important knowledge resources more easily, so the knowledge importance rose faster in this stage. The curves revealed the features that, with the passing of the time period of collaborative management, knowledge importance rose slower in the beginning and grew rapidly later, and this indicates that during the process of collaborative knowledge resource management, attention should be paid to the training of adaptation of participants so as to reduce friction cost and promote the increase of knowledge importance. In later stage, strategies and tools of collaborative management should be optimized constantly to further improve the rising speed of knowledge importance, and realize efficient collaborative management of knowledge resources.

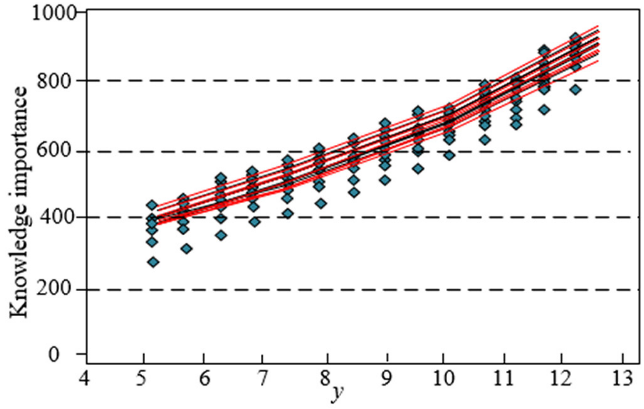

Fig. 2. Changes of knowledge importance in different time periods

Figure 3 gives several curves showing the variation of knowledge scarcity with the passing of time period of collaborative knowledge resource management. It's observed that knowledge scarcity differed greatly in different time periods: in the first half, knowledge scarcity was low, while in the second half, knowledge scarcity maintained at a high level. This trend change may be related to the difficulty of knowledge mining and sharing during the process of collaborative management. In the first half, most knowledge resources involved were conventional and easily accessible knowledge, so knowledge scarcity was low; then, with the deepening of collaborative management, participants gradually uncovered more scarce and unique knowledge resources, so the knowledge scarcity in the second half was increased. Moreover, in the second half period, as more scarce knowledge involved specialized fields and contents with higher skill requirements, it's more difficult to share and utilize these knowledge resources, so knowledge scarcity was maintained at a relatively high level. The curves revealed that the knowledge scarcity exhibited the feature of lower in the beginning and higher in later stage with the passing of time period, indicating that during collaborative management of knowledge resources, in the first half period, attention needs to be paid to the integration and sharing of conventional and easily accessible knowledge, while in the second half period, attention should be placed on scarce and highly specialized knowledge resources, and effective measures should be taken to promote the sharing and utilization efficiency of these knowledge resources, so as to achieve efficient collaborative management of knowledge resources.

Figure 4 gives curves showing the changes of knowledge applicability with the cumulative synergy cycle, as can be observed from the figure, with the increase of cumulative synergy cycle, knowledge applicability became increasingly discrete, indicating greater differences in knowledge applicability under different collaborative knowledge management strategies. This trend may be related to the continuous adjustment of participants' knowledge requirements and the optimization of strategies during the collaboration process. With the accumulation of synergy cycle, participants gradually acquired more information about each other's knowledge requirements and preferences, so the screening and integration strategies of knowledge resources may change, resulting in significant differences in knowledge applicability under different collaborative knowledge management strategies. Moreover, with the deepening of synergy process, participants may develop different expertise and knowledge systems in specific areas, which further affected the discrete degree of knowledge applicability. The curves revealed that, with the increase of cumulative synergy cycle, knowledge applicability became increasingly discrete, indicating that during the process of collaborative knowledge resource management, with the accumulation of synergy cycle, attention should be paid to differences in knowledge applicability under different strategies, and the collaborative management strategy should be continuously optimized to meet the ever-changing knowledge requirements of participants. Also, understandings of the participants' expertise and knowledge system should be increased to improve knowledge applicability in a targeted manner, thereby achieving efficient and collaborative management of knowledge resources.

Figure 5 gives curves showing the variation of knowledge usability with cumulative synergy cycle. As can be observed from the figure, knowledge usability was very discrete on both sides of the average usability degree. With the increase of cumulative synergy cycle, although knowledge usability tended to be constant, there were still large fluctuations in knowledge usability under different collaborative knowledge management strategies. This trend may be related to the adjustment of usability standards and tools for participants in the collaboration process. With the accumulation of synergy cycle, participants may gradually clarify their requirements of knowledge usability, so the knowledge usability converged to a constant value. However, under different collaborative knowledge management strategies, the attention degree and implementation method of knowledge usability may differ, causing fluctuations in knowledge usability. For instance, some strategies may emphasize the classification and retrieval of knowledge resources, and some may focus on user experience and interaction design of collaboration tools, and these differences might affect knowledge usability during the collaboration process. The curves revealed that with the accumulation of synergy cycle, knowledge usability maintained discrete and fluctuations were large under different collaborative knowledge management strategies, indicating that during the collaboration process, attention should be paid to differences in knowledge usability, so that the design and implementation methods of knowledge usability could be optimized in a targeted manner to improve the use effect of knowledge resources. Also, attention should be paid to the adjustment of standards and tools of knowledge usability during cumulative synergy cycle to ensure stable improvement of knowledge usability and realize efficient collaborative management of knowledge resources.

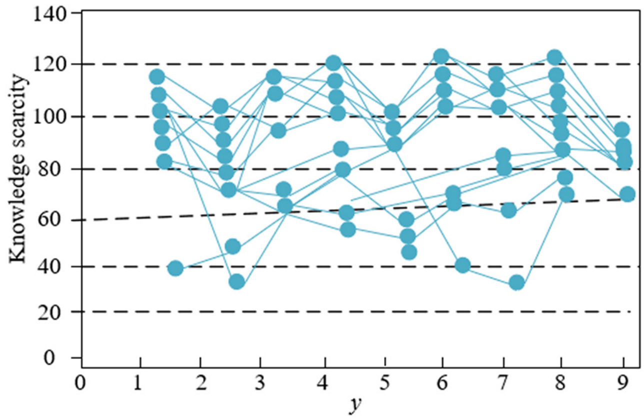

Fig. 3. Changes of knowledge scarcity in different time periods

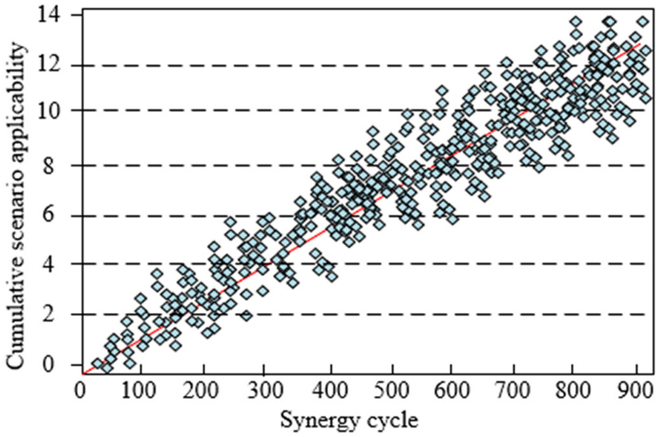

Fig. 4. Changes of knowledge applicability with cumulative synergy cycle

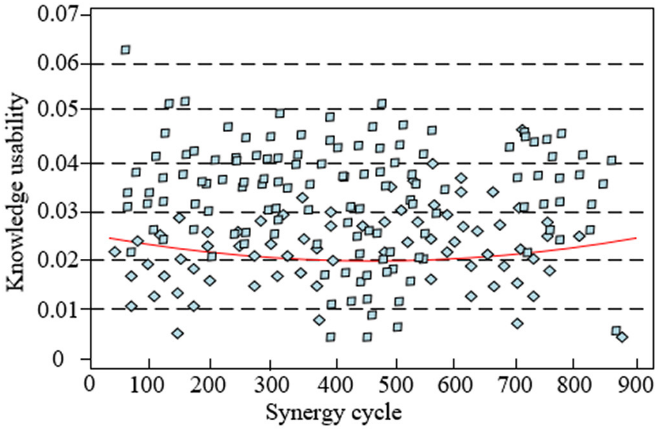

Fig. 5. Changes of knowledge usability with cumulative synergy cycle

Table 1. The interaction between collaborative management strategy direction and theoretical knowledge

Model		Non-Standardized Coefficient		Standardized Coefficient	*t*	*Sig.*
		B	Standard Error	*Beta*		
1	(Constant)	1.258	0.263		6.352	0.025
	Collaborative management strategy direction	0.415	0.082	0.451	7.519	0.041
2	(Constant)	1.306	0.274		4.352	0.036
	Collaborative management strategy direction	0.392	0.036	0.392	6.514	0.002
	Theoretical knowledge	0.281	0.095	0.241	4.362	0.009
3	(Constant)	1.629	0.281		5.382	0.058
	Collaborative management strategy direction	0.325	0.098	0.392	5.269	0.041
	Theoretical knowledge	1.602	0.025	0.205	3.625	0.035
	Theoretical knowledge * Collaborative management strategy direction	0.152	0.093	0.162	2.014	0.016

According to data in Table 1, the interaction between collaborative management strategy direction and theoretical knowledge can be analyzed. In Model 1, collaborative management strategy direction was the only explanatory variable. Its standardized coefficient (*Beta*) was 0.451, *t*-value was 7.519, and significance value (*Sig.*) was 0.041, indicating that collaborative management strategy direction had a significant positive effect on dependent variables (may be knowledge synergy effect, knowledge applicability or knowledge usability). In Model 2, theoretical knowledge was added as an explanatory variable. In this model, the standardized coefficient of collaborative management strategy direction slightly decreased to 0.392, *t*-value was 6.514, significance was 0.002; the standardized coefficient of theoretical knowledge was 0.241, *t*-value was 4.362, and significance was 0.009, indicating that both collaborative management strategy direction and theoretical knowledge had a significant positive effect on dependent variables. In Model 3, an interaction term of theoretical knowledge and collaborative management strategy direction was introduced. In this model, the standardized coefficient of collaborative management strategy direction was 0.392, *t*-value was 5.269, and significance was 0.041; the standardized coefficient of theoretical knowledge was 0.205, *t*-value was 3.625, and significance was 0.035; the standardized coefficient of the interaction term was 0.162, *t*-value was 2.014, and significance was 0.016, indicating that the interaction term had a significant positive effect on dependent variables. Based on the analysis results of stepwise regression, both collaborative management strategy direction and theoretical knowledge had significant positive effects on dependent variables, and there's a significant interaction between them. This indicates that collaborative management strategy direction and theoretical knowledge would influence and promote each other, and jointly improve the effect of knowledge synergy.

5 CONCLUSION

This study explored the role of knowledge attribute regulation in collaborative knowledge resource management in a research background of the collaborative development of vocational education. Main contents include the establishment of collaborative knowledge resource management evolution model, and the proposal of knowledge attribute regulation decision-making method. The construction of the evolution model had fully considered the dynamic and complex features of knowledge resources and the changes in knowledge attributes during the collaborative management process. The knowledge attribute regulation decision-making method was proposed to make up for the defects of existing methods in the decision-making process of knowledge attribute regulation. Experiments conducted in this study considered the effects of collaborative management strategy direction, theoretical knowledge, collaborative management behavior and technical knowledge on knowledge synergy and the interactions between them. Based on the attained experimental results, following conclusions were drawn:

1. Both collaborative management strategy direction and theoretical knowledge have a significant positive effect on knowledge synergy, and there is a significant positive interaction between them. This means that collaborative management strategy direction and theoretical knowledge influence and promote each other, and jointly improve the effect of knowledge synergy.
2. Both collaborative management behavior and technical knowledge have a significant positive effect on knowledge synergy, but there is a significant negative

interaction between them. This implies that collaborative management behavior and technical knowledge inhibit each other to some extent, which may limit of the effect of knowledge synergy.

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7 REFERENCES

[1] Eambunnapong, K., Nilsook, P., Wannapiroon, P. (2023). A systematic review of the intelligent digital storytelling process in disseminating health information. International Journal of Online and Biomedical Engineering, 19(7): 200–223. https://doi.org/10.3991/ijoe.v19i07.37431

[2] Ninghardjanti, P., Dirgatama, C.H.A. (2021). Building critical thinking skills through a new design mobile-based interactive learning media knowledge framework. International Journal of Interactive Mobile Technologies, 15(17): 49–68. https://doi.org/10.3991/ijim.v15i17.23801

[3] Liu, J.L., Li, K. (2019). An information system of clinical pathway management based on the integration between knowledge management and learning organization. Ingénierie des Systèmes d'Information, 24(5): 473–480. https://doi.org/10.18280/isi.240503

[4] Tan, F., Yang, P. (2023). Use of a knowledge network for management and sharing of teaching resources for building construction simulations. International Journal of Emerging Technologies in Learning, 18(8): 222–237. https://doi.org/10.3991/ijet.v18i08.39245

[5] Wang, J.X., Mangmeechai, A. (2022). Impact of entrepreneurship knowledge literacy curriculum on college graduates' sustainable entrepreneurial competence based on entrepreneurial learning theory. International Journal of Sustainable Development and Planning, 17(4): 1309–1316. https://doi.org/10.18280/ijsdp.170428

[6] Yang, L., Huang, X. (2022). Research on tourism resources management method based on deep learning and knowledge graph. In 2022 6th International Symposium on Computer Science and Intelligent Control (ISCSIC), 127–131. https://doi.org/10.1109/ISCSIC57216.2022.00036

[7] Turmuzi, M., Suharta, I.G.P., Astawa, I.W.P., Suparta, I.N. (2023). Mapping of mobile learning research directions and trends in scopus-indexed journals: A bibliometric analysis. International Journal of Interactive Mobile Technologies, 17(3): 39–69. https://doi.org/10.3991/ijim.v17i03.36461

[8] Zhang, Y., Cheng, X., Li, Y., Wang, F., Liu, X., Wu, W. (2022). Research on land and resources management and retrieval using knowledge graph. Geomatics and Information Science of Wuhan University, 47(8): 1165–1175. https://doi.org/10.13203/j.whugis20210714

[9] Ma, X. (2023). The use of knowledge correlation for classification and evaluation of a distance education teaching resource database. International Journal of Emerging Technologies in Learning, 18(5): 217–230. https://doi.org/10.3991/ijet.v18i05.38501

[10] Incerti, V., Bellesia, F., Bertolotti, F., Chudoba, K., Fadel, K.J., Mattarelli, E., Ungureanu, P. (2020). Working in the era of multiple virtual team membership. A Study on the Effects of Variety of Communication Rules on Individual Management of Knowledge Resources. In 2020 International Conference on Information Systems – Making Digital Inclusive: Blending the Local and the Global, ICIS 2020, 13–16 december 2020.

[11] Wang, J.X., Mangmeechai, A. (2022). Impact of entrepreneurship knowledge literacy curriculum on college graduates' sustainable entrepreneurial competence based on entrepreneurial learning theory. International Journal of Sustainable Development and Planning, 17(4): 1309–1316. https://doi.org/10.18280/ijsdp.170428

[12] Sabree, M., Mustafa, M.M. (2023). Importance and role of live projects in architectural education using a descriptive and analytical approach. Education Science and Management, 1(1): 7–18. https://doi.org/10.56578/esm010102

[13] Xiao, Y., Yang, G., Zhang, X. (2023). A new learning resource retrieval method based on multi-knowledge association mining. International Journal of Emerging Technologies in Learning (iJET), 18(4): 104–119. https://doi.org/10.3991/ijet.v18i04.38243

[14] Guliyeva, K. (2022). Omar Faik Nemanzadeh education problem and professional competency of a teacher. Journal of Corporate Governance, Insurance, and Risk Management, 9(2): 374–380. https://doi.org/10.56578/jcgirm090208

[15] Mohd Arzaman, A.F., Salleh, H.S., Nik Mat, N.H., Wan Talaat, W.I.A. (2022). Traditional knowledge of marine resources and their relations to the coastal community's economic well-being in peninsular Malaysia. International Journal of Sustainable Development and Planning, 17(6): 1973–1982. https://doi.org/10.18280/ijsdp.170633

[16] Li, N. (2020). Curriculum data association organization and knowledge management method for unstructured learning resources. International Journal of Emerging Technologies in Learning (Online), 15(6): 79. https://doi.org/10.3991/ijet.v15i06.13173

[17] Lee, O.K.D., Choi, B., Lee, H. (2020). How do knowledge management resources and capabilities pay off in short term and long term? Information & Management, 57(2): 103166. https://doi.org/10.1016/j.im.2019.05.001

[18] Munne, R.F., Ichise, R. (2023). Attribute enhancement using aligned entities between knowledge graphs. In 2023 IEEE 17th International Conference on Semantic Computing (ICSC), 191–198. https://doi.org/10.1109/ICSC56153.2023.00038

[19] Zhang, F., Li, J., Cheng, J. (2023). Improving entity alignment via attribute and external knowledge filtering. Applied Intelligence, 53(6): 6671–6681. https://doi.org/10.1007/s10489-022-03744-5

[20] Ge, Z., Cheng, H., Tong, Z., Wang, N., Alhudhaif, A., Alenezi, F., Wang, Z. (2023). ECG-MAKE: An ECG signal delineation approach based on medical attribute knowledge extraction. Information Sciences, 637: 118978. https://doi.org/10.1016/j.ins.2023.118978

[21] Shajini, M., Ramanan, A. (2022). A knowledge-sharing semi-supervised approach for fashion clothes classification and attribute prediction. The Visual Computer, 38(11): 3551–3561. https://doi.org/10.1007/s00371-021-02178-3

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