The Cultivation of Teamwork Quality from the Perspective of Competitive-Complementary Relations

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Abstract—During the process of starting a business, in an entrepreneur team, there's not only a collaborative relationship among team members, there're also competitions between them. To avoid the consequence of team output reduction caused by the competitive behavior of team members to fight for rights and interests, it's necessary to figure out the influence of the Competitive-Complementary Relations (CCR) among members on the performance of the team, so this paper aims to study the cultivation of teamwork quality of college students in entrepreneur team from the perspective of CCR. At first, relevant indexes were selected from four aspects of team factor, teacher factor, team member factor, and efficacy factor to form an Evaluation Index System (EIS) for assessing the teamwork quality of the college student entrepreneur team; then, this paper employed a combinatorial weighing method to integrate the weights obtained by the Entropy Weight Method (EWM) and the Variation Coefficient Method (VCM), constructed conceptual models for the competitive efficacy and complementary efficacy of the college student entrepreneur team, and introduced the methods for calculating the competitive degree index and complementary degree index of team members in detail. After that, the paper used a gray prediction model GM (1, 1) to predict the teamwork quality of several sample college student entrepreneur teams within the study period based on the completion degree of entrepreneurial tasks, and used a coupling model to analyze the coupling and coordination degree between competitive degree, complementary degree, and team performance. At last, experiment results proved the effectiveness of the proposed EIS and models.

Keywords—competitive-complementary relations (CCR), college student entrepreneur team, teamwork quality; combinatorial weighing, entropy weight method (EWM), variation coefficient method (VCM)

1 Introduction

In the face of stiff market competition, if an enterprise created by college student entrepreneur team wants to succeed, it cannot solely rely on the personal ability of one person, only by joining the efforts of team members and harnessing their collective intelligence can the start-up business have a stronger market competitiveness [1-5]. When dealing with the complex entrepreneurial tasks, reasonable division of labor and

sound cooperation of team members can increase the flexibility of the team, as a result, the overall performance of the organization will be improved [6-13]. In an entrepreneur team with quality complementation as common objective, knowledge exchange and experience sharing of team members have great influence on the development of both the enterprise and the individuals and the improvement of teamwork quality of the entrepreneur team. However, during the process of starting a new business, in an entrepreneur team, there's not only a collaborative relationship among the team members, there're also competitions between them [14-18]. To avoid the consequence of team output reduction caused by the competitive behavior of team members to fight for rights and interests, it's necessary to figure out the influence of the CCR among members in the college student entrepreneur team on the performance of the team.

Although most of the workplace collaboration and communication are conducted online, Nguyen et al. [19] proposed a novel solution leveraging an AI-based, dynamic affective recognition system, which significantly increased shared understanding and creativity within virtual teams. Mehta et al. [20] developed and tested an Eplum model that engages students and teacher instructors on campus in various international social entrepreneurial ventures and integrates disciplines, concepts, cultures, and countries, and the principles, mechanics, and assessment framework of the model were given in the study. At present, the theoretical research on the combination of knowledge sharing and gaming in entrepreneur teams is falling behind the practice, however, knowledge sharing and collaboration can directly or indirectly affect the fulfillment of psychological contracts of team members and the development and performance of the team. Bai and Yin [21] studied the static and dynamic games of two members in a same entrepreneur team based on complete information, and employed the prisoner's dilemma model to study whether the members are willing to share their knowledge with each other. Entrepreneur teams are usually interdisciplinary in nature, so the effectiveness of interdisciplinary design teams is important for both start-ups and innovative companies. Lugo et al. [22] investigated the features in personalities required by successful entrepreneur design teams, and the results suggested that teams with best performance generally had high variability in neuroticism and extraversion and average personality traits. Thus, the analysis supported that each member's personality would affect his or her team's performance.

According to the research results of world field scholars, existing theoretical and empirical studies on teamwork quality improvement of entrepreneur teams have formed a rich system already. The existing results showed that the harmonious relationship between team members can affect the behavior direction of the team, and it has a significant correlation with the sustainable development and performance of entrepreneurial enterprise. However, current results are mostly theoretical discussions on the modes and evaluations, few have concerned about the CCR of entrepreneur team or the collaboration and interaction among team members. To fill in this research blank, this paper aims to study the cultivation of teamwork quality of college student entrepreneur teams from the perspective of CCR. In the second chapter, relevant indexes were selected from four aspects of team factor, teacher factor, team member factor, and efficacy factor to construct an EIS for assessing the said teamwork quality, and a combinatorial weighing method was employed to integrate the weights obtained by EWM

and VCM. In the third chapter, two conceptual models of the competitive efficacy and complementary efficacy of college student entrepreneur team were established, and the methods for calculating the competitive degree index and complementary degree index of team members were introduced in detail. In the fourth chapter, a gray prediction model GM (1, 1) was adopted to predict the teamwork quality of several sample college student entrepreneur teams within the study period based on the completion degree of entrepreneurial tasks, and a coupling model was used to analyze the coupling and coordination degree between competitive degree, complementary degree, and team performance. At last, experiment results proved the effectiveness of the proposed EIS and models.

2 Strategies for evaluating the teamwork quality of college student entrepreneur teams

Indexes in the EIS were selected from four aspects of team factor, teacher factor, team member factor, and efficacy factor. After subjected to dimensionality reduction processing, 16 indexes including team stability and team goals were determined to constructed the EIS for assessing the said teamwork quality. Details are given below.

First layer (Factor layer):

CA={CA_1, CA_2, CA_3, CA_4}={team factor, teacher factor, team member factor, efficacy factor};

Second layer (index layer):

CA_1={CA_{11}, CA_{12}, CA_{13}, CA_{14}, CA_{15}, CA_{16}}={stability, regulations, scale, internal competitiveness, goals, complementarity};

CA_2={CA_{21}, CA_{22}, CA_{23}}={cultivation mode, teacher-student relationship, sense of responsibility};

CA_3={CA_{31}, CA_{32}, CA_{33}, CA_{34}, CA_{35}}={cultural literacy, team motivation, team satisfaction, team role, skill level};

CA_4={CA_{41}, CA_{42}}={Entrepreneurial performance, team influence}.

To eliminate the interference of dimensions on the calculation results of teamwork quality, the data of above evaluation indexes were standardized. Assuming: CA_{ij} represents the original value of the i-th evaluation index of the j-th evaluation sample; CA'_{ij} represents the corresponding value after the extreme values are subject to standardization processing; $MAX(CA_{ij})$ and $MIN(CA_{ij})$ represent the maximum and minimum values of the i-th evaluation index, then the formula for processing positive indexes is:

$$CA'_{ij} = \frac{CA_{ij}}{MAX\left(CA_{ij}\right)} \tag{1}$$

The formula for processing negative indexes is:

$$CA'_{ij} = \frac{MIN\left(CA_{ij}\right)}{CA_{ij}} \tag{2}$$

To attain more objective and scientific weights of evaluation indexes, this paper adopted a combinatorial weighing method to integrate the weights obtained by EWM and VCM. Assuming: T_{ij} represents the proportion of the i-th evaluation index of the j-th evaluation sample, then its calculation formula is given by Formula 3:

$$T_{ij} = \frac{CA_{ij}^{'}}{\sum_{i=1}^{m} CA_{ij}^{'}}, (i = 1,...,m; j = 1,...,n) \tag{3}$$

Assuming: f_{ij} represents the entropy value of the i-th evaluation index of the j-th evaluation sample, then its calculation formula is:

$$f_i = -l\sum_{i=1}^{m} t_{ij} ln\left(t_{ij}\right), \left(j = 1,...,n\right)\ l = 1/ln\left(n\right) > 0 \tag{4}$$

Formula 5 give the formula for calculating the redundancy of information entropy:

$$c_i = 1 - f_i, \left(i = 1,...,m\right) \tag{5}$$

Assuming: $Q_i(r)$ represents the weight of evaluation index i attained by EWM; c_i represents the redundancy of its information entropy, then Formula 6 gives the formula for calculating the weight of each evaluation index based on EWM:

$$Q_i\left(r\right) = \frac{c_i}{\sum_{i=1}^{m} c_i}, \left(j = 1,...,n\right) \tag{6}$$

Assuming: ρ_i represents the coefficient of variation of the i-th evaluation index within the study period; n represents the evaluation year, then Formula 7 gives the formula for calculating weight $Q_i(y)$ based on VCM:

$$U_i = \frac{\rho_i}{CA_{ij}^{'}} \tag{7}$$

$$Q_i\left(y\right) = \frac{U_i}{\sum_{j=1}^{n} U_i} \tag{8}$$

At last, the weight values attained by EWM and VCM were integrated:

$$Q_i = \frac{Q_i\left(r\right) + Q_i\left(y\right)}{2} \tag{9}$$

3 Calculation methods for the complementary degree index and competitive degree index of team members

Figure 1 gives a diagram of the conceptual model of complementary efficacy of college student entrepreneur team, as can be seen from the figure, the teamwork method is determined by the different relationships of team members, which in turn promotes the generation of teamwork quality and the improvement of the entrepreneurial performance of the team.

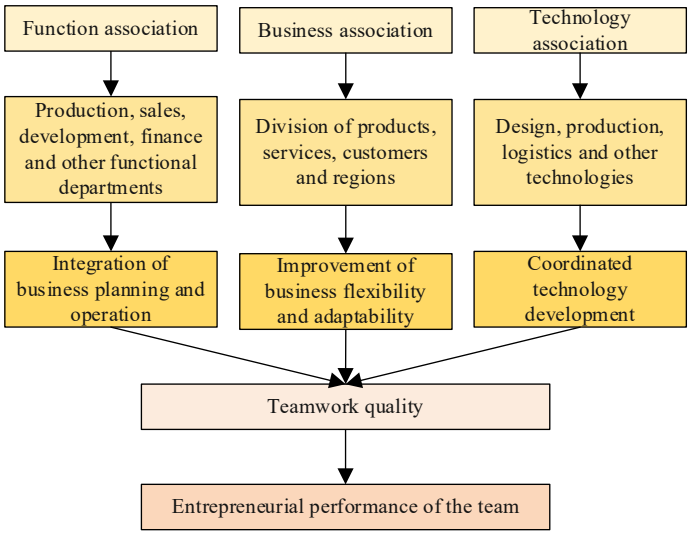

Fig. 1. Conceptual model of complementary efficacy of college student entrepreneur team

The comprehensive index method was adopted to calculate the weighted sum, which was used to measure the complementary degree of college student entrepreneur team. In the paper, the score of the i-th evaluation index in the i-th year R_{ij} was defined as the product of the weight of the index and the standardized value of the index. Assuming: $CA'_{i\tau}$ represents the standardized value; Q_i represents the weight of the i-th evaluation index, then there is:

$$R_{i\tau} = CA'_{ij} * Q_i \tag{10}$$

Assuming: O_i represents the complementary degree index of college student entrepreneur team; R_{ij} represents the score in the i-th year, then, by summing the scores of all evaluation indexes, the value of O_i could be attained:

$$O_i = \sum_{i=1}^{m} R_{ij} \tag{11}$$

Assuming: ρ represents covariance; λ represents standard deviation, then, based on the coefficient of variation, the temporal and spatial variation features of the complementary degree of college student entrepreneur team could be expressed as:

$$DU = \frac{\rho}{\lambda} \tag{12}$$

$$\rho = \sqrt{\frac{1}{M}\sum_{i=1}^{M}\left(E_i - \lambda\right)^2} \tag{13}$$

To study the influence of the competitions for rights and interests inside the entrepreneur team on the entrepreneurial performance of the team and discuss the regulatory effects of cultivation fairness, regulation fairness, and job position fairness, this paper also established a conceptual model of competitive efficacy of college student entrepreneur team, see Figure 2.

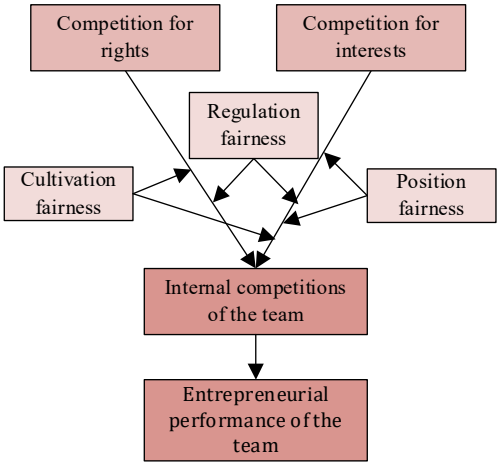

Fig. 2. Conceptual model of competitive efficacy of college student entrepreneur team

This paper employed an obstacle degree model to analyze the influence of obstacle factors (internal competitions of entrepreneur team) on the entrepreneurial performance of the team. Assuming: θ_i represents the weight of the i-th evaluation index in each cultivation scheme layer; ω_i represents the weight of the i-th evaluation index; FC_i represents factor contribution degree, which is used measure the size of the influence of teamwork quality evaluation index and complementarity degree index on the entrepreneurial performance of the team, then there is:

$$FC_i = \theta_i * \omega_i \tag{14}$$

Assuming: G_i represents the deviation degree of evaluation index, which is the distance from the i-th evaluation index to the general goal of the entrepreneurial performance of the team, then its calculation formula is:

$$G_j = 1 - CA_{ij}^{'} \tag{15}$$

Assuming: DE_j represents the obstacle degree of each evaluation index, which is used to measure the size of the influence of each evaluation index on the performance of the team, it is the result and objective of the diagnosis of the internal competitions of the entrepreneur team, its calculation method is given by Formula 16:

$$DE_{ij} = \frac{G_i * FC_i}{\sum_{i=1}^{m} G_i * FC_i} * 100\% \tag{16}$$

Then, the total obstacle degree W of all evaluation indexes to the performance of the team is:

$$W = \sum DE_i \tag{17}$$

4 Prediction of teamwork quality of team members and the analysis of coordination degree

Then, in this paper, a gray prediction model GM (1, 1) was adopted to predict the teamwork quality of college student entrepreneur team within the study period based on the completion degree of entrepreneurial tasks. Assuming: $CA_\tau(\tau=1,2,3,...,m)$ represents the original data of the completion degree of entrepreneurial tasks; τ represents the study period; CA_τ represents the data of the completion degree of entrepreneurial tasks within the τ-th time period, then Formula 18 gives the accumulation formula of original data:

$$B_\tau = \sum_{i=1}^{\tau} CA_\tau \tag{18}$$

A mean value sequence was attained based on Formula 19:

$$J_\tau = \left(B_\tau + B_{\tau-1}\right)/2 \tag{19}$$

Assuming: γ and λ are the coefficients to be solved, then the GM (1,1) prediction model constructed based on Formula 20 satisfies the first-order univariate differential equation of year τ:

$$\lambda = \frac{dB_\tau}{d_\tau} + \gamma B_\tau \tag{20}$$

The values of γ and λ were attained based on the above formula, then, the accumulated value B_τ was attained:

$$\begin{aligned} B_\tau &= \left(A_\tau - \frac{\lambda}{\gamma}\right) f^{-\gamma\tau} + \frac{\lambda}{\gamma} \\ \lambda &= \frac{\left(\sum_{\tau=1}^{m} J_\tau^2\right)\left(\sum_{\tau=1}^{m} A_O\right) - \left(\sum_{\tau=1}^{m} J_\tau\right)\left(\sum_{\tau=1}^{m} A_O J_O\right)}{m\left(\sum_{\tau=1}^{m} J_\tau^2\right) - \left(\sum_{\tau=1}^{m} J_\tau\right)^2} \\ \gamma &= \frac{\left(\sum_{\tau=1}^{m} A_O\right)\left(\sum_{\tau=1}^{m} J_\tau^2\right) - m\left(\sum_{\tau=1}^{m} A_O J_O\right)}{m\left(\sum_{\tau=1}^{m} J_\tau^2\right) - \left(\sum_{\tau=1}^{m} J_\tau\right)^2} \end{aligned} \tag{21}$$

The calculation formula of the predicted value is:

$$A^* = B_\tau - B_{\tau-1}, (\tau = 1, 2, 3, ..., m) \tag{22}$$

After completing the calculation, the prediction accuracy of the teamwork quality of college student entrepreneur team should be tested based on the size of small residual probability and variance ratio of the prediction results given by Formula 22; if the test is passed, it indicates that the constructed *GM* (1, 1) model works well, and its prediction result is effective.

At last, this paper used a coupling model to analyze the coupling and coordination degree of complementary degree, competitive degree, and entrepreneurial performance of the team. Assuming: $v_i(i=1,2,...,n)$ and $v_j(i=1,2,...,m)$ represent the evaluation indexes of the orderly development of each system, then there is:

$$D_m = \left\{\left(v_1 \times v_2 \times \cdots v_m\right) / \prod\left(v_i + v_j\right)\right\}^{1/m} \tag{23}$$

Assuming: E_1 represents the calculated value of complementary degree index; E_2 represents the calculated value of competitive degree index; *OH* represents the coupling degree; then the coupling model for assessing the complementary degree and competitive degree of college student entrepreneur team is given by the following formula:

$$OH = \left\{\left(E_1 \times E_2\right) / \left[\left(E_1 + E_2\right)\left(E_1 + E_2\right)\right]\right\}^{1/2} \tag{24}$$

The coordination degree focuses on measuring the relationship between the complementary degree and competitive degree of college student entrepreneur team. Assuming: *PU* represents the comprehensive coordination index of complementary degree and competitive degree, which is used to measure the contribution of the overall level of the two to the coordination degree; γ and δ represent undetermined coefficients, then there are:

$$PU = \sqrt{\gamma E_1 \times \delta E_2} \tag{25}$$

$$QS = \sqrt{OH \times PU} \tag{26}$$

The greater the value of *PU*, the more coordinated the influence of complementary degree and competitive degree of college student entrepreneur team on the performance of the team.

5 Experimental results and discussion

Table 1 shows the variance ratio, small error probability, and the mean of predicted values of the teamwork quality of 10 entrepreneur teams. According to the data shown in the table, the relative errors of the prediction results of the 10 teams were all relatively small, indicating that the prediction results were objective. Since the prediction made by the prediction model was based on the teamwork quality of entrepreneur teams, the prediction results were all relative values. Moreover, since the evaluation indexes had been standardized, all results were within the [0,1] interval. Because the predicted values of the teamwork quality of entrepreneur teams were attained based on the evaluation results of the teamwork quality of entrepreneur teams and the predictions were made by the constructed GM (1, 1) model, the predicted values of the teamwork quality of some entrepreneur teams were greater than 1, so the attained predicted values were only for reference.

Table 1. Predicted value of teamwork quality of college student entrepreneur teams

Team No.	Variance ratio	Small error probability	Mean of predicted values
1	0.3152	1.5162	0.8627
2	0.2684	0.9174	0.9185
3	0.3715	0.9685	0.9641
4	0.3192	1.3629	0.9062
5	0.2847	1.7482	0.9386
6	0.3925	0.9843	1.3852
7	0.4715	0.8156	0.9684
8	0.3927	0.9158	0.9157
9	0.4718	0.9683	0.9628
10	0.4625	0.9286	0.8615

Table 2 shows the calculation results of the obstacle degree of internal competitions of college student entrepreneur teams. According to the data shown in the table, the competition items, mediators, and response had different effects on the teamwork quality of college student entrepreneur teams. Wherein, the competing items include the competition for rights and the competition for interests; the mediators include the cultivation fairness, regulation fairness, and position fairness; the response is the entrepreneurial performance. On the whole, the proportions of mediators and response were larger, indicating that the fairness of cultivation, regulation and position and the entrepreneurial performance greatly hindered the improvement of the teamwork quality of

college student entrepreneur teams; the proportion of internal competitions for rights and interests was smaller, indicating that they only slightly hindered the teamwork quality of college student entrepreneur teams. However, for some teams, the proportion of internal competitions accounted for a greater part, this means that the execution of incentive measures in these teams was not good enough, but still, there's a certain effect. In a word, the entrepreneurial performance was the main obstacle to the improvement of the teamwork quality of college student entrepreneur teams.

Table 2. Obstacle degree of internal competitions of college student entrepreneur teams

Team No.	Competing item	Mediator	Response
1	0.0125	0.2651	0.7224
2	0.0626	0.1362	0.8012
3	0.0748	0.1986	0.7266
4	0.0521	0.1527	0.7952
5	0.4526	0.1385	0.4089
6	0.0958	0.1967	0.7075
7	0.0268	0.1284	0.8448
8	0.0483	0.1392	0.8125
9	0.0651	0.1157	0.8192
10	0.0958	0.1648	0.7394

After that, the combinatorial weighing method was adopted to process the standardized values of evaluation indexes, then the weights of each index in the EIS for assessing the teamwork quality of college student entrepreneur teams were attained. This paper calculated the teamwork quality index of college student entrepreneur teams based on the weighted sum method. Figure 3 shows the variations of the teamwork quality index of college student entrepreneur teams. According to the figure, during the study period from 2004 to 2020, the teamwork quality index showed a fluctuated increasing trend, with an increasing rate of 0.0168.

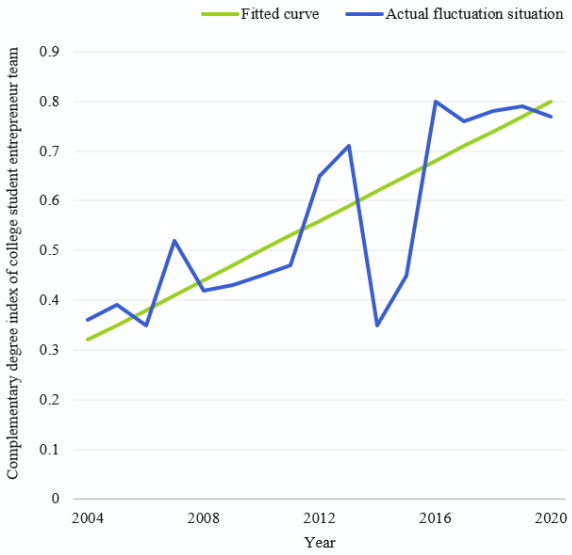

Fig. 3. Teamwork quality index of college student entrepreneur teams

Figure 4 gives the variation coefficients of the calculation results of teamwork quality of 10 entrepreneur teams. According to the figure, during the study period from 2004 to 2020, Team 10's variation coefficient was the largest, followed by Team 6, Team 1, Team 4, and Team 8, this means that, compared with other teams, the annual variation of Team 10's teamwork quality index was the greatest during the cultivation process.

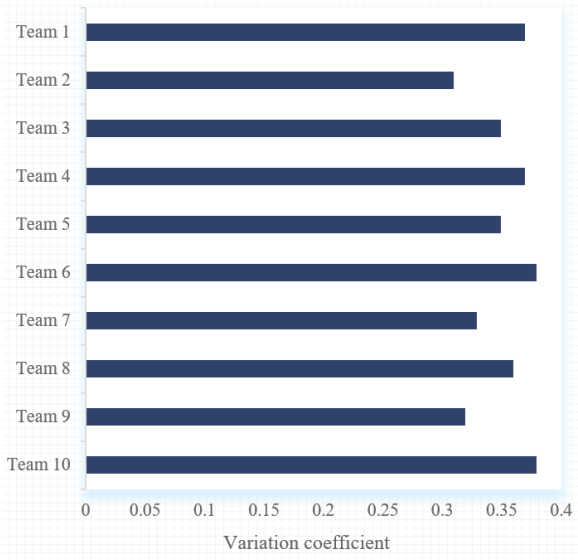

Fig. 4. Variation coefficient of teamwork quality of college student entrepreneur teams

Numerous studies suggest that, teamwork quality and entrepreneurial performance affect and promote each other, and the most intuitive manifestation is the completion degree of entrepreneurial tasks. Teams with a high completion degree of entrepreneurial tasks generally have better teamwork quality. In this paper, the completion degrees of entrepreneurial tasks and scores of teamwork quality of 10 entrepreneur teams were compared and analyzed. The correlation between the evaluation score of teamwork quality and the completion degree of entrepreneurial tasks was analyzed, the results are given in Figure 5. According to the figure, there's a significant positive correlation between the two, indicating that in teams with higher teamwork quality, the cooperation is closer among team members, and they tend to achieve higher completion degree of entrepreneurial tasks during the entrepreneurial process.

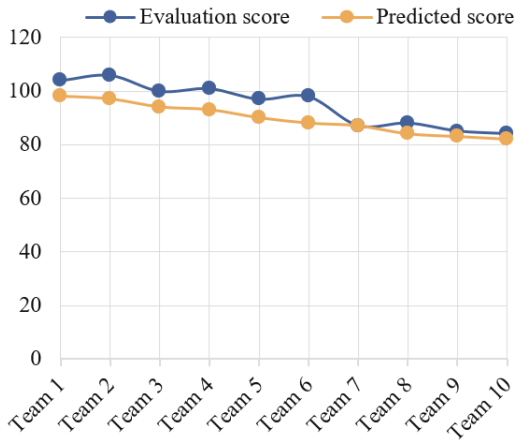

Fig. 5. Comparison of evaluation scores and predicted scores of teamwork quality of college student entrepreneur teams

6 Conclusion

This paper studied the cultivation of teamwork quality of college student entrepreneur team from the perspective of CCR. At first, relevant indexes were selected from four aspects of team factor, teacher factor, team member factor, and efficacy factor to form an EIS for assessing the said teamwork quality; then, a combinatorial weighing method was employed to integrate the weights obtained by EWM and VCM, two conceptual models of the competitive efficacy and complementary efficacy of college student entrepreneur team were built, and the methods for calculating the competitive degree index and complementary degree index of team members were introduced in detail. After that, a gray prediction model GM (1, 1) was used to predict the teamwork quality of several sample college student entrepreneur teams within the study period based on the completion degree of entrepreneurial tasks, and a coupling model was used to analyze the coupling and coordination degree between competitive degree, complementary degree, and entrepreneurial performance of the team.

In the experiment, this paper gave the variance ratio, small error probability, and mean of the predicted values of teamwork quality of 10 entrepreneur teams attained from the GM (1, 1) prediction model, calculated the obstacle degree of the internal competitions of entrepreneur teams, plotted the curves of teamwork quality index of entrepreneur teams, and counted the variation coefficients of the calculation results of teamwork quality of the 10 teams. At last, the completion degrees of entrepreneurial tasks and the scores of teamwork quality of the 10 teams were compared and analyzed, and the results proved that in teams with higher teamwork quality, the cooperation is closer among team members, and they tend to achieve higher completion degree of entrepreneurial tasks during the entrepreneurial process.

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