A study on the competence of middle school mathematics teachers in Hebei province under the background of craftsmanship spirit

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ABSTRACT

Purpose: Excellent education is only possible with teachers who possess exceptional skills. This study is based on the competency characteristics of middle school mathematics teachers, constructs a teacher competency model that integrates the spirit of craftsmanship and identifies the professional qualities, motivations and attitudes that outstanding mathematics teachers possess.

Design/Methodology/Approach: This study collected information and interview data from 12 experts through in-depth interviews and then encoded and summarized the themes through theme analysis to construct a competency system for high school mathematics teachers in Hebei Province. Thirty experts were given questionnaires to complete. The competency model was then validated and revised using the fuzzy Delphi method (FDM) and the relative importance of each indication was examined using the analytical hierarchy process (AHP).

Findings: The fuzzy Delphi questionnaire shows that the expert consensus meets the requirements of the verification value while the analytic hierarchy process questionnaire shows that the expert opinions have passed the consistency test.

Conclusion: This study integrates the spirit of craftsmanship with the competency characteristics of middle school mathematics teachers and constructs a teacher competency model. The constructed model was subjected to fuzzy Delphi validation and analytic hierarchy process weight analysis by distributing questionnaires. The conclusion verifies the reliability and validity of the established model.

Contribution to the Literature: This study introduces the spirit of craftsmanship into the teacher competency model enriching the connotation and extension of teacher competency research. Interpreting teacher competency with craftsmanship traits can make the competency characteristics of teachers more concrete.

1. INTRODUCTION

Society is increasingly in need of quality education and only remarkable teachers can provide outstanding education. In-depth investigation of the competency attributes of middle school math teachers in Hebei Province and the development of a teacher competency model can aid in pinpointing deficiencies in the competency of middle school math teachers, offer focused direction and instruction to educational institutions and administrative departments and serve as a valuable resource.

The spirit of craftsmanship includes craftsmanship ethics which are similar to the professional ability, attitude and spirit of teacher competence. They are all concentrated manifestations of excellent qualities such as unity of knowledge and action, dedication, innovation and pursuit of excellence. The two have a high degree of consistency.

This study explores the competency characteristics of high school mathematics teachers through in-depth interviews, constructs a competency model for high school mathematics teachers that integrates the spirit of

craftsmanship and verifies the model through the fuzzy Delphi method and the analytic hierarchy process for importance analysis. (1) Drawing on the dimensional model of craftsmanship spirit, construct a competency model for middle school mathematics teachers. (2) Verify the competency model of middle school mathematics teachers established through the fuzzy Delphi method. (3) Construct a hierarchical structure model to rank the importance of competency indicators for middle school mathematics teachers.

2. RESEARCH FRAMEWORK

The present study aims to examine the relationship between middle school mathematics teachers' individual qualities and craftsmanship by first reviewing and analyzing pertinent literature on teacher competency and craftsmanship. Additionally, the study seeks to extract the fundamental ideas and connotation features of the two concepts. Design semi-structured interview outlines and behavioral event interview outlines as research tools based on iceberg theory, onion theory and STAR (situation task action result) tools in behavioral event interviews. The in-depth interviews were used to collect information and interview data and then encode the theme analysis, summarize the themes and construct a competency system for high school mathematics teachers in Hebei Province. The fuzzy Delphi method was used to verify and revise the competency model and the analytic hierarchy process was used to analyze the weight of each indicator in the revised model. A flowchart for this study was developed using this methodology (see Figure 1).
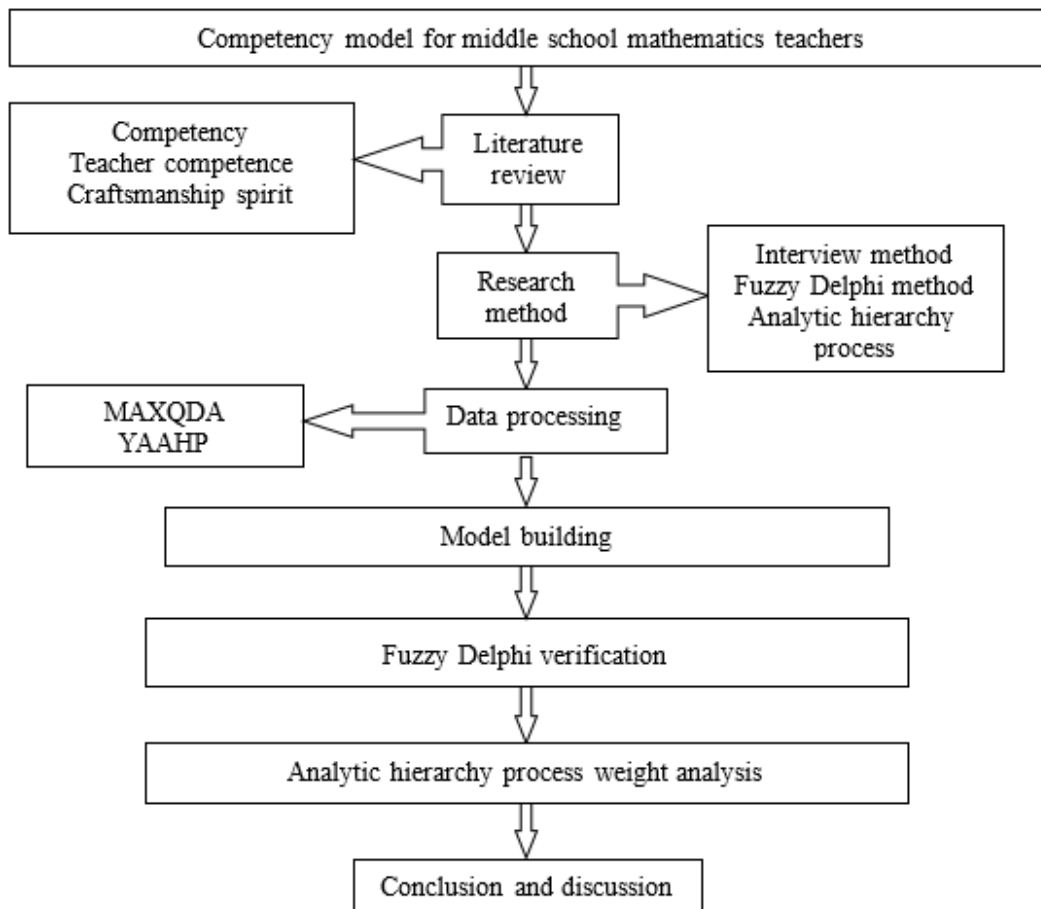

Figure 1. Research framework.

The following research questions are established using the research process mentioned above:
(1) Constructing a competency model for middle school a mathematics teachers that integrates the spirit of craftsmanship.

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(2) Verify the competency model of middle school mathematics teachers through the fuzzy Delphi method.
(3) Perform weight analysis on the competency model of middle school mathematics teachers through the analytic hierarchy process.

3. LITERATURE REVIEW

This study provides a review of three core concepts: competence, teacher competence and craftsmanship spirit.

There is no unified expression of the concept of competence but research by different scholars has similar characteristics. The selection of competence features is based on job performance as the criterion for discrimination and is closely related to job performance. Competency characteristics can effectively distinguish outstanding performers from average performers in job performance and there are significant differences in the performance of competency characteristics between the two types of personnel. According to David C. McClelland (1973) competence is a human quality that may differentiate employee performance levels, challenging the traditional view and putting an excessive amount of emphasis on intellect in the talent selection process. Lado, Boyd, and Wright (1992) argue that competence is the manifestation of individual traits that can be used to understand, analyze and distinguish the excellence of employee performance. Marpa (2021) believes that traditional intelligence, performance and personality tests cannot effectively assess employee competence and should be based on actual situations and raw materials that reflect employee work performance.

3.1. Connotation of Competence
The connotation of competence can be classified into two categories: first, the knowledge and skills possessed by individuals in specific jobs as well as the advantages demonstrated in certain fields. The second category is performance which means that individuals have significant abilities to surpass others in a certain field or perform excellently in a certain field. In other words, the more significant these characteristics are, the more outstanding their job performance will be.

McClelland (1987) believes that competence refers to the knowledge, skills and personality traits exhibited by employees when engaging in innovative work. On the basis of McClelland's competency theory, Hofrichter and Spencer (1996) proposed the famous competency iceberg model. Amhag, Hellström, and Stigmar (2019) believe that competence encompasses multiple abilities required to achieve the goals set by superiors such as knowledge, skills and attitudes. Starkey (2020) pointed out that competency traits are potential and implicit personal characteristics of employees that vary in different fields including employees' knowledge, skills, motivation, traits, attitudes, etc. and these characteristics are measurable.

The competency theory can effectively implement human resource management and is increasingly being valued by managers (Barcelona, 2001). The concept of competence is still prevalent today and is applied extensively in a number of areas, including performance management, training and hiring (Bisschoff & Grobler, 1998).

3.2. Teacher Competence
The competency qualities that teachers especially principals need to have in order to perform at a high level were the subject of early research on teacher competency. The United States, the United Kingdom, Germany and other countries have developed standards at the national level to evaluate teacher competence. The American Association of Educators conducted a 7-year study on teacher competency traits. Researchers used various methods such as classroom observation, influencing factor analysis and correlation validation to ultimately identify 9 competency traits that are closely related to teacher teaching and have an impact on teaching effectiveness (Juntunen & Westerlund, 2011). Countries such as the United Kingdom, Germany, the Netherlands and the United States have evaluated teacher competence earlier but their evaluation systems are later than those of the United States (Sandberg, 2000). According to Wiesner and Cronshaw (1988) the UK government has created the "National Education Evaluation Centre" to create competence assessments for education management and places an emphasis on competency research with a focus on teacher performance. However, early competency research mainly focused on principals and managers in the field of education, lacking research and evaluation of teacher competency characteristics (Vannatta-Hall, 2010).

The competencies of primary teachers are progressively coming into focus as research becomes deeper. Shulman (1987) explored a teacher competency model based on the knowledge, skills, attitudes and traits required by

frontline teachers to complete educational and teaching work. A universal competence model was developed to assess teacher effectiveness through the use of standards and grading. The emphasis of competence research has steadily shifted from education management to teachers as a result of the education system reform (York-Barr & Duke, 2004). According to Chapman and Lovell (2006) teachers' knowledge, abilities, motivation, psychological traits and self-concept as well as the impact these features have on their job, are classified as teacher competence qualities. Gangani, McLean, and Braden (2006) proposed a teacher competency model that covers four core indicators: pre- class preparation, classroom atmosphere, teaching effectiveness and sense of responsibility. This model contains 22 behavioral indicators forming a complete teaching behavior structure diagram. This model is frequently used in teacher assessment since it is a traditional model of teacher performance competence.

3.3. Craftsmanship Spirit
The early research on the spirit of craftsmanship has strong industry characteristics while Chinese scholars are more enthusiastic about the core components of the spirit of craftsmanship. According to academic explanations, the spirit of craftsmanship encompasses the professional ethics of workers who pursue perfection and strive for excellence in their abilities and goods as well as the professional qualities of commitment, unity of knowledge and action shown in their work.
Plato (1986) believes that craftsmen can only become specialized and focused if they commit all of their time and resources to learning a technique and making it their lifelong career. Wang and Wang (2017) defined the spirit of craftsmanship as the pursuit of innovation emphasizing excellent quality and a high emphasis on user service. Wood, Rust, and Horne (2009) pointed out that modern master craftsmen have abundant online learning resources and even when working independently, they can still receive support from online communities enabling them to acquire new skills and innovate. People also gain happiness in this process of labor. Li (2019) believes that the spirit of craftsmanship is an advancement of professional attitude which constrains the professional practice behavior of professionals through professional values. The spirit of craftsmanship is not limited to traditional manufacturing craftsmen but rather the attitude of all professionals towards work excellence, the pursuit of excellent quality, the spirit of innovation and the life pursuit of the unity of Taoism and technology (Xiao & Liu, 2015).
Li and Zhao (2017) believe that love for work and striving for excellence are the constituent elements of the spirit of ancient Chinese craftsmen. Yu (2016) conducted in-depth research from the perspective of craftsmanship ethics and believed that rigor, dedication and focus are the constituent elements of craftsmanship spirit. Qiao and Gao (2018) extracted four core dimensions of craftsmanship spirit: striving for excellence, pursuing excellence, perseverance and dedication through an open questionnaire survey.

4. RESEARCH DESIGN
The purpose of this study is to construct a competency model for middle school mathematics teachers in Hebei Province that integrates the spirit of craftsmanship. The research design is as follows based on the iceberg theory model: In the first stage, a review is conducted on competency and craftsmanship spirit, extracting the core concepts and connotation characteristics of the two and exploring the consistency between the individual characteristics of middle school mathematics teachers and craftsmanship spirit. In the second stage, combining the iceberg theory and the STAR tool in behavioral event interviews, the interview content is formulated and the interview outline is determined. After determining the interview outline, conduct in-depth interviews with the interviewees through intentional sampling. In the third stage, the interview results are organized and analyzed to extract the competency characteristics of high school mathematics teachers in Hebei Province using the thematic analysis method. In the fourth stage, construct a competency model for high school mathematics teachers in Hebei Province. In the fifth stage, the competency model of middle school teachers is verified through the fuzzy Delphi method. In the sixth stage, the analytic hierarchy process is used to analyze the importance of each indicator in the revised model. The following research design was constructed (see Figure 2).
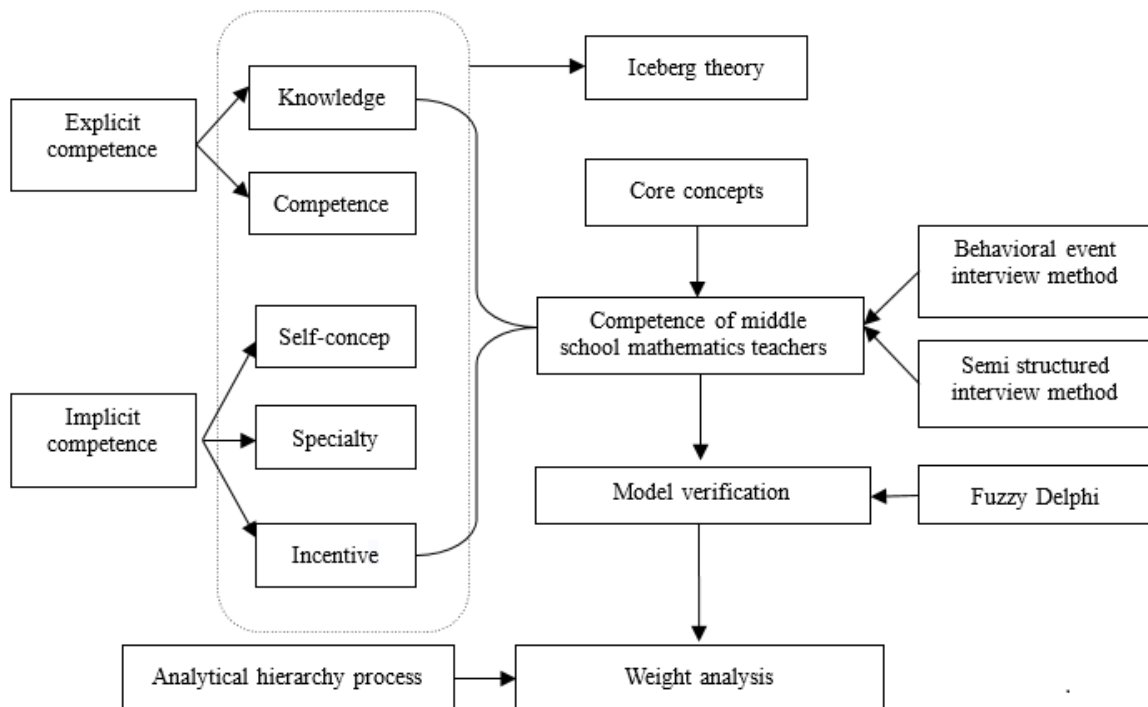
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Figure 2. Research design.

5. RESEARCH PROCESS ANALYSIS

The competence traits of middle school teachers in Hebei Province are the primary focus of this study which also makes use of pertinent literature on teacher competency and handicraft spirit. Materials from behavioural events and in-depth interviews were reviewed several times. According to the research paradigm of thematic analysis, the interview materials are open coded, classified into open codes, summarized into spindle codes and condensed into selective codes based on the dimensions of craftsmanship spirit. This serves as the foundation for the model's verification and weight analysis using the analytic hierarchy method and fuzzy Delphi.

5.1. Data Collection

The competence features of high school math teachers in Hebei Province were the subject of the interviews conducted for this study. The researcher used the semi-structured interview outline and the study's theme to create specific questions by determining the work of researchers such as Spanierman et al. (2011); Pantić, Wubbels, and Mainhard (2011) and Zeuch, Förster, and Souvignier (2017). The study's theoretical sample size meets the standards with 12 frontline teachers of mathematics chosen as participants in the interviews (Larsson & Karlefors, 2015). The selection of frontline experts in middle school mathematics education meets the following three conditions: a high school senior professional title, 20 years or more of work experience in high school mathematics education and receiving honorary titles such as provincial-level or above teaching masters and special level teachers.

The interviewees for this study were selected based on the geographical division of Hebei Province including Shijiazhuang City, Hengshui City, Tangshan City, Langfang City, Handan City, Qinhuangdao City, Zhangjiakou City, and Cangzhou City. The interviewed experts consist of 12 frontline mathematics teachers from high schools (as shown in Table 1) including 2 from Shijiazhuang, 2 from Hengshui, 1 from Tangshan, 1 from Langfang, 2 from Handan, 1 from Qinhuangdao, 1 from Zhangjiakou and 1 from Cangzhou, all of whom come from state-owned public high schools. Among them, there are 10 associate professors, 2 professors, 7 male mathematics teachers and 5 female mathematics teachers. The longest teaching experience is 30 years and the shortest is 20 years.

Interviewee	Gender	Age	Teaching experience	Region	Interview time	Technical title	Honorary title
A	M	45	20	Shijiazhuang city	72 min	Associate professor	Backbone teachers
B	M	53	30	Hengshui city	75 min	Professor	Special-grade teacher
C	M	46	22	Langfang city	68 min	Associate professor	Master teachers
D	F	50	26	Shijiazhuang city	71 min	Professor	Special-grade teacher
E	M	44	21	Hengshui city	67 min	Associate professor	Master teachers
F	M	44	20	Handan city	69 min	Associate professor	Prominent teacher
G	M	46	23	Qinhuangdao city	73 min	Associate professor	Prominent teacher
H	F	46	22	Tangshan city	65 min	Associate professor	Master teachers
I	F	44	21	Cangzhou city	70 min	Associate professor	Backbone teachers
J	F	43	20	Zhangjiakou city	64 min	Associate professor	Teacher's moral model
K	M	45	21	Handan city	70 min	Associate professor	Prominent teacher
L	F	46	23	Tangshan city	81 min	Associate professor	Backbone teachers

The interview tool uses China Tencent conference software and conducts interviews through online videos. Meeting recording and synchronous transcription functions are enabled during the interview. Anonymously numbered the interview documents of 12 interviewees while organizing the personal information of the interviewees. The total interview time was 835 minutes with an average of nearly 70 minutes. The transcribing function of Tencent meeting provided convenience for the organization of text materials resulting in a total of 150000 words of text materials obtained.

5.2. Model Construction
This study summarizes the logical structure of open coding, spindle coding and selective coding to obtain the competency characteristics system of high school mathematics teachers in Hebei Province.
Open coding explores and studies the competency characteristics of high school mathematics teachers in Hebei Province. 77 open codes and conceptual explanations were obtained based on the collected raw interview data of 12 interviewees. Open coding has completed the basic coding work for the competency characteristics of high school mathematics teachers in Hebei Province.
31 open codes reflecting professional abilities such as social responsibility, mathematical thinking and innovation consciousness were extracted into 9 main axis codes such as ideal beliefs and innovation after repeated research on open coding and sorting out the logical relationship between codes. Extract the 14 open codes of lifelong learning, firm belief and sustainable development into four main codes: achievement driven, striving and reflective improvement. Summarize the 32 open codes of educational belief, focus and respect into 10 main codes of educational sentiment, fairness and respect and professional ethics. A total of 23 spindle codes were obtained covering the competency characteristics of high school mathematics teachers in terms of professional ability, motivation and professional attitude.

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The 23 major axes are categorized into 5 cores based on the study subject and the craftsman's spirit dimension's characteristics: integration of knowledge and action, courage to innovate, pursuit of perfection, devotion and dedication. It was established by the theoretical saturation test that no additional target elements were discovered suggesting that the investigation has achieved a theoretical saturation condition.

5.3. Fuzzy Delphi Verification

The content validity of the first and second level indicators of the competency model for middle school mathematics teachers in Hebei Province was verified using the fuzzy Delphi expert survey method to analyze the convergence of indicator elements. The aim is to understand whether there is inconsistency in experts' understanding of the core competencies and secondary indicators of high school mathematics teachers in Hebei Province and to ensure the scientific and rigorous nature of the model.

Implementation steps of the fuzzy Delphi method: The implementation steps of the fuzzy Delphi method mainly include the following four steps: establishing core dimensions and their behavioral indicator groups collecting opinions from decision-making groups; establishing triangular fuzzy functions and filtering metrics.

This study retained 12 middle school frontline teachers who participated in in-depth interviews and supplemented 18 experts from applied undergraduate universities engaged in mathematics education teaching and management work in order to make the verification more scientific. Researchers can gain a deeper understanding of the phenomena of interest and obtain richer data and insights by carefully selecting individuals with relevant experience, knowledge or specific characteristics as samples (Velde, 1999).

A fuzzy expert questionnaire is designed and a sampling is conducted based on the intention to select a suitable group of 30 experts to participate based on the research topic and indicator factors. Each expert needs to provide three numerical values for each evaluation element in the questionnaire: the most conservative estimate (denoted as C^i), the most optimistic estimate (denoted as O^i) and the personal best value.

The most conservative and optimistic estimates provided by the experts were statistically analyzed and the extreme values outside of twice the standard deviation were removed after retrieving the questionnaire. Subsequently, calculate the minimum value (denoted as C_L^i), geometric mean value (denoted as C_M^i) and maximum value (denoted as C_U^i) among the remaining most conservative estimates while calculating the minimum value (denoted as O_L^i), geometric mean value (denoted as O_M^i) and maximum value (denoted as O_U^i) among the remaining most optimistic estimates. The formula for calculating the geometric mean of the most conservative and optimistic estimates is: $C_M^i = \sqrt{C_L^i \times C_U^i}$ $O_M^i = \sqrt{O_L^i \times O_U^i}$

Construct the most conservative estimate of the triangular fuzzy number for each evaluation indicator $C^i = (C_L^i,\ \ C_M^i,\ \ C_U^i)$ and the most optimistic estimate of the triangular fuzzy number to form a double triangular fuzzy number $O^i = (O_L^i,\ \ O_M^i,\ \ O_U^i)$. If there is no intersection between the two ($C_U^i \le O_L^i$), it indicates that the opinions of the experts have achieved consensus and the formula for calculating the consensus degree of the expert group for the indicator is $G_i = \dfrac{C_M^i + O_M^i}{2}$.

If the triangular fuzzy numbers of the most optimistic estimate and the most conservative estimate intersect ($C_U^i > O_L^i$) but the grey area of the double fuzzy triangle relationship($Z^i = C_U^i - O_L^i$) is smaller than the difference ($M^i = O_M^i - C_M^i$) between the geometric mean values of the most optimistic estimate and the most conservative estimate of the evaluation index i given by the expert, that is $Z^i < M^i$, it indicates i that there are differences between the estimated values given by some experts leading to the emergence of the grey fuzzy space. However, the opinions of the expert group are still convergent in the presence of differences (Lei, 2014). The calculation formula for the consensus degree of the expert group of indicators adopts the simplified calculation and publicity method ($G^i = \dfrac{\left[(C_U^i \times O_M^i)\ -\ (O_L^i \times C_M^i) \right]}{\left[(C_U^i - C_M^i)\ +\ (O_M^i - O_L^i) \right]}$) proposed by Zhao and Li (2015).

When there is a cross between the most optimistic estimate and the most conservative estimate of the triangular fuzzy number ($C_U^i > O_L^i$), and $Z^i > M^i$. In this case, there are fuzzy areas within the evaluation range of

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experts and scholars that cannot reach consensus and some experts have put forward opinions that are very different from others. This divergence of opinions leads to fuzzy areas. Therefore, it is necessary to provide the minimum, geometric mean and maximum values of the most conservative and optimistic estimates of evaluation indicators that have not converged to the expert group as a reference and repeat steps 1 to 4. If evaluation indicators still fail to fulfil convergence standards after the second set of questionnaire surveys, they will be removed.

Determine the relevant consensus degree based on the three scenarios mentioned above for indicators that have passed the convergence test. The size of the threshold directly affects the number of selected indicator factors in the process of selecting indicator factors. This study mainly adopts the common threshold range of 6-7 in terms of setting threshold values.

5.4. Weight Analysis

The AHP method is divided into five steps: establishing a hierarchical structure model, constructing a judgment matrix, calculating weights and ranking, consistency testing, comprehensive analysis and decision-making. It should be noted that the last three steps of the analytic hierarchy process need to be implemented layer by layer. The research idea is to establish a hierarchical structure model for the competency of middle school mathematics teachers in Hebei Province based on the results of the first stage expert questionnaire survey. Analyse the expert questionnaire survey data using the analytic hierarchy process to identify the essential components of middle school maths teachers' competency in Hebei Province in addition to the relative weights of the secondary indicators for each component. The evaluation method adopts pairwise comparison between indicators mainly based on experts' judgments of relative importance and the ratio weight between various behavioral indicators depends on the subjective determination of experts.

In March 2023, an electronic questionnaire was sent to 30 experts through email and all 30 experts answered the questionnaire.

The competency of middle school mathematics teachers in Hebei Province is the target layer of the hierarchical model with 5 core elements of unity of knowledge and action, courage to innovate, pursuit of excellence, dedication and dedication as the first level criterion layer and 22 secondary indicators of ideal belief, mathematical literacy, educational literacy, management literacy, practical ability, diligent research, problem orientation, exploration and development, adaptability, active learning, reflection and improvement, continuous improvement, and striving for progress education , perseverance, steadfastness and patience, self-control and inclusiveness, fairness and respect, resilient commitment, professional ethics, tireless teaching and integrity are the secondary criteria layer and personnel A have been added as the plan layer to ensure the completeness of the hierarchical model.

Firstly, the importance evaluation of each indicator by 30 experts is imported into Yaahp software and a paired comparison matrix is constructed to calculate the maximum eigenvalue λ_{max} of the matrix. The consistency index of the matrix is calculated by substituting λ_{max} into the formula $CI = \dfrac{\lambda_{max} - n}{n - 1}$ and the consistency ratio is calculated by substituting the consistency index into the formula $CR = \dfrac{CI}{RI}$, where (RI) is the random index (see Table 2). It ($CR < 0.1$) is generally believed that the judgment matrix has good consistency (Saaty, 1972). The corresponding feature vectors λ_{max} are normalized to obtain the weights of each indicator after the consistency check of the judgment matrix is passed.

Table 2. Random index.

n	3	4	5	6	7	9	10	11	12
RI	0.52	0.89	1.12	1.26	1.36	1.46	1.49	1.52	1.54

6. RESULTS

This study constructed a competency model for high school mathematics teachers in Hebei Province through open coding, spindle coding and selective coding. The fuzzy Delphi method was used to test the scientific nature and

rationality of the competency model and the weights of each indicator in the model were calculated using an analytic hierarchy process.

6.1. Competency Model for Middle School Mathematics Teachers

The competency model for middle school mathematics teachers in Hebei Province includes five core indicators: unity of knowledge and action, courage to innovate, pursuit of excellence, dedication, responsibility and dedication. 23 secondary indicators are as follows: ideal beliefs, mathematical literacy, educational literacy, management literacy, practical ability, pioneering and innovative, proactive learning, achievement driven, educational sentiment, perseverance, steadfast patience, fairness and respect, professional ethics, integrity, etc. 77 behavioral indicators are as follows: social responsibility, compliance with laws and regulations, values, mathematical thinking, interdisciplinary knowledge, educational literacy, psychological literacy, modern educational technology, communication and expression, etc.

The unity of knowledge and action, the courage to innovate, the pursuit of excellence, dedication and the commitment to dedication are a series of values and behavioral norms with internal connections in the competency model of middle school mathematics teachers. Dedication and the unity of knowledge and action are the foundation of excellent teachers the courage to innovate is the pursuit of excellent teachers. The pursuit of excellence is the soul of excellent teachers and the commitment to dedication is the mission of excellent teachers. They are interdependent and complementary to each other. It constitutes the complete professional literacy, motivation and attitude of outstanding teachers in secondary schools (see Figure 3).
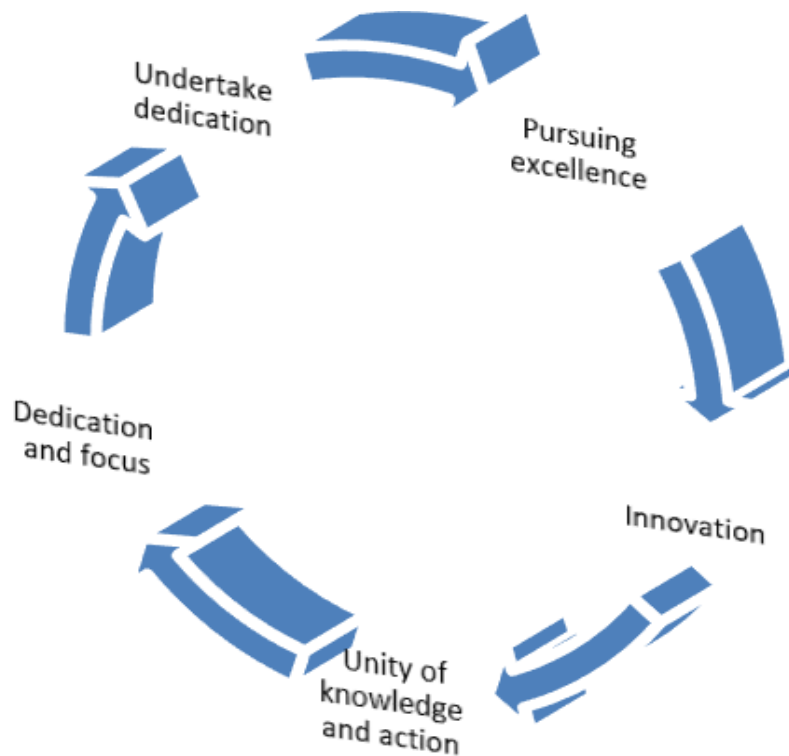
Figure 3. Core element association diagram.

6.2. Fuzzy Delphi Method Verification Results

The most conservative estimate provided by experts for the core factor in the fuzzy Delphi questionnaire calculating technique using the unity of knowledge and action as an example varies from 5 to 8. The arithmetic mean of the most conservative estimate given by experts for this element is 6.25 with a standard deviation of 1.01 excluding the extreme value (6.25 ± 2.02) beyond twice the standard deviation. The most conservative estimates of all experts are within the range of twice the standard deviation so they are all retained. Similarly, for the four

core elements of innovation, pursuit of excellence, dedication, the most conservative and optimistic estimates have been tested and retained (see Table 3).

Table 3. Reasonability test of core indicators.

Core elements	C_L^i	C_U^i	O_L^i	O_U^i	Conservative lower	Conservative upper	Optimistic lower	Optimistic upper
P	5	8	8	10	4.2	8.3	7.8	10.4
I	5	7	8	10	4.2	7.4	7.8	10.4
O	4	7	8	10	3.9	7.6	7.4	10.4
D	4	8	9	10	3.5	8.3	8.6	10.6
U	5	8	8	10	3.9	8.3	7.0	10.6

Calculate the geometric mean of the most conservative estimate of the unity of knowledge and action $C_M^i = \sqrt{C_L^i \times C_U^i} = \mathbf{5.65}$ and establish the triangular fuzzy number of the most conservative estimate $C_i = (5, 5.65, 7)$. The geometric mean of the most optimistic estimate of the combination of knowledge and action is $O_M^i = \sqrt{O_L^i \times O_U^i} = \mathbf{8.94}$. Triangular fuzzy numbers with the most optimistic estimate is $O_i = (8, 8.94, 10)$. Next, the grey zone test method is used to test whether the 30 experts have reached a consensus. For the core element of knowledge and action unity, it is satisfied $C_U^i \le O_L^i$, indicating that there is consensus among the experts' personal opinions. At the same time, all expert valuation ranges fall within the consensus range and the evaluation of the 30 experts on this knowledge and action has reached convergence. Therefore, there is a consensus among 30 experts on the unity of knowledge and action $G_i = \frac{C_M^i + O_M^i}{2} = \mathbf{7.63}$.

Similarly, the consensus values of 30 experts on the other four core elements can be calculated (see Table 4).

Table 4. Convergence test of core elements.

Core elements	C_L^i	C_U^i	O_L^i	O_U^i	C_M^i	O_M^i	M^i	Z^i	$M^i - Z^i$	G^i
P	5	7	8	10	6.32	8.94	2.62	0	2.62	7.63
I	4	7	8	10	5.92	8.94	3.03	-1	4.03	7.43
O	4	8	9	10	5.29	8.94	3.65	-1	4.65	7.12
D	5	8	8	10	5.66	9.49	3.83	-1	4.83	7.57
U	5	8	8	10	6.32	8.94	2.62	0	2.62	7.63

From Table 4, it can be seen that the two triangles fuzzy numbers for the five core indicators of knowledge and action integration, innovation, pursuit of excellence and dedication meet the consensus range $C_U^i \le O_L^i$ and all expert valuation ranges fall within the consensus range. The evaluation of this knowledge and action integration by 30 experts has reached convergence. Among them, the consensus level of unity of knowledge and action and commitment to dedication is the highest at 7.63 while the consensus level of pursuing excellence is the lowest at 7.12 which is higher than the threshold set by the research group.

The expert verification results of 23 secondary indicators for the competency of high school mathematics teachers in Hebei Province including the integration of knowledge and action, courage to innovate, pursuit of excellence, dedication, mathematical literacy, pioneering and innovation, adaptability, reflection and improvement, striving for progress, perseverance, fairness and respect, conscious responsibility, integrity and courageous progress are set under the five core elements (the calculation method is the same as above). The results showed that the most conservative estimates of all experts were within the range of twice the standard deviation, so they were all retained.

According to the formula, $C_M^i = \sqrt{C_L^i \times C_U^i}$ $O_M^i = \sqrt{O_L^i \times O_U^i}$ calculating the geometric mean of the most conservative and optimistic estimates for 23 secondary indicators such as ideal beliefs and establishing triangular fuzzy numbers. Use the grey zone test method to test whether 30 experts have reached a consensus. After

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inspection, all 23 secondary indicators meet the requirements $C_U^i \leq O_L^i$, there is no duplication between the most conservative estimate triangular fuzzy number and the most optimistic estimate triangular fuzzy number indicating that there is consensus among experts' personal opinions. At the same time, all expert valuation intervals fall within the consensus range and the evaluation of 23 secondary indicators by 30 experts has reached convergence. According to the formula, $G_i = \dfrac{C_M^i + O_M^i}{2}$ the consensus degree of each secondary indicator is calculated (see Table 5).

Table 5. Convergence test of secondary indicators.

Core elements	C_L^i	C_U^i	O_L^i	O_U^i	C_M^i	O_M^i	M^i	Z^i	$M^i - Z^i$	G^i
P1	4	8	8	10	5.66	8.94	3.29	0.00	3.29	7.30
P2	6	8	9	10	6.93	9.49	2.56	-1.00	3.56	8.21
P3	5	7	8	10	5.92	8.94	3.03	-1.00	4.03	7.43
P4	5	8	8	10	6.32	8.94	2.62	0.00	2.62	7.63
P5	3	7	8	10	4.58	8.94	4.36	-1.00	5.36	6.76
I1	4	8	8	10	5.66	8.94	3.29	0.00	3.29	7.30
I2	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
I3	3	7	9	10	4.58	9.49	4.90	-2.00	6.90	7.03
I4	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
O1	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
O2	3	8	9	10	4.90	9.49	4.59	-1.00	5.59	7.19
O3	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
O4	5	8	9	10	6.32	9.49	3.16	-1.00	4.16	7.91
D1	4	7	8	10	5.29	8.94	3.65	-1.00	4.65	7.12
D2	4	8	8	10	5.66	8.94	3.29	0.00	3.29	7.30
D3	3	8	8	10	4.90	8.94	4.05	0.00	4.05	6.92
D4	3	8	8	10	4.90	8.94	4.05	0.00	4.05	6.92
D5	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
U1	4	8	8	10	5.66	8.94	3.29	0.00	3.29	7.30
U2	5	8	9	10	6.32	9.49	3.16	-1.00	4.16	7.91
U3	4	8	9	10	5.66	9.49	3.83	-1.00	4.83	7.57
U4	5	8	8	10	6.32	8.94	2.62	0.00	2.62	7.63
U5	4	8	8	10	5.66	8.94	3.29	0.00	3.29	7.30

6.3. Analytic Hierarchy Process Calculation Results

Teacher A's core element judgment matrix is used as an example to demonstrate the consistency of the testing process. Firstly, based on teacher A's evaluation of the core elements of unity of knowledge and action, courage to innovate, pursuit of excellence, and dedication a paired comparison matrix is constructed

$$\begin{pmatrix} 1 & 4 & 2 & \frac{1}{2} & 3 \\ \frac{1}{4} & 1 & 1 & \frac{1}{3} & \frac{1}{2} \\ \frac{1}{2} & 1 & 1 & \frac{1}{8} & 2 \\ 2 & 3 & 8 & 1 & 4 \\ \frac{1}{3} & 2 & \frac{1}{2} & \frac{1}{4} & 1 \end{pmatrix}$$

Then $\lambda_{max} = 5.3359$, $CI = \dfrac{\lambda_{max} - n}{n - 1} = \dfrac{5.3359 - 5}{5 - 1} = 0.0840$,

$CR = \dfrac{CI}{RI} = \dfrac{0.0840}{1.12} = 0.0750 < 0.1$ Through consistency testing, normalize the feature vector corresponding

of λ_{max} to obtain the weight vector $\begin{pmatrix} 0.2489 \\ 0.0976 \\ 0.0857 \\ 0.4611 \\ 0.1068 \end{pmatrix}$ .The highest weight of dedication and focus is 0.4611 indicating

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that teacher A believes that dedication and focus have the greatest impact on the competency of middle school mathematics teachers. Similarly, the consistency test results of various indicators can be obtained from 30 experts. The individual indicators of individual experts did not pass the consistency test at the beginning which may be related to the experts' unfamiliarity with the 9-level indicator evaluation system. The researchers revised the paired comparison matrix of individual indicators to ensure consistency in response to this circumstance by communicating with the experts later on and obtaining their approval.

Assemble the core indicators and behavioral indicator judgment matrix of 30 experts who have passed consistency testing using the arithmetic mean as the aggregation principle to obtain the core indicator judgment matrix

$$\begin{pmatrix} 1 & \frac{8}{3} & \frac{13}{8} & \frac{5}{6} & \frac{31}{12} \\ \frac{3}{8} & 1 & \frac{53}{36} & \frac{43}{60} & \frac{4}{3} \\ \frac{8}{13} & \frac{36}{53} & 1 & \frac{23}{28} & \frac{5}{4} \\ \frac{6}{5} & \frac{60}{43} & \frac{28}{23} & 1 & \frac{12}{35} \\ \frac{12}{31} & \frac{3}{4} & \frac{4}{5} & \frac{35}{12} & 1 \end{pmatrix}$$, the maximum eigenvalue is calculated $\lambda_{max} = 5.1156$. The consistency ratio is $CR = 0.0258 < 0.1$.

and then the weight vector is obtained as $\begin{pmatrix} 0.2949 \\ 0.1113 \\ 0.1665 \\ 0.2683 \\ 0.1589 \end{pmatrix}$. The expert gathering results indicate that the unity of knowledge, action and dedication are the most important while the weight coefficient of innovation is the lowest. Similarly, the judgment matrix, consistency test results and weight vector of behavioral indicators for unity of knowledge and action, courage to innovate, pursuit of excellence and dedication can be obtained (see Table 6).

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Table 6. Expert aggregation evaluation results.

Secondary indicators	Comparison matrix					λ_{max}	CR	Intragroup weigh	Overall weight
P	1	8/3	13/8	5/6	31/12			0.2949	
I	3/8	1	53/36	43/60	4/3			0.1665	
O	8/13	36/53	1	23/28	5/4	5.116	0.026	0.1589	
D	6/5	60/43	28/23	1	35/12			0.2683	
U	12/31	¾	4/5	12/35	1			0.1113	
P1	1	35/12	29/8	11/4	35/12			0.4313	0.1272
P5	12/35	1	43/36	19/15	13/12			0.1576	0.0465
P4	8/29	36/43	1	69/58	19/18	5.025	0.005	0.1385	0.0408
P3	4/11	15/19	58/69	1	12/11			0.1359	0.0401
P2	12/35	12/13	18/19	11/12	1			0.1366	0.0403
O3	1	7/3	22/17	81/49				0.3649	0.0608
O4	3/7	1	41/36	5/4				0.2150	0.0358
O2	17/22	36/41	1	85/72		4.048	0.018	0.2283	0.0380
O1	49/81	4/5	72/85	1				0.1918	0.0319
U2	1	5/4	31/24	5/3				0.3130	0.0498
U1	4/5	1	13/8	5/3				0.2960	0.0470
U4	24/31	8/13	1	37/36		4.054	0.020	0.2042	0.0325
U3	3/5	3/5	36/37	1				0.1868	0.0297
D1	1	61/36	19/6	53/24	5/2			0.3539	0.0950
D2	36/61	1	17/6	19/9	2			0.2667	0.0716
D4	6/19	6/17	1	31/24	47/36	5.089	0.020	0.1296	0.0348
D5	24/53	9/19	24/31	1	63/43			0.1356	0.0364
D3	2/5	½	36/47	43/63	1			0.1142	0.0306
I4	1	11/12	62/45	7/6				0.2722	0.0303
I3	12/11	1	44/35	86/61				0.2882	0.0321
I1	45/62	35/44	1	7/4		4.019	0.007	0.2493	0.0278
I2	6/7	61/86	4/7	1				0.1903	0.0212

7. DISCUSSION

There is relatively little qualitative research on the competency characteristics of middle school teachers and there are few studies on the integration of craftsmanship spirit and teacher competency. The interviewees of this study are 12 experts in the field of frontline mathematics education in middle schools from urban and country areas such as Shijiazhuang, Hengshui, Zhangjiakou and Tangshan in Hebei Province. The research methods include behavioral event interviews and semi-structured interviews. This study integrates the dimensions of craftsmanship spirit with the elements of teacher competence to construct a competency model for middle school mathematics teachers in Hebei Province. In addition, the fuzzy Delphi method and the analytic hierarchy process were also used to validate the established model and calculate weights. The research findings show that the secondary indicators of issue orientation, flexibility, exploration and development all score lower than the core sign of courage to innovate which has the lowest weight. These secondary indicators belong to the category of courage to innovate. This indicates that the innovation ability of middle school mathematics teachers in Hebei Province is generally insufficient and targeted training is needed. The development of training requires further research on the behavioral indicators which are the next level indicators of relevant secondary indicators to make the training more focused. At present, research on the competence of middle school teachers mainly focuses on the construction of theoretical models and indicator evaluation. However, the study on developing teacher competency traits and advancing teacher prospects' pre-service literacy in a different direction is very lacking. This will be the direction of future research on teacher competence.

8. CONCLUSION

This study constructed a competency model for middle school mathematics teachers in Hebei Province. After conducting in-depth interviews with twelve high school math teachers in Hebei Province, an extensive study yielded 77 open codes, 23 spindle codes and five core codes. Subsequently, it was possible to summarize the competency characteristics system of middle school math teachers in Hebei Province by combining the logical structure of these open codes, spindle codes and some core codes. At the same time, a detailed interpretation of the connotation of this characteristic system was provided. Selective coding, spindle coding and open coding have clear levels, rich content, strong correlation and logical structure which effectively unify the dimensions of craftsmanship spirit with the competency characteristics of middle school mathematics teachers. Effective middle school teachers possess comprehensive professional literacy, motivation and attitude that are formed by these five interdependent and complimentary fundamental qualities. A verification questionnaire was distributed to 30 experts using the fuzzy Delphi method. The convergence of the evaluation indicators was tested using the grey area of two triangular fuzzy numbers and a revised competency model for high school mathematics teachers in Hebei Province was obtained after verifying the rationality of the questionnaire. It can be seen that the two triangular fuzzy numbers of the 23 secondary indicators meet the requirements $C_U^i \leq O_L^i$. The valuation range of the family is all within the consensus range and the assessment of the combination of knowledge and action by 30 experts has reached convergence. Among them, the consensus level of the indicator's mathematical literacy is the highest at 8.12 while the consensus level of the indicator's practical ability is the lowest at 6.76. The expert consensus level of all indicators is higher than the preset threshold value of 6-7 by the research group. The indicators of expert consensus below 7 are: practical ability, down-to-earth patience, self-control and tolerance but they are also close to 7. In addition, there are two indicators i.e. professional ethics and the expert consensus of striving for progress which is 7.91 indicating that experts have a high consensus on these two indicators.

A weight survey questionnaire was distributed to 30 experts again for the verified core elements and behavioral indicators of the model. The analytic hierarchy process was used to establish a hierarchical structure model for the competency characteristics of middle school mathematics teachers and the weight models of each core element and behavioral indicator were calculated. According to expert evaluation findings, integrating knowledge and action scores highest among the five key indicators with a score of 0.2949. Secondly, it is dedicated and focused with a weight of 0.2683. The weight coefficient of innovation is the lowest at only 0.1113. The core indicators are ranked as unity of knowledge and action, dedication, pursuit of excellence, responsibility and dedication and courage to innovate. Ideal belief has the most weight (0.0212) out of the 22 secondary indicators followed by educational sentiment (0.0950). Solve the problem with the lowest weight of 0.0212. The specific weight ranking is ideals and beliefs, educational sentiments, perseverance, excellence, professional ethics,

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resilient commitment, practical ability, management literacy, mathematical literacy, educational literacy, reflection and improvement, fairness and respect, striving for progress, self-control and inclusiveness, integrity and integrity, exploration and development, active learning, steadfast patience, adaptability, tireless teaching, diligent research and being problem-oriented. The top 5 behavioral indicators in the ranking are ideals and beliefs, educational sentiment, perseverance, excellence, and professional ethics with a total weight of 40% for these five indicators. The other four indications which are essentially measures of personal, emotional and professional attitude are all placed first in the group with the exception of perseverance.

INSTITUTIONAL REVIEW BOARD STATEMENT
The Ethical Committee of the International College, Krirk University, Thailand has granted approval for this study on 1 February 2023 (Ref. No. 2023-0201).

TRANSPARENCY
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

COMPETING INTERESTS
The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS
Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

REFERENCES

Amhag, L., Hellström, L., & Stigmar, M. (2019). Teacher educators' use of digital tools and needs for digital competence in higher education. *Journal of Digital Learning in Teacher Education, 35*(4), 203-220. https://doi.org/10.1080/21532974.2019.1646169

Barcelona, R. J. (2001). *An analysis of the perceived competencies of recreational sport managers: Toward a competency-based model for academic and professional development.* Unpublished Doctoral Dissertation, Indiana University, Indiana.

Bisschoff, T., & Grobler, B. (1998). The management of teacher competence. *Journal of in-Service Education, 24*(2), 191-211. https://doi.org/10.1080/13674589800200041

Chapman, J. A., & Lovell, G. (2006). The competency model of hospitality service: Why it doesn't deliver. *International Journal of Contemporary Hospitality Management, 18*(1), 78-88. https://doi.org/10.1108/09596110610642000

Gangani, N., McLean, G. N., & Braden, R. A. (2006). A competency-based human resource development strategy. *Performance Improvement Quarterly, 19*(1), 127-139.

Hofrichter, D. A., & Spencer, J. L. M. (1996). Competencies: The right foundation the right foundation for effective human resources management. *Compensation & Benefits Review, 28*(6), 21-26. https://doi.org/10.1177/088636879602800605

Juntunen, M.-L., & Westerlund, H. (2011). The legacy of music education methods in teacher education: The metanarrative of Dalcroze Eurhythmics as a case. *Research Studies in Music Education, 33*(1), 47-58. https://doi.org/10.1177/1321103X11404653

Lado, A. A., Boyd, N. G., & Wright, P. (1992). A competency-based model of sustainable competitive advantage: Toward a conceptual integration. *Journal of Management, 18*(1), 77-91. https://doi.org/10.1177/014920639201800106

Larsson, H., & Karlefors, I. (2015). Physical education cultures in Sweden: Fitness, sports, dancing… learning? *Sport, Education and Society, 20*(5), 573-587. https://doi.org/10.1080/13573322.2014.979143

Lei, L. (2014). Evaluation of key success factors in industry based on FAHP and fuzzy delphi method. *Statistics and Decision Making, 15*, 44-47. https://doi.org/10.13546/j.cnki.tjyjc.2014.15.006

Li, H. W., & Zhao, Y. (2017). On the spirit of great country craftsmen. *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition), 46*(1), 158-162.

Li, S. L. (2019). Construction of a new structural system of craftsman spirit under the background of intelligence: A qualitative study based on outstanding craftsmen. *Human Resource Development of China, 36*(8), 114-127. https://doi.org/10.16471/j.cnki.11-2822/c.2019.08.010

Marpa, E. P. (2021). Technology in the teaching of mathematics: An analysis of teachers' attitudes during the COVID-19 pandemic. *International Journal on Studies in Education, 3*(2), 92-102. https://doi.org/10.46328/ijonse.36

McClelland, D. C. (1973). Testing for competence rather than for" intelligence". *American Psychologist, 28*(1), 1-14. https://doi.org/10.1037/h0034092

McClelland, D. C. (1987). Characteristics of successful entrepreneurs. *Journal of Creative Behavior, 21*(3), 219-233. https://doi.org/10.1002/j.2162-6057.1987.tb00479.x

Pantić, N., Wubbels, T., & Mainhard, T. (2011). Teacher competence as a basis for teacher education: Comparing views of teachers and teacher educators in five Western Balkan countries. *Comparative Education Review, 55*(2), 165-188. https://doi.org/10.1086/657154

Plato. (1986). The republic, Translated by B. H. Guo & Z. M. Zhang. In (pp. 223). Beijing: Commercial Press.

Qiao, J., & Gao, D. (2018). A study on the relationship between volunteer spirit, entrepreneurship spirit, craftsmanship spirit, and perceived entrepreneurship behavior control among college students. *Educational Theory and Practice, 38*(30), 20-22.

Saaty, T. L. (1972). Operations research: Some contributions to mathematics: Applied mathematics gets a new surge of life from techniques of operations research. *Science, 178*(4065), 1061-1070. https://doi.org/10.1126/science.178.4065.1061

Sandberg, J. (2000). Understanding human competence at work: An interpretative approach. *Academy of Management Journal, 43*(1), 9-25.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Spanierman, L. B., Oh, E., Heppner, P. P., Neville, H. A., Mobley, M., Wright, C. V., . . . Navarro, R. (2011). The multicultural teaching competency scale: Development and initial validation. *Urban Education, 46*(3), 440-464. https://doi.org/10.1177/0042085910377442

Starkey, L. (2020). A review of research exploring teacher preparation for the digital age. *Cambridge Journal of Education, 50*(1), 37-56. https://doi.org/10.1080/0305764X.2019.1625867

Vannatta-Hall, J. E. (2010). *Music education in early childhood teacher education: The impact of a music methods course on pre-service teachers' perceived confidence and competence to teach music.* Doctoral Dissertation, University of Melbourne.

Velde, C. (1999). An alternative conception of competence: Implications for vocational education. *Journal of Vocational Education and Training, 51*(3), 437-447. https://doi.org/10.1080/13636829900200087

Wang, L., & Wang, Y. (2017). *The academic connotation of innovation and entrepreneurship equivalence the spirit of craftsman*. Paper presented at the In 2nd International Conference on Education, Management and Systems Engineering, DEStech Publications, Inc..

Wiesner, W. H., & Cronshaw, S. F. (1988). A meta-analytic investigation of the impact of interview format and degree of structure on the validity of the employment interview. *Journal of Occupational Psychology, 61*(4), 275-290. https://doi.org/10.1111/j.2044-8325.1988.tb00467.x

Wood, N., Rust, C., & Horne, G. (2009). A tacit understanding: The designer's role in capturing and passing on the skilled knowledge of master craftsmen. *International Journal of Design, 3*(3), 65-78.

Xiao, Q., & Liu, Y. (2015). Craftsmanship spirit and Its contemporary value. *Social Sciences in Hunan, 6*, 6-10.

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research, 74*(3), 255-316. https://doi.org/10.3102/00346543074003255

Yu, W. D. (2016). An ethical and cultural analysis of the spirit of craftsmanship. *Ethics Research, 06*, 69-73. https://doi.org/10.15995/j.cnki.llxyj.2016.06.015

Zeuch, N., Förster, N., & Souvignier, E. (2017). Assessing teachers' competencies to read and interpret graphs from learning progress assessment: Results from tests and interviews. *Learning Disabilities Research & Practice, 32*(1), 61-70. https://doi.org/10.1111/ldrp.12126

Zhao, H., & Li, N. (2015). Evaluating the performance of thermal power enterprises using sustainability balanced scorecard, fuzzy Delphic and hybrid multi-criteria decision making approaches for sustainability. *Journal of Cleaner Production, 108*, 569-582. https://doi.org/10.1016/j.jclepro.2015.07.141