Eng Int Syst (2025) 6: 657–666

Engineering
Intelligent Systems

Relationship between Industry-University-Research Collaborative Education Model Combined with Kohonen Network and the Improvement of Students' Multiple Intelligences

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The purpose of this study is to explore the effect of applying the Kohonen network to the Industry-University-Research (IUR) collaborative education model. An improved system based on the Kohonen network is designed and applied to the educational intervention of 200 students, and the students' multiple intelligences in eight dimensions are evaluated. The results show that: (1) After implementing this model, students' scores for multiple intelligences are significantly improved. The average score for logical mathematics intelligence increased from 65.3 to 74.5, an improvement of 14.1%. Interpersonal intelligence and spatial intelligence scores increased by 12.1% and 11.9% respectively. The scores for language intelligence, body movement intelligence, music intelligence, introspection intelligence and natural observation intelligence increase by 10.9%, 11.4%, 10.1%, 11.1% and 10.4% respectively. (2) The Kohonen network had an obvious impact on data analysis. By means of visualization, the Kohonen network divides students into four groups through self-organizing clustering. The 41 students in Cluster 1 performed well in all types of intelligence, with a score of 83.2 for music intelligence and 80.3 for body movement intelligence. The overall score of 25 students in Cluster 2 is low, and their logical and mathematical intelligence is only 59.9. The intelligence scores of 91 students in Cluster 3 are relatively balanced, but lower than those in Cluster 1, and their language intelligence is 65.7. The 82 students in Cluster 4 are outstanding in spatial intelligence and limb movement intelligence, which are 69.8 and 71.9 respectively. These results show that the Kohonen network can effectively classify students' multiple intelligences levels and provide data support for further educational intervention. In addition, this model has significantly improved students' innovation skills and team cooperation ability. More than 80% of students' feedback suggested that this model helps them to better understand and apply what they have learned. The Kohonen network as a means of fostering multiple intelligences has demonstrated its great potential for application in the field of education, supports the strong integration of theory and practice, and provides a strong incentive for future education reform.

Keywords: Kohonen network; Industry-University-Research Collaborative Education Model; multiple intelligences; logical mathematical intelligence; average score

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1. INTRODUCTION

In today's constantly developing knowledge economy, global competition has gradually become fiercer, and increased the need to cultivate high-quality and innovative talents. As the cradle of talent cultivation, the mission of higher education is no longer limited to imparting knowledge; instead, tertiary institutions need to stimulate students' internal potential and promote their holistic development enabling them to adapt to and lead the future social changes [1]. The theory of multiple intelligences, proposed and developed by Professor Howard Gardner, provides a solid theoretical basis for this educational goal. This theory posits that human intelligence is diverse and complex, and emphasizes the unique advantages and potentials of individuals in eight intellectual fields: language, logic-mathematics, space, music, body-kinesthetic, interpersonal, introspection and natural observation, and points out a new direction for educators to promote students' personalized and holistic development [2].

Faced with the dilemma that students' innovative ability is inadequate and their holistic quality cannot be improved effectively under the single teaching model, the education sector is actively exploring diversified and open ways to educate people. Hence, the Industry-University-Research (IUR) collaborative education model came into being, which broke the barriers of the traditional education system and achieved the efficient integration and optimal allocation of educational resources by building a close cooperative network comprising universities, enterprises, research institutions and education departments [3]. It provides students with a rich theoretical knowledge system, and also allows them to learn and develop by participating in practical real-world projects. Enterprise internships and the guidance of scientific research innovation can effectively promote the deep integration of theoretical knowledge and practical ability and opens new ways for cultivating high-quality talents with innovative spirit and the ability to put theory into practice [4]. However, how to identify and improve students' multiple intelligences more accurately under the framework of collaborative education has become a key issue to be addressed as a matter of urgency in current educational research [5]. The rapid development of information technology, especially the wide application of artificial intelligence (AI) and machine learning technology, provides an unprecedented opportunity to solve this problem [6, 7]. The Kohonen network, as an outstanding representative of Self-Organizing Map (SOM), with its powerful data clustering and pattern recognition capabilities, has shown great potential in the fields of educational evaluation and the planning of personalized learning paths. Via the Kohonen network, students' performance and learning needs can be analyzed more scientifically, and then the teaching content and methods can be customized to better ensure the balanced development of students in different intellectual fields.

Therefore, the aim of this study is to explore in-depth the internal relationship and interaction mechanism between IUR collaborative education model combined with the Kohonen network and their impact on the development of students' multiple intelligences. By combining theoretical analysis and empirical research, this study revealed the unique advantages and effective strategies of this model in promoting the development of students' multiple intelligences, and provides theoretical support and practical guidance for building a more efficient and personalized higher education system, contributing valuable insights regarding talent training in China and beyond.

2. RELATED WORKS

Many researchers have explored the theory of multiple intelligences and its application. Doğgün [8] discussed the application of multiple intelligence theory in terms of visual, emotional and kinaesthetic learning styles, especially the performance of students aged 13–16 in team and individual sports. The research showed that the application of the theory of multiple intelligences not only promoted the development of one kind of intelligence, but also could effectively helped to develop other intelligences. Widayanti et al. [9] proposed a Self-Organizing Map-Similarity to Ideal Solution (SOM-SIS) method combining Kohonen SOM and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to automatically summarize the clustering results of university students' academic performance. Although the traditional clustering method could reveal the characteristics of students and graduates, it was difficult to explain and support academic decision-making. SOM-SIS technology was tested on the data of a university in Indonesia, and the results showed that the compatibility of this method with the quality assurance system of higher education was up to 100%. Their study provided a more effective tool for understanding students' academic performance, and provided strong support for the comparison of universities' national status. Zhu et al. [10] analyzed the influence of teachers' cognitive ability and teaching motivation on students' academic achievement, based on employment data. Traditional decision tree algorithms, such as C4.5 and a decision tree generation algorithm based on rough set, were used to analyze employment data, but had difficulty dealing with different decision accuracy requirements and noise adaptability. In the study, a multi-scale rough set model was used to generate decision tree. The results showed that the decision tree generated by this method was simpler in structure and faster in calculation, which provided new methods and ideas for the study of the correlation between teachers' cognitive ability and teaching motivation and students' employment. Ballestar et al. [11] studied the effectiveness of school counselling programs, especially their role in reducing academic failure rate of high-risk students. Based on the data of academic success plan of Castilla and Leon Community Alliance in Spain, a machine learning model based on Kohonen was developed to group students and evaluate the results of the tutoring project. The results showed that different factors and components had a significant impact on students' participation and academic success.

To sum up, these studies provide rich empirical data and analytical tools by applying the theory of multiple intelligences, self-organizing mapping technology and both combined, to reveal the influence of various factors in educational activities on the development of students' multiple

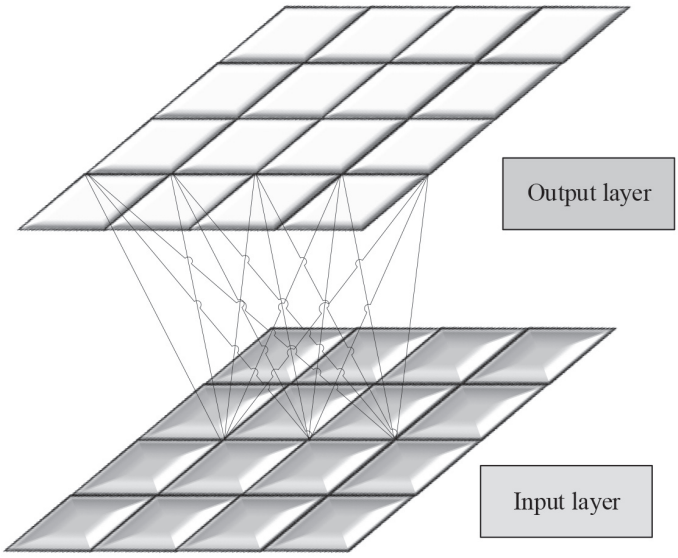

Figure 1 Network structure diagram.

intelligences. This provides an important theoretical basis and practical guidance for further exploration of the IUR collaborative education model combined with the Kohonen network.

3. KOHONEN NETWORK AND THE CULTIVATION OF MULTIPLE INTELLIGENCES UNDER THE MODEL OF IUR

3.1 Kohonen Network

The Kohonen network, commonly called SOM, was proposed by Finnish scholar Teuvo Kohonen in the 1980s, and it is an artificial neural network model with unsupervised learning algorithm. SOM is used mainly for dimensionality reduction, clustering and visualization of data. Its core idea is to adjust the weights of the network through self-organizing learning, so that the nodes in the output layer of the network can react sensitively to specific pattern classes, thus forming an orderly feature map in the output layer and showing the distribution of samples [12–15]. The network structure diagram is shown in Figure 1, where the nodes of the input layer and the output layer are connected by weights, and the network completes the training process by adjusting these weights.

(1) Network initialization

The training of the Kohonen network begins with initializing network weights [16]. Before training, the weight vector w_i of each node is set to a small random normalized value to ensure the uniform weight distribution at the beginning of the network [17, 18]. The selection of initial weights has an important influence on the convergence and performance of the network. Usually, the weight vector is initialized as:

$$w_i^{(0)} = rand() \tag{1}$$

where $rand()$ represents a randomly generated small value, which ensures that the weight vectors of all nodes are distributed in the same range.

(2) Input data

After the network is initialized, the preprocessed data sample x is input into the network. Each sample x is an n-dimensional vector, which is used to train the network and update the weight of nodes [19].

(3) Look for Best Matching Unit (BMU)

To find the node that is most similar to the input sample, the network calculates the Euclidean distance between the weight vector of each output node and the input vector. BMU is the node with the smallest distance, and its calculation equation is:

$$BMU = argmin_i \|x - w_i\| \tag{2}$$

$\|x - w_i\|$ is the Euclidean distance between the input data sample x and the weight vector w_i of the node i in the output layer.

(4) Update BMU and its neighborhood weights

Once the BMU is determined, the network will update the weights of BMU and its neighboring nodes according to Kohonen algorithm. The weight updating rules are as follows:

$$w_i(t+1) = w_i(t) + \alpha(t) \cdot \exp\left(-\frac{\|r_i - r_{BMU}\|^2}{2\sigma(t)^2}\right) \cdot (x - w_i(t)) \tag{3}$$

where $w_i(t)$ is the weight vector of the i-th node after the t-th iteration. $\alpha(t)$ is the learning rate, which gradually decreases with the training. $\sigma(t)$ is the width of the neighborhood function, which gradually decreases with the training. r_i and r_{BMU} are the network location coordinates of the ith node and BMU, respectively.

(5) Iterative training

Steps 2 to 4 are repeated until the network converges, that is, when the weight change is lower than the set threshold or the maximum number of iterations is reached. The training process usually includes several iterations to ensure that the network can effectively adjust the weights and form a stable feature map [20, 21]. In this study, the Neural Clustering (nctool) toolbox in Matlab 2023b software was used to cluster the Kohonen network. To ensure the stability of clustering results, different training steps (50,

100, 200, 500, 1000) are set. It was found that there is no obvious change in the clustering results when the step size exceeds 100, so Kohonen network with 1×4 output layer structure and the 100-training-step size is selected to cluster the normalized data. This configuration can effectively group data, create an orderly feature map, and reveal the complex relationship and structural characteristics between data, thus providing powerful data support and analysis tools for research. Through the self-organizing ability of the Kohonen network, this study effectively clustered students' multiple intelligence data, and then determined the relationship between the IUR collaborative education model and students' improvement in intelligence scores. This method increases the depth of data mining, and also reveals the complex nonlinear relationship between data, providing a powerful data support and analysis tool for research.

3.2 IUR Educational Model

The implementation of IUR collaborative education model needs the joint efforts of many parties to establish an effective cooperation mechanism. Specifically, it can be achieved through the following aspects: (1) Establish a cooperation mechanism: Universities, scientific research institutions and enterprises need to establish a long-term and stable cooperation mechanism to clarify the responsibilities and interests of all parties. People can sign cooperation agreements and set up joint research centres to ensure the smooth progress of cooperation. At the same time, the government should actively play a guiding and supporting role, and provide policy and financial support for the implementation of IUR collaborative education model. (2) Joint courses: Universities and enterprises can jointly design and offer courses to integrate the actual needs of enterprises and the latest technological progress into the teaching content. For example, technical experts and managers of enterprises can be invited as part-time teachers to teach practical cases and project management experience of enterprises, so that students can better understand the practical application of theoretical knowledge [22]. (3) Implement project-based teaching: By implementing project-based teaching, students' learning process is combined with the research and development of actual projects. For example, enterprise R&D projects can be introduced into the classroom, so that students can participate in the design, development and implementation of projects under the guidance of teachers and enterprise experts, thus improving their practical ability and innovation ability. (4) Practice: Colleges and universities should establish long-term practice bases with enterprises to provide students with abundant practice opportunities. Through the internship in the enterprise, students can deeply understand the operation model and actual needs of the enterprise and accumulate valuable practical experience. Meanwhile, enterprises can also discover and cultivate outstanding talents through internships and reserve forces for their own development [23]. (5) Promote scientific research cooperation: Universities and scientific research institutions should actively carry out scientific research cooperation with enterprises to jointly overcome technical problems and promote the transformation and application of scientific and technological achievements. The scientific research cooperation can not only improve the scientific research level of universities and scientific research institutions, but also provide technical support for enterprises and promote the development and upgrading of industries [24, 25].

3.3 Cultivation and Promotion of Multiple Intelligences

In the era of rapidly changing knowledge economy, higher education not only shoulders the heavy responsibility of imparting knowledge, but also shoulders the historical mission of cultivating students' multiple intelligences and promoting their all-round development. As an important part of modern educational theory, the theory of multiple intelligences provides educators with a brand-new perspective and method to understand and cultivate each student's unique potential more comprehensively and deeply. Under this theoretical framework, IUR collaborative education model combined with Kohonen network explores how to effectively improve students' multiple intelligences and cultivate them into compound talents to meet the needs of the future society.

3.3.1 Overview of Multiple Intelligences Theory

The theory of multiple intelligences was put forward by Professor Howard Gardner in 1980s. It subverts the single dimension of "IQ is everything" in the traditional intelligence concept and emphasizes the diversity and complexity of human intelligence. Gardner believes that everyone has at least eight relatively independent areas of intelligence, as shown in Figure 2. These intelligent fields are independent and interrelated with each other, which together constitute a complete intelligent structure of individuals.

The core of the theory of multiple intelligences lies in respecting individual differences and encouraging individualized development. It requires educators to realize that each student's intelligence combination is unique, and should make personalized teaching plans according to their superior intelligence, while paying attention to and promoting the balanced development of other intelligence fields. Through diversified teaching activities and evaluation methods, students' internal potential is stimulated and they are trained to become all-round talents with innovative spirit and practical ability [26].

3.3.2 Cultivation of Multiple Intelligences Under the Cooperative Education Model of IUR

Through the deep cooperation among universities, enterprises, research institutions and education departments, IUR collaborative education model provides students with rich learning resources and practical opportunities, and provides a broad space for the cultivation of multiple intelligences. The cultivation of multiple intelligences is shown in Figure 3.

In this model, the cultivation of multiple intelligences is mainly reflected in the following aspects:

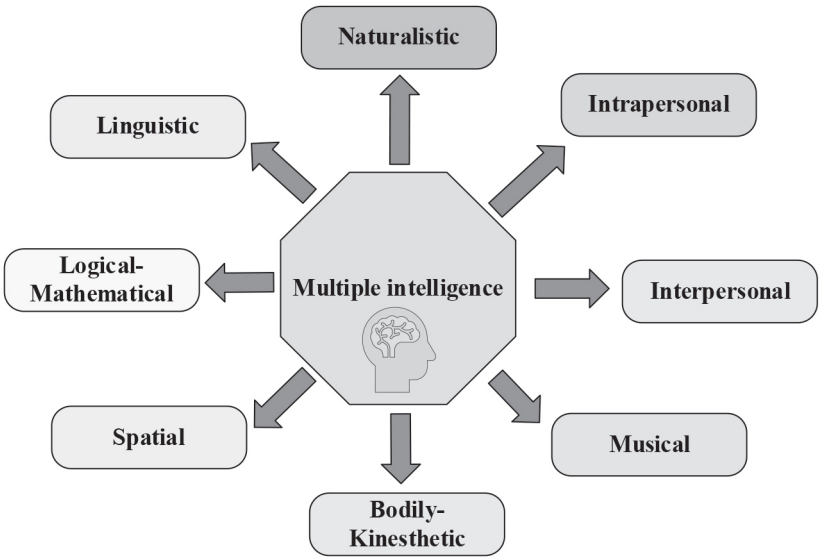

Figure 2 Multiple intelligence fields.

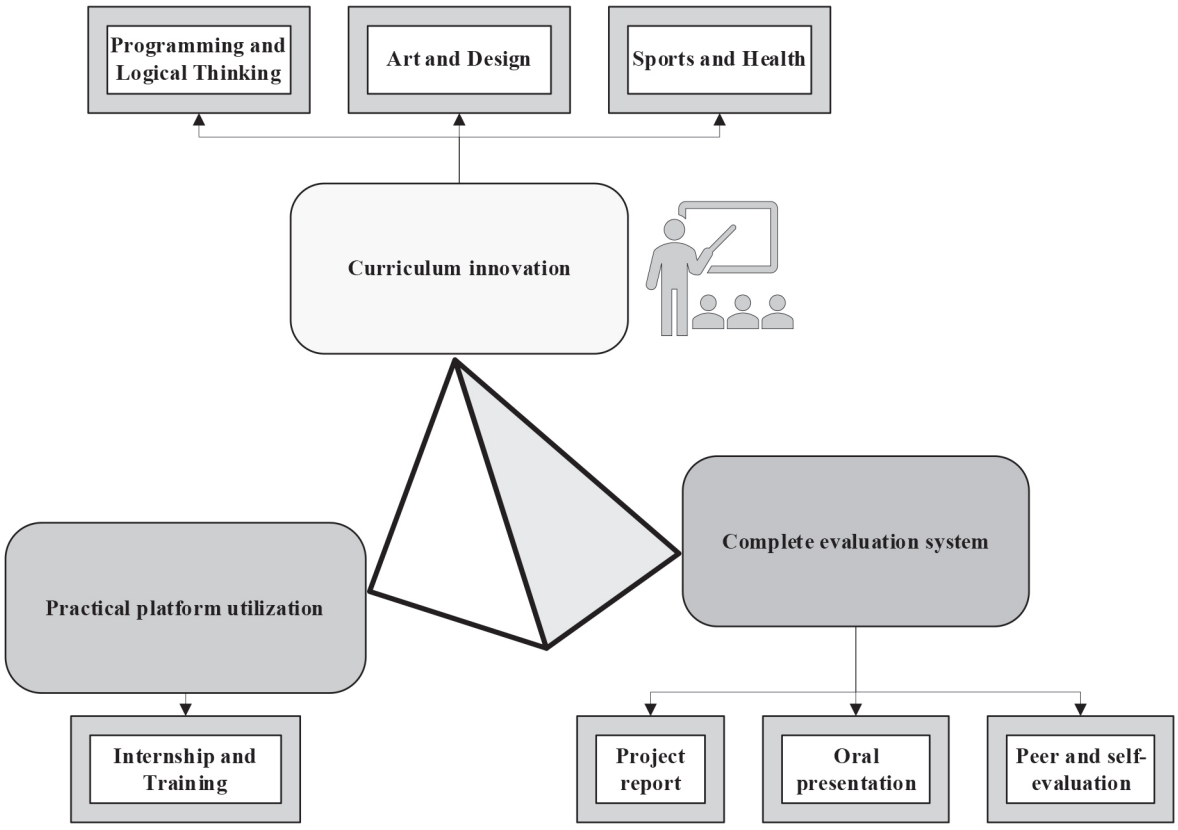

Figure 3 Cultivation methods of multiple intelligences.

(1) Innovation of curriculum and teaching content

Combined with the theory of multiple intelligences, IUR collaborative education model has made bold innovations in curriculum and teaching content. On the one hand, according to the characteristics and needs of different intelligent fields, a variety of elective courses and interdisciplinary course, such as programming and logical thinking, art and design, physical education and health, are offered to meet the needs of students' individualized development. On the other hand, the latest scientific research achievements and industry trends are integrated into the teaching content, and students can exercise and improve their intelligence in the process of solving practical problems through case teaching and project driving.

(2) Construction and utilization of practice platform

IUR collaborative education model pays attention to the setting and implementation of practical links. By establishing close cooperative relations with enterprises and research institutions, students are provided with practical opportunities such as internship training and scientific research partici-

pation. These practice platforms not only enable students to apply what they have learned to practical work, but also promote the development of their language intelligence, interpersonal intelligence and body-kinaesthetic intelligence. For example, in enterprise practice, students need to communicate with colleagues, coordinate and cooperate to exercise their language intelligence and interpersonal intelligence; In scientific research projects, students need hands-on experiments and data analysis to improve their logical-mathematical intelligence and spatial intelligence [27].

(3) Improvement and personalized development of evaluation system

The traditional evaluation system often takes test scores as the only criterion, and these scores do not fully reflect the development level of students' multiple intelligences. The IUR collaborative education model advocates the establishment of a diversified evaluation system, and adopts various evaluation methods and tools, such as project report, oral report, peer evaluation and self-evaluation, to comprehensively and objectively evaluate students' intellectual performance. Meanwhile, combined with the data clustering and pattern recognition ability of the Kohonen network, students' intelligent development can be accurately analyzed, which provides a scientific basis for personalized teaching. Through regular evaluation and feedback, teaching strategies and methods are timely adjusted to promote students' personalized development and comprehensive improvement of multiple intelligences.

3.3.3 Application of Kohonen Network in Multiple Intelligences Promotion

The Kohonen network is an unsupervised learning algorithm that has obvious advantages when applied to data clustering and pattern recognition. Applying it to IUR collaborative education model can provide strong support for students' multiple intelligences in the following ways.

(1) Intelligence evaluation and diagnosis: Using the Kohonen network to cluster and analyze students' learning data, people can identify the development level and characteristics of different students in different intelligence fields. By constructing an intelligent evaluation model, students' intelligent structure can be accurately diagnosed, providing a scientific basis for personalized teaching. For example, those students with weak language intelligence can strengthen their training in reading and writing; students with strong logic-mathematics intelligence can be given more opportunities to enter mathematics competitions and undertake scientific research projects.

(2) Learning path optimization: Based on the clustering results of the Kohonen network, personalized learning paths can be tailored for students. By analyzing the strengths and weaknesses of students in different fields of intelligence, educators can create targeted learning plans and teaching strategies to maximize their students' potential and address their academic shortcomings. For example, students with strong spatial intelligence can be encouraged to participate in practical activities such as architectural design and 3D printing. For students with weak interpersonal intelligence, activities such as teamwork and social skills training can be organized.

(3) Teaching effect monitoring and feedback: In IUR collaborative education, the application of the Kohonen network to monitor and feedback the teaching effect in real time can adjust the teaching strategies and methods in time and ensure the maximization of teaching outcomes. After collecting students' data changes during their learning, this study analyzes their development trends and existing problems in different intelligence fields, and provides teachers with targeted teaching suggestions and improvement measures. Meanwhile, students can also view their own intelligence development reports.

4. RESULT ANALYSIS

Through empirical analysis, this study determined the influence of the IUR collaborative education model combined with the Kohonen network on the improvement of students' multiple intelligences. The analysis of results was conducted to reveal changes in students' multiple intelligences level, the performance of the Kohonen network in data analysis, and the evaluation of the outcomes resulting from the collaborative education model.

4.1 Changes of Students' Multiple Intelligences Level

The change of intelligence level before and after the implementation of IUR collaborative education model is shown in Figure 4.

The pre-test and post-test data show that the students' scores for all types of intelligence have been significantly improved. Among them, the improvement of logical mathematics intelligence is the most remarkable, with the average score increasing from 65.3 to 74.5, an increase of 14.1%, indicating that this model can significantly improve students' logical thinking and mathematical ability. The improvement of interpersonal intelligence and spatial intelligence is also obvious, increasing by 12.1% and 11.9% respectively, demonstrating the effectiveness of this model in promoting students' social skills and spatial perception. In addition, the improvement of language intelligence, body movement intelligence, music intelligence, introspection intelligence and natural observation intelligence are 10.9%, 11.4%, 10.1%, 11.1% and 10.4% respectively. These results indicate that the IUR collaborative education model promotes the holistic and comprehensive development of students' various intelligences.

4.2 The Performance of Kohonen Network in Data Analysis

The self-organizing clustering results of the Kohonen network for the experimental group's evaluation model are shown in Figure 5.

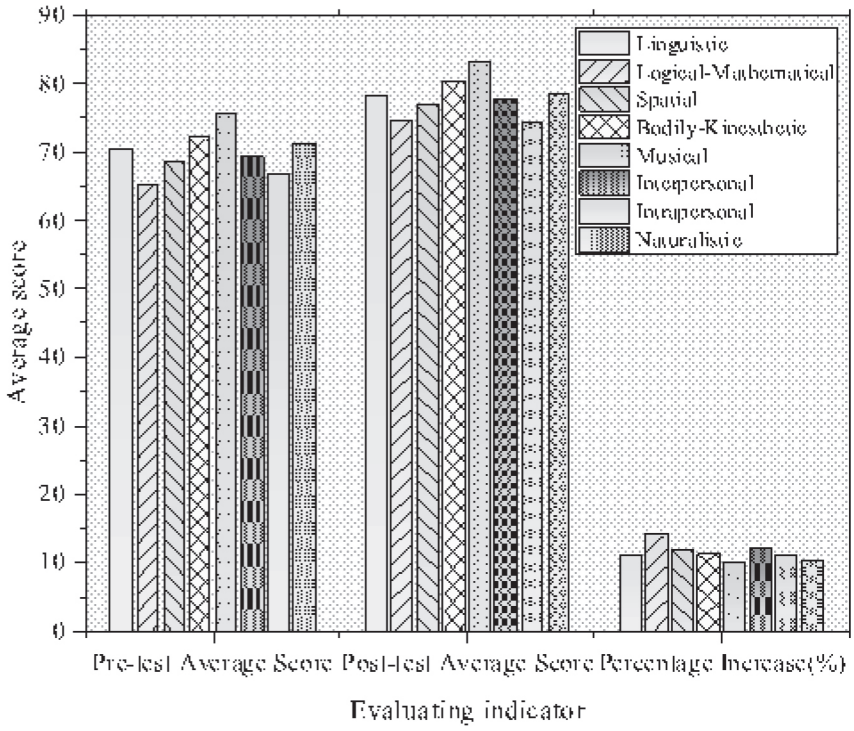

Figure 4 Changes of intelligence level before and after the implementation of IUR collaborative education model.

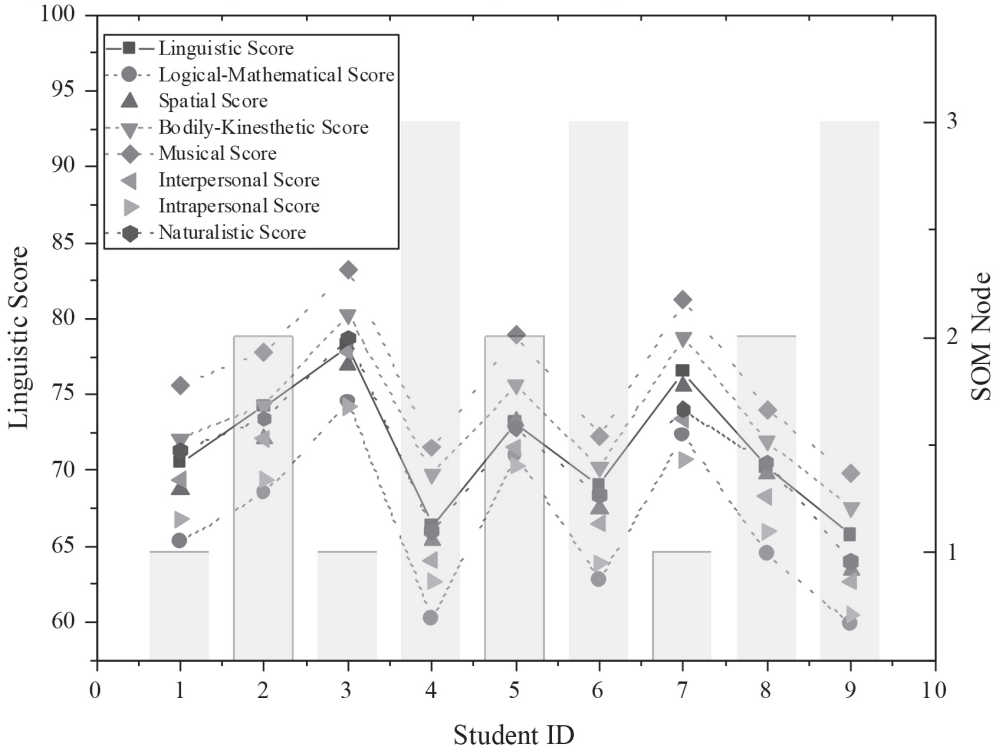

Figure 5 Self-organizing clustering results of Kohonen network.

The SOM Node indicates the SOM network node to which each student's evaluation model is mapped, and the node number indicates different clustering categories. Node 1 comprises students with high scores, showing a relatively balanced and excellent intelligence type score. Node 2 contains students with moderate scores, showing a certain balance but may be lacking in some types of intelligence. Node 3 represents students with relatively low scores, and the overall level of intelligence type scores is low. Thus, the Kohonen neural network can effectively cluster students' assessment patterns in different categories, which provides visual data support for the analysis of students' multiple intelligence characteristics.

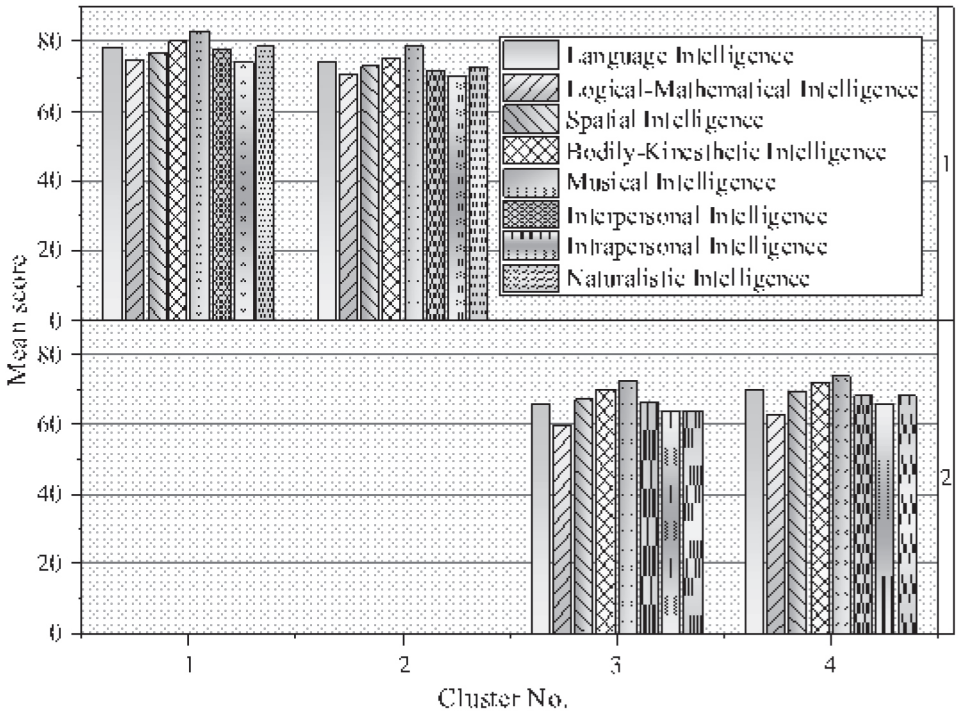

Figure 6 Classification of student groups based on Kohonen network.

4.3 Classification of Student Groups Based on Kohonen Network

Based on the Kohonen network, students' multiple intelligence data are self-organized clustered. The following figure shows the main characteristics of student groups under different clustering nodes, and the average scores of multiple intelligence types. The classification of student groups based on the Kohonen network is shown in Figure 6.

Cluster 1 contains 41 students. This group scores higher in all types of intelligence, with an average score of 83.2 in music intelligence and 80.3 in body movement intelligence, which are significantly higher than other groups. This shows that this group has strong ability in these fields. In addition to music and physical intelligence, the scores of language intelligence and spatial intelligence are also high, which are 78.2 and 76.9 respectively. The students in Cluster 1 perform well in the multiple intelligence test, with a comprehensive ability score of 0.750, which is higher than other groups. Cluster 2 contains 25 students. The scores of this group in various types of intelligence are generally low, among which the average score of logical mathematics intelligence is only 59.9 and the score of interpersonal intelligence is 66.5. This shows that this group is weak in these fields. Overall, the students in Cluster 2 perform poorly in the multiple intelligence test, and their comprehensive ability score is 0.182, which is significantly lower than other groups. The scores of all types of intelligence are at the lowest level, which reflects that the intelligence development of this group is lagging. Cluster 3 comprised 91 students. The scores of this group on all types of intelligence are balanced, but the overall level is lower than that of Cluster 1 and Cluster 4. Specifically, the average score of language intelligence is 65.7, and that of logical mathematics intelligence is 59.9, which is lower than the score of Cluster 1. Although the scores of various intelligence types are relatively balanced, the students of Cluster 3 perform moderately in the multiple intelligence test, with a comprehensive ability score of 0.500, showing a certain intelligence gap. Cluster 4 contains 82 students. This group performs well in spatial intelligence and limb movement intelligence, which are 69.8 and 71.9 respectively, which are significantly higher than those of Cluster 2 and Cluster 3. However, the scores of language intelligence and music intelligence are low, with language intelligence of 70.2 and music intelligence of 74.0. The students of Cluster 4 have strong performance in some types of intelligence, but they are weak in other types. The comprehensive ability score is 0.682, which shows that the performance of this group is outstanding, but there is still room for improvement in some fields.

5. CONCLUSION

In this study, the promotion of students' multiple intelligences is discussed in depth together with the IUR collaborative education model based on Kohonen network. The research results show that the students' multiple intelligence level has been significantly improved after the implementation of this model. Specifically, the scores of logical mathematics intelligence, language intelligence, interpersonal intelligence, spatial intelligence, limb movement intelligence, music intelligence, introspection intelligence and natural observation intelligence have all improved significantly, ranging from 10.1% to 14.1%. These results demonstrate that this collaborative education model not only promotes the all-round development of students' various intelligences, but also effectively improves their comprehensive quality. The self-organizing clustering results of Kohonen network further support this discovery. By

dividing students into different groups, the study reveals the differences in the characteristics of multiple intelligences of each group. The students of Cluster 1 perform best in all types of intelligence, while Cluster 2 shows that the development of intelligence is lagging. Cluster 3 has a balanced score for all types of intelligence, but the overall level is low. Cluster 4 is outstanding in some areas of intelligence, but there is still room for improvement in other areas. To sum up, the IUR collaborative education model combined with the Kohonen network has achieved remarkable results in improving students' multiple intelligences. This model not only promotes the all-round development of students; it also provides scientific data support for educators and assists with the formulation of more effective educational intervention strategies. Future research can further explore the long-term influence of different educational models on the development of students' multiple intelligence.

ACKNOWLEDGEMENTS

This work was supported by Research on Innovation and Entrepreneurship Education Based on Project learning and Practice under the title of "Innovation and Integration" in Henan Vocational Education Reform Research and Practice Project in 2022 (Project number: Yu Jiao [2023] 03122), Henan Provincial Health Commission 2021 Project, "Research on the Curriculum System of Training Three Creative Talents through Innovation and Competition Integration under the Background of New Medicine" (Project Number: WJLX2021039), and The fourth batch of "Wellness and recuperation" technical and technical skilled teachers' studios of local universities in Zhengzhou (Project Number: Zheng Jiao Gao Han[2023]864).

REFERENCES

1. Nadziroh I F, Karisma L A. Implementation of lifelong educational based on multiple intelligences in inclusive elementary schools. Shibghoh: Prosiding Ilmu Kependidikan UNIDA Gontor, 2023, 2(2): 440–457.
2. Legowo E. Model pembelajaran berbasis penstimulasian multiple intelligences siswa. Jurnal Kajian Bimbingan Dan Konseling, 2024, 2(1): 11.
3. Rossoni A L, de Vasconcellos E P G, de Castilho Rossoni R L. Barriers and facilitators of university-industry collaboration for research, development and innovation: A systematic review. Management Review Quarterly, 2023, 1(1): 1–37.
4. Abbas J, Kumari K, Al-Rahmi W M. Quality management system in higher education institutions and its impact on students' employability with the mediating effect of industry–academia collaboration. Journal of Economic and Administrative Sciences, 2024, 40(2): 325–343.
5. Setyawan A A, Prabowo H, Simatupang B, et al. The influence of quality management practices and digital innovation on organizational performance mediated by competitiveness strategy and moderated industrial collaboration in vocational higher education in Indonesia. Tec Empresarial, 2023, 18(1): 398–403.
6. Duan L., Wang W. Early detection of serious but struggling learners in MOOCs using ensemble deep learning. Enterprise Information Systems, 2024, 18(11). 2416696.
7. Cho H H, Chen S Y, Lan P H, et al. Leveraging human-centred AI in interactive English education for generating learning materials. Enterprise Information Systems, .2025, 19(3–4). 2482772.
8. Doğgün M. Comparison of multiple intelligence theory in visual, affective and kinesthetic learning forms of team and individual athletes in 13–16 years age group. Eurasian Journal of Educational Research, 2023, 103(103): 324–340.
9. Widayanti R, Madenda S, Wibowo E P, et al. SOM-SIS approach to auto summary of clustering results on university academic performance. Telkomnika (Telecommunication Computing Electronics and Control), 2023, 21(1): 104–112.
10. Zhu H, Zheng X, Zhao L. Analysis of teachers' cognitive ability and teaching motivation on the academic achievement of students in higher education via employment data guidance. Electronics, 2023, 12(3): 572.
11. Ballestar M T, Mir M C, Pedrera L M D, et al. Effectiveness of tutoring at school: A machine learning evaluation. Technological Forecasting and Social Change, 2024, 199(7): 123043.
12. Purbasari I Y, Puspaningrum E Y, Putra A B S. Using self-organizing map (SOM) for clustering and visualization of new students based on grades. Journal of Physics: Conference Series, 2020, 1569(2): 022037.
13. Delgado S, Morán F, San José J C, et al. Analysis of students' behavior through user clustering in online learning settings, based on self organizing maps neural networks. IEEE Access, 2021, 9(2): 132592–132608.
14. Victory Brodman M, Zaidi A, Qureshi S. Confidence-building in a collaborative, multidisciplinary mock page activity for fourth-year medical students. Medical Education Online, 2023, 28(1): 2173995.
15. Junior P R W, Antoniassi N P, Bindo V F, et al. Self organizing maps (SOM) and statistical methods for describing the physicological profile of undergraduates students of engineering. Journal of Technology and Science Education, 2024, 14(3): 664–682.
16. Rodríguez-Hernández C F, Kyndt E, Cascallar E. A cluster analysis of academic performance in higher education through self-organizing maps. What AI Can Do (1st Edition), Cebral-Loureda, M., Rincón-Flores, E.G., Gildardo Sanchez-Ante, G., (eds.), New York: Chapman and Hall/CRC, 2023, pp. 115–134.
17. Jevtić M, Mladenović S, Granić A. Source code analysis in programming education: evaluating learning content with self-organizing maps. Applied Sciences, 2023, 13(9): 5719.
18. Gunawan A R, Sudarmin S, Rais Z. Applied of the Self-Organizing Maps (SOM) method for clustering educational equity in south Sulawesi. ARRUS Journal of Mathematics and Applied Science, 2024, 4(1): 6–19.
19. Ariani S, Nusrang M, Aidid M K. Application of cluster analysis of self organizing map (SOM) method in the community literacy development index in Indonesia. Journal of Applied Science, Engineering, Technology, and Education, 2024, 6(1): 56–62.
20. Bedle H, Garneau C R H, Vera-Arroyo A. Clustering energy support beliefs to reveal unique sub-populations using self-organizing maps. Heliyon, 2023, 9(7): 32.
21. Talei H, Benhaddou D, Gamarra C, et al. Identifying energy inefficiencies using self-organizing maps: Case of a highly efficient certified office building. Applied Sciences, 2023, 13(3): 1666.
22. Li X. Research on the five-dimensional driven collaborative education model of "politics, industry, education, research

and application" in undergraduate vocational education pilot schools. Lifelong Education, 2021, 10(1): 34–36.
23. Inada Y. A comparative study of physical versus online classrooms: Co-creation in industry-academia collaborative education. Review of Integrative Business and Economics Research, 2023, 12(2): 97–117.
24. Shah R, Gillen A L. A systematic literature review of university-industry partnerships in engineering education. European Journal of Engineering Education, 2024, 49(3): 577–603.
25. Supit S. Model pembelajaran multiple intelligences pendidikan agama Kristen bagi anak dalam menghadapi era society 5.0. Kurios (Jurnal Teologi dan Pendidikan Agama Kristen), 2023, 9(1): 136–147.
26. Sudhini M K S, Amuthasree N. Multiple intelligence in relation to the academic achievement of college students of Andaman and Nicobar islands. Journal of Research Administration, 2023, 5(2): 2933–2940.
27. Peramunugamage A, Ratnayake U W, Karunanayaka S P. Systematic review on mobile collaborative learning for engineering education. Journal of Computers in Education, 2023, 10(1): 83–106.