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Molecular & Cellular Biomechanics 2025, 22(4), 1227.
https://doi.org/10.62617/mcb1227

Article

Ideological and political education's impact on medical students' bioethical concept formation: A GNN-based analysis

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CITATION

Gong X, Wang J, Wang S, Wang Z. Ideological and political education's impact on medical students' bioethical concept formation: A GNN-based analysis. Molecular & Cellular Biomechanics. 2025; 22(4): 1227. https://doi.org/10.62617/mcb1227

ARTICLE INFO

Received: 20 December 2024
Accepted: 22 January 2025
Available online: 13 March 2025

Abstract: Biomechanics plays a crucial role in understanding the physiological and mechanical processes within the medical field. In the context of medical education, integrating ideological and political education with bioethical concepts has become an important aspect. This study explores the intersection of these elements and its impact on medical students. The cultivation of bioethical concepts in medical education plays a critical role in enhancing medical students' professional ethics and overall quality. Bioethics education not only helps students understand the ethical challenges in medical practice, but also shapes their values and social responsibility, improving their ethical decision-making abilities in real-world situations. The results show that through a survey of 300 medical students and GNN model analysis, it was found that ideological and political education significantly enhanced students' understanding of bioethics and decision-making abilities. Students' ethical awareness scores increased by 57% ($p < 0.05$), and the accuracy of ethical decision-making tasks improved by 30%. This indicates a strong positive correlation between ideological and political education and bioethical concept formation, which may have implications for the biomechanical aspects of medical practice and education. The educational effect is evident not only in the improvement of knowledge but also in the development of students' ethical judgment and social responsibility. This study validates the effectiveness of integrating ideological and political education with medical ethics education, providing a theoretical basis and practical guidance for reforms in medical education.

Keywords: college students; ideological and political education; bioethical concepts; medical education psychology; GNN; impact path; biomechanics in medical education; ethical biomechanics

1. Introduction

Biomechanics has revolutionized the understanding of biological systems in medicine. It provides essential insights into the mechanical behaviors of cells, tissues, and organs, which are closely related to medical ethics and professional practices. In the training of medical students, integrating biomechanical knowledge with ethical education is of great significance. Medical education, as a critical field for cultivating future healthcare professionals, has core objectives that go beyond imparting technical knowledge and skills. It aims to nurture individuals with a strong sense of social responsibility and high professional ethics. In recent years, with the increasing complexity of medical ethics issues, the limitations of traditional medical education models in ethical education have become progressively evident [1,2]. Particularly in the cultivation of medical students' awareness of life ethics, the importance of ideological and political education has become increasingly highlighted. However, current research and practice indicate that the integration of ideological and political

education with life ethics education in medical training has not yet formed an effective mechanism. There remains a significant gap in the cultivation of medical students' ethical judgment and critical thinking abilities. Life ethics, as an interdisciplinary field, encompasses numerous moral dilemmas in medical practice, such as patient autonomy, life extension, euthanasia, and organ donation. These issues often involve profound ethical conflicts. Medical education must not only provide students with technical knowledge but also shape their correct ethical values. Especially within the framework of ideological and political education, medical training should promote the cultivation of ethical judgment and decision-making abilities in complex situations. Currently, exploratory studies at home and abroad suggest that ideological and political education helps enhance students' sense of social responsibility, sense of justice, and deep understanding of life ethics issues. However, there is still a lack of in-depth empirical research on how to effectively achieve these goals through systematic educational pathways. This study aims to explore from the perspective of biomechanics how ideological and political education affects the bioethical concepts of medical students. By using graph neural network (GNN) models and empirical data analysis, we will delve into the formation mechanism of bioethical concepts and their association with biomechanical factors in medical education [3,4]. By analyzing extensive survey data from medical students and leveraging the strengths of GNN models, the study explores the multidimensional interactive relationships between ideological and political education and life ethics concepts, examining the mechanisms through which these relationships influence ethical judgment and decision-making processes. The study innovatively applies GNN models in terms of methodology and attempts to break the constraints of traditional educational pathways in its content. Through data-driven analysis, it provides new perspectives and theoretical support for the integration of ideological and political education into medical education. By using GNN models, the research delves deeply into the complex relationships between ideological and political education and medical ethics education, addressing limitations in traditional empirical research. The study employs data-driven analytical methods, focusing not only on the direct impacts of ideological and political education but also considering its potential influence on students' ethical decision-making processes. This exploration enriches the application scenarios of ideological and political education and provides theoretical foundations and practical guidance for the further development of medical ethics education.

2. Methods

2.1. Data collection and research design

In medical education, this study uses GNN to analyze the influence of ideological and political education on life ethics concepts. The data collection phase consists of two main parts: Data sources and the selection of research subjects. The selection of three medical schools of different levels aims to cover a wide range of students with varying exposure to biomechanical knowledge and ethical education, allowing for a comprehensive analysis of the influence of ideological and political education on bioethical concepts across different educational backgrounds.

Before conducting the main survey, a series of focus group discussions were held to explore key ethical dilemmas relevant to the target population, euthanasia, organ donation, and professional medical ethics. In the survey section, the study designed scales to collect data on three dimensions: Ethical concepts, social responsibility, and participation in ideological and political education [5,6]. The questionnaires were distributed via an online platform, and all data underwent rigorous screening to ensure the quality of valid samples. The collected data will undergo several preprocessing steps to prepare it for subsequent analysis using GNN. The data collection method and preprocessing steps are shown in **Table 1**.

Table 1. A data collection methods and preprocessing steps [7].

No.	Data Collection Method/Preprocessing Step	Specific Content	Purpose	Tools/Methods	Notes	Results
1	Ethical Concept	Student attitudes towards euthanasia, organ donation, and bioethical issues in biomechanics (e.g., mechanical interventions in the human body)	To understand students' ethical views in relation to biomechanics	Survey	Ensure anonymity	Collect valid data
2	Social Responsibility	Recognition of medical professional ethics, concern for medical ethics, and ethical considerations in biomechanics (e.g., use of prosthetics, biomechanical interventions)	To assess students' social responsibility in the context of medical and biomechanical ethics	Survey	Design reasonable questions	Collect valid data
3	Political Education Participation	Students' participation and awareness in political education courses, including awareness of how political education integrates with bioethical concepts	To evaluate the effectiveness of political education on ethical decision-making in biomechanics	Survey	Focus on participation	Collect valid data
4	Biomechanics Knowledge and Ethical Perception	Student understanding of biomechanical principles and their ethical implications in medical practice (e.g., the ethics of robotic surgery, biomechanics in rehabilitation)	To assess how biomechanics knowledge influences students' ethical perspectives	Survey/Interviews	Assess students' knowledge and awareness	Collect valid data
5	Biomechanical Case Study Influence	Impact of biomechanical case studies (e.g., prosthetics, mechanical assistive devices) on ethical decision-making	To investigate how exposure to biomechanical cases shapes ethical judgments	Case study analysis	Focus on relevance to real-world applications	Evaluate impact on ethical decision-making
6	Missing Value Handling	Mean imputation or interpolation	To ensure data completeness	Data processing software	Choose appropriate method	Data completeness
7	Standardization & Normalization	Standardize continuous variables	To ensure data comparability	Data processing software	Choose appropriate standard	Data consistency
8	Text Data Vectorization	Use bag-of-words model to convert text data	To extract numerical features	Natural language processing tools	Ensure model validity	Feature extraction success

In order to represent data in GNN, the study transformed various types of student data into a graph structure, where each student is treated as a node, and the relationships between students (such as similar bioethical beliefs, social responsibility, etc.) are represented by edges. The graph structure representation of the data is shown in **Figure 1**.

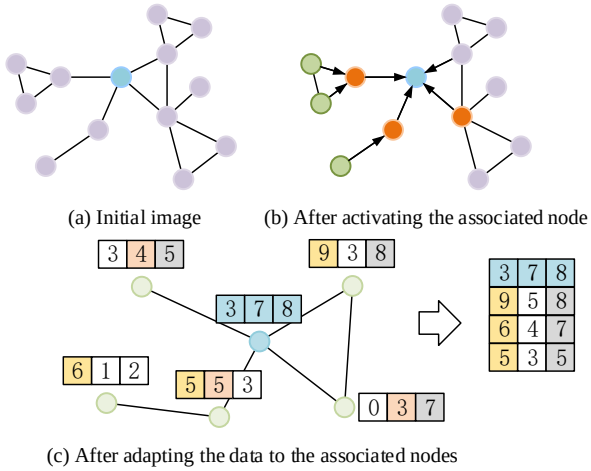

Figure 1. Graph structure representation of data.

In **Figure 1**, each node represents a student, and each edge represents some kind of similarity relationship between students. It demonstrates how to represent collected data through graph structure transformation for processing and analysis in GNN models. Through the definition of nodes, feature extraction, and matrix representation, teaching features can be displayed in the graph through the relationship of edges. The student nodes include multiple attributes (ethical views, social responsibility, political education participation) that are encoded into numerical values for easy input into the GNN. These attributes were carefully selected to reflect core aspects of students' ideological and ethical formation. The edges between nodes are weighted based on similarity scores, with a higher weight representing stronger similarity between the students in terms of the selected features.

2.2. Construction and optimization of GNN model

After data preprocessing is completed, the study adopts GCN as the main model architecture. GCN propagates information in the graph structure through a message passing mechanism, GCN propagates information in graph structures through an information transmission mechanism, similar to the signal transmission between cells and the interaction between tissues in biomechanics. Each node (student) obtains information about the surrounding environment through interaction with neighboring nodes, thereby self-renewal. This mechanism helps to better understand the mutual influence of students in the ethical decision-making process. allowing each node to obtain information from its neighboring nodes for self research updates. The input of the model includes the feature vectors of each node (such as bioethical concepts, social responsibility, etc.) and graph structure information (relationships between nodes), as shown in Equation (1).

$$H^{(k+1)} = \sigma\left(\hat{A}H^{(k)}W^{(k)}\right) \quad (1)$$

In Equation (1), $H^{(k)}$ is the node feature of layer k, $\hat{A}$ is the normalized adjacency matrix, $W^{(k)}$ is the weight matrix of layer k, and σ is the ReLU activation function. The node features of each layer are updated by multiplying them with the adjacency matrix and combining them with the features of neighboring nodes [7,8]. As the number of layers increases, the model can gradually aggregate information from a wider neighborhood, thereby improving its predictive ability for students' ethical beliefs and social responsibility. The schematic diagram of GCN model architecture is shown in **Figure 2**.

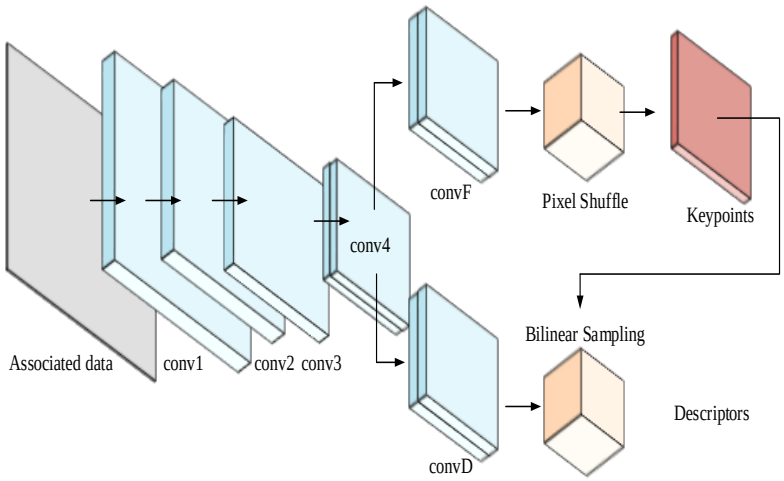

Figure 2. Schematic diagram of GCN model architecture.

In **Figure 2**, in this study, the data input includes each student's ethical concepts, social responsibility, political education participation, and other characteristics, as well as the relationship network among the students. Each student's feature vector is represented as a node feature, and the relationships among students are constructed in the form of a graph structure. To ensure the applicability of the data, the student features are first standardized to eliminate the impact of dimensional differences. Ethical concepts and social responsibility are assessed using scales, and each student's score is treated as a continuous feature. After standardization, the data is input into the model, this process helps to prevent certain features from exerting disproportionate influence on the model during computation.

The adjacency matrix of the graph defines the connection relationships among students. To measure the similarity between students, the elements of the adjacency matrix can be calculated using methods such as cosine similarity or Euclidean distance. If the ethical concept scores of Student i and Student j are similar, the similarity measure can be used to weight the connection strength in the adjacency matrix, reflecting the potential similarity between the two in the ethical decision-making process. To enhance the expressive power of the model, the study also incorporates graph embedding techniques. The embedding algorithm further transforms the structural information of the nodes into low-dimensional vectors. This

approach helps capture more complex nonlinear relationships among students and provides more latent information for model training.

During the training process of the GCN model, the goal is to optimize the weight matrix through the backpropagation algorithm, minimizing the error between the predicted values and the actual labels. Throughout the training, the model relies on graph convolution operations to update node features layer by layer, allowing it to capture the interrelationships between students and the evolving trends in their ethical concepts. The GCN optimization training process is shown in **Figure 3**.

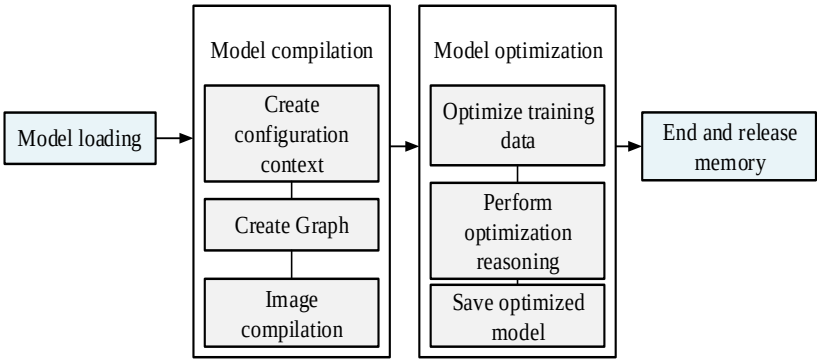

Figure 3. GCN optimization training process.

In **Figure 3**, to evaluate the effectiveness of the model in predicting students' ethical concepts and social responsibility, the study selects appropriate loss functions based on the nature of the prediction task. If the prediction task is a classification problem, the Cross-Entropy Loss function is chosen. This function measures the model's prediction performance across categories and optimizes by maximizing the probability of the correct category. If it is a regression problem, the Mean Squared Error (MSE) loss function is chosen. This loss function helps minimize the difference between predicted and actual values, ensuring the accuracy of the model in predicting ethical concept scores.

To improve the model's generalization ability and prevent overfitting, in order to improve the generalization ability of the model and prevent overfitting, this study adopted various regularization methods, including L2 regularization (weight decay), Dropout, and early stopping. These optimization methods not only help improve the stability of the model, but also enhance its ability to capture the complex relationship between biomechanical factors, ideological and political education, and bioethical concepts, thereby improving the interpretability and effectiveness of the model. The study employs various regularization methods, including L2 regularization (weight decay), Dropout, and early stopping [9,10].

To further enhance the performance of the GCN model, the study uses hyperparameter tuning methods such as grid search and random search. These methods automatically explore the optimal learning rate, number of GCN layers, node feature dimensions, and other hyperparameters within a predefined hyperparameter space. In practice, grid search exhaustively evaluates all possible combinations of hyperparameters, while random search randomly selects hyperparameter combinations for training, thereby finding the optimal solution in a shorter time. The setup for hyperparameter tuning is shown in **Table 2**.

Table 2. Hyperparameter tuning settings table.

Hyperparameter	Value Range	Optimization Method
Learning Rate	1×10^{-4}, 1×10^{-3}, 1×10^{-2}	Grid Search
GCN Layers	2, 3, 4	Random Search
Feature Dimensions	32, 64, 128	Grid Search
Dropout Rate	0.2, 0.4, 0.6	Random Search

In order to evaluate the effectiveness of the GCN model in analyzing the relationship between ideological and political education and student ethical decision-making, K-fold cross validation was used in the study. Divide the dataset into H subsets, use $H-1$ subsets each time the model is trained, and use the remaining subset as the validation set. The specific verification formula is shown in Equation (2).

$$L_{CV} = \frac{1}{H}\sum_{h=1}^{H} L_h \tag{1}$$

In Equation (2), L_h is the loss of the h-th validation set, and H is the fold.

2.3. Data analysis

In the data analysis and model evaluation phase, the study used Python as the primary programming language and leveraged the Scikit-learn library for data processing, model training, and evaluation. To ensure the model's generalization ability, the study employed K-fold cross-validation, dividing the dataset into 10 subsets. In each iteration, one subset is used as the validation set and the remaining subsets as the training set. This process is repeated 10 times, yielding the average evaluation result of the model across different data splits [10,11]. This method effectively reduces biases caused by uneven data splits and ensures the stability and reliability of the evaluation results. For performance evaluation, the study selected accuracy, precision, recall, and F1-score as the primary metrics to comprehensively assess the model's classification performance. To gain deeper insights into the model's performance, the study also computed the confusion matrix and conducted a detailed analysis of the classification results based on the matrix data. The study performed hypothesis testing on the model, using a *t*-test to assess the difference between the model and random classification, and calculated the *P*-value. If $p < 0.05$, the study concludes that the model's classification performance is significantly better than random guessing, indicating statistical significance.

3. Results and discussion

3.1. The influence of ideological and political education on bioethical concepts

The study collected a large amount of data through a questionnaire survey of medical students and, leveraging the advantages of the GNN model, explored the multidimensional interactive relationship between ideological and political education and bioethics concepts. In analyzing the influence pathway of ideological and political

education, the study examined the relationship between the frequency of students' participation in ideological and political education activities and their ethical concepts. Data analysis revealed that students with higher levels of participation in ideological and political education exhibited stronger sense of responsibility and moral judgment in their bioethics concepts, which may imply that they are better equipped to handle the biomechanical and ethical challenges in future medical practice. In procedures involving biomechanical devices, such as prosthetics or surgical robots, students with a higher level of ethical awareness are more likely to make appropriate decisions considering both the technical and ethical aspects. The model results show a strong positive correlation between the level of participation in ideological and political education and bioethics concepts, with this influence being significant in most student groups. The main parameter settings for the model evaluation are shown in **Table 3**.

Table 3. Main parameter settings for model evaluation.

Parameter	Description	Value
GNN Layers	Number of model layers	3
Node Feature Dimensions	Dimensions of node features	64
Learning Rate	Learning rate of the model	0.001
Number of Iterations	Number of training iterations	100
Batch Size	Number of samples per training	32
Regularization Coefficient	L2 regularization coefficient	0.0001

The relationship between educational participation and students' ethical concepts is shown in **Figure 4**.

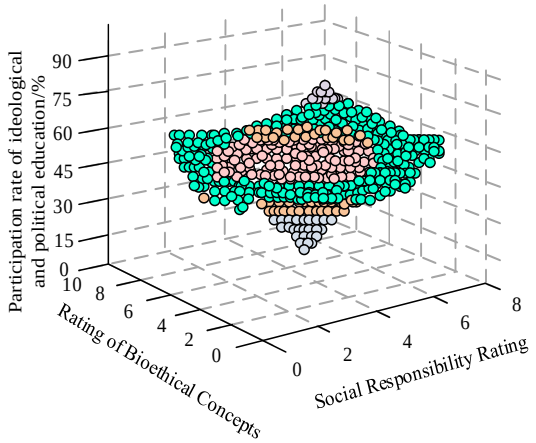

Figure 4. The relationship between educational participation and students' ethical concepts.

Figure 4 displays the three-dimensional relationship between the level of participation in ideological and political education, students' bioethics concept scores, and social responsibility scores. The X-axis represents the level of educational participation (from 0% to 100%), the Y-axis represents the bioethics concept score (from 0 to 10), and the Z-axis represents the social responsibility score (from 0 to 10). Each point represents an individual student. The analysis shows that students with high

levels of participation (> 80%) have bioethics concept scores concentrated between 8 and 10, and social responsibility scores between 7 and 10. Students with 90% participation have an average bioethics concept score of 8.5 and a social responsibility score of 8.3. In contrast, students with participation below 20% have bioethics concept scores concentrated below 5 and social responsibility scores below 4. Students with 10% participation have an average bioethics concept score of 4.2 and a social responsibility score of 3.8. Statistical analysis shows that for every 1% increase in educational participation, the bioethics concept score increases by 0.5 points and the social responsibility score increases by 0.4 points ($p < 0.05$).

In examining the impact of ideological and political education methods, the study focused on analyzing the influence of different teaching methods (such as lectures, discussion-based teaching, case analysis, etc.) on medical students' ethical decision-making abilities. Educational methods based on case analysis and discussion-based teaching were found to be most effective in enhancing students' ethical decision-making abilities. Case analysis and discussion-based teaching were found to be more effective in enhancing students' ethical decision-making abilities. In the context of biomechanics, case studies can present real-world scenarios where students need to consider the mechanical and ethical implications simultaneously. For instance, in a case of designing a new biomechanical implant, students can discuss the ethical issues related to patient safety, device durability, and the impact on the body's biomechanical environment. Analysis through the GNN model revealed that, compared to classroom teaching, more practical teaching methods can effectively enhance students' ethical decision-making abilities in a shorter time. The changes in students' ethical decision-making ability scores under different teaching methods are shown in **Table 4**.

Table 4. Changes in the grading of students' ethical decision-making ability.

Educational Method	Ethical Decision-Making Ability Score (Mean)	Standard Deviation
Lecture	75.3	8.2
Discussion-Based Teaching	82.6	7.4
Case Study	85.2	6.8

The relationship between educational methods and students' ethical decision-making abilities is shown in **Figure 5**.

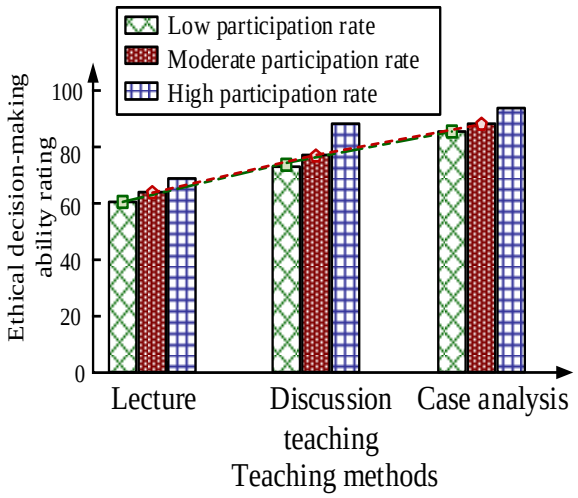

Figure 5. The relationship between educational methods and students' ethical decision-making abilities.

Figure 5 shows the impact of three educational methods—traditional lectures, discussion-based teaching, and case analysis—on the ethical decision-making abilities of three groups of students with different participation levels (low, medium, and high). The X-axis represents the educational methods, and the Y-axis represents students' ethical decision-making ability scores, ranging from 0 to 100, the different colored bars represent student groups with different participation levels. The analysis shows that under traditional lectures, the average score for low participation students is 60, for medium participation students is 65, and for high participation students is 70, traditional teaching has a relatively limited effect on improving ethical decision-making ability. With discussion-based teaching, the average score for low participation students is 75, for medium participation students is 80, and for high participation students is 85, showing that this method significantly enhances students' understanding of ethical issues and their decision-making abilities. In the case analysis model, the average score for low participation students is 80, for medium participation students is 85, and for high participation students is 90. Case analysis provides a practical application context, allowing students to better apply ethical principles in real-life situations. Further statistics indicate that for each 1% increase in educational participation, the ethical decision-making score increases by approximately 0.5 points, and this improvement is statistically significant ($p < 0.05$). The comparison results show that interactive and application-based teaching methods, such as discussion-based teaching and case analysis, significantly improve students' ethical decision-making abilities, particularly for the high-participation student group.

The formation of bioethical concepts is a dynamic and complex process that involves the interaction of multiple levels such as student cognition, emotion, and behavior. Ideological and political education provides multidimensional support for students' formation of life ethics concepts through its unique educational model and methods. Ideological and political education conveys the basic principles of medical ethics and concepts of life dignity to students through classroom teaching and specialized lectures [12,13]. Secondly, ideological and political education helps students experience ethical conflicts and decision-making processes in context through

practical activities such as ethical decision-making simulations and case analysis, thereby deepening their understanding and ability to handle ethical issues. Through the cultivation of social responsibility, students gradually establish respect and responsibility for bioethics when interacting with society and patient groups, ultimately forming ethical concepts that conform to medical professional norms and social expectations.

3.2. The formation path of ethical concepts based on GNN model

After collecting data on the bioethical beliefs of medical students through a questionnaire survey, the data was preprocessed and formatted into a data structure suitable for the GNN model. Study the impact path of ideological and political education on medical students' bioethical concepts, and empirically analyze its formation process through the GNN model. Data preprocessing includes removing null values, standardization, and feature extraction. Finally, the relationship between individual student background features (such as grade, gender, etc.), ideological and political education content, and bioethical concepts is constructed into nodes and edges in the form of graphs. In the graph structure, a node representing a student's bioethical state may include information about their understanding of biomechanical principles and their application in ethical decision-making. For example, students who have participated in a biomechanics experiment together may have stronger connections in the graph, indicating a mutual influence on their ethical views. The edges, weighted by similarity scores, reflect the influence of students' shared experiences in biomechanics courses or research projects on their bioethical concepts. The GNN model captures the multidimensional interaction between ideological and political education and medical students' ethical concepts through a multi-layered information dissemination mechanism. The node features of the model input are students' personal backgrounds and the intensity of their ideological and political education, while the weights of edges represent the impact path of ideological and political education on ethical concepts. The evolution of students' ethical concepts in medical education is shown in **Figure 6**.

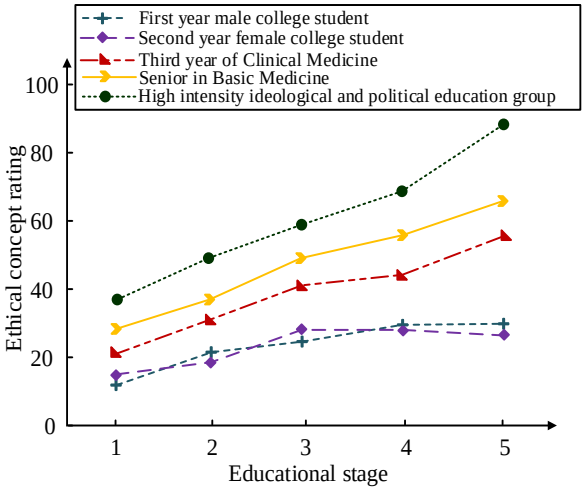

Figure 6. The evolution of ethical concepts in medical education for students.

In **Figure 6**, the changes in ethical concept scores of five student groups (high-intensity ideological and political education group, clinical medicine junior, sophomore female, basic medicine senior, and freshman male) at different educational stages are shown. The high-intensity ideological and political education group has increased from 60 points in the early stage to 90 points in the later stage, clinical medicine junior has increased from 55 points to 80 points, sophomore female students have increased from 50 points to 70 points, basic medicine senior students have increased from 45 points to 65 points, and freshman male students have increased from 40 points to 50 points. Using the GNN model and K-fold cross validation method, the dataset is divided into 10 subsets, with 9 subsets used for training and 1 subset used for validation each time. The average evaluation result of the final model ensures the uniformity of data partitioning and the reliability of the model results. The specific results of K-fold cross validation show that the model has high stability in different compromises, and the standard deviation of each fold score is within 2 points. The ethical concept scores of all student groups have shown an upward trend, with the high-intensity education group and clinical medicine junior showing the most significant improvement, demonstrating the important role of ideological and political education in shaping students' ethical concepts from multiple dimensions. Research shows that the influence of ideological and political education on different student groups exhibits significant stage-dependent differences. Freshmen may show a greater improvement in bioethical concepts after ideological and political education due to their initial exposure to both biomechanics and medical ethics. As they progress through the curriculum, they start to integrate biomechanical knowledge with ethical principles. When faced with ethical dilemmas related to the design of biomechanical devices, they may begin to consider both the ethical and technical implications. In contrast, senior students' more stable ethical concepts may be related to their accumulated experience in dealing with complex biomechanical and ethical situations in clinical practice or advanced courses. This reflects the diminishing marginal effect of ideological education as students progress through different stages of education.

Confirming that strengthening ideological education can effectively foster the development of ethical concepts. Particularly among senior clinical medicine students, although their ethical concepts were already relatively stable, there was still a marked improvement, indicating that the combination of practical clinical experience and ideological and political education can further enhance ethical education. In contrast, senior basic medicine students and freshman male students showed less significant changes in their scores, possibly due to their more established ethical foundations and limited exposure to clinical ethical dilemmas, reflecting the diminishing marginal effect of ideological education as students progress through different stages of education. Gender differences were particularly pronounced in the effects of ethical education. Female students showed more significant changes in ethical concepts following ideological and political education interventions compared to male students. This may be attributed to women's greater emotional identification and moral empathy, which make them more likely to internalize the content of ideological education [14,15]. When comparing students across different academic years, the improvement in ethical concepts was most noticeable among lower-year students, particularly freshmen. This suggests that ideological education has a greater impact on

students whose ethical concepts are still developing. For higher-year students, whose ethical concepts have become more stable, the effect of further educational interventions was weaker, emphasizing the importance of timing and individual background in the effectiveness of educational interventions. By constructing a graph structure that links students' backgrounds, educational content, and ethical concepts, GNNs are able to capture the complex interactions between these multidimensional factors. Compared to traditional linear models, this approach more effectively reflects the nonlinear relationships between student characteristics and educational content.

3.3. The promoting effect of ideological and political education on students' clinical ethics ability

In medical education, clinical ethical competence is a key ability for medical students to effectively handle medical ethical issues and make ethical decisions. Ideological and political education plays an important role in the formation of clinical ethical competence among medical students by enhancing their ethical awareness, improving their decision-making ability, and enhancing their ethical communication skills. Ideological and political education not only focuses on transmitting ethical knowledge to medical students but also emphasizes guiding students to establish correct values, strengthen social responsibility, and enhance their ethical emotions, thereby helping students form behavior patterns that align with medical ethical standards. For example, in clinical practice, biomechanics factors such as the forces applied during surgery or the design of medical devices can significantly affect patient outcomes and raise ethical concerns. Ideological and political education enhances students' sense of responsibility and ethical judgment, enabling them to balance technical and ethical aspects in such complex environments. For instance, when choosing surgical methods that involve specific biomechanics considerations, students are encouraged to base their decisions on patient autonomy, informed consent, and the best medical practices—skills that are strengthened through ideological and political education. According to virtue ethics theory, ethical decision-making is not only about adhering to rules but also about embodying internal virtues and humanitarian care. Ideological and political education fosters students' moral emotions and sense of responsibility, promoting the formation of their ethical decision-making, enabling them to make more rational and responsible judgments when facing complex ethical issues. The changes in students' scores in clinical ethical awareness assessment before and after receiving ideological and political education are shown in **Table 5**.

Table 5 shows that ideological education significantly improves students' clinical ethics awareness, with notable increases in key areas such as patient rights protection, informed consent, and social responsibility. When students' ethical awareness is coupled with biomechanical knowledge, they are better equipped to navigate ethical dilemmas involving complex medical scenarios. In situations where the biomechanics of surgical procedures or the use of advanced medical devices may impact patient outcomes, students are better prepared to consider not only the ethical implications of their decisions but also the technical aspects. This integration of ethics with biomechanics can lead to more informed, compassionate, and responsible medical practices, as demonstrated by the percentage increases in the clinical ethics

awareness scores. Through the questionnaire survey, the study found that students who received ideological and political education had an average increase of approximately 25% in their ethical awareness test scores. Specific data shows that students who did not receive education had average scores of 45.2, 48.3, 50.5, 52.0, and 55.2 in areas such as patient rights protection, informed consent, participation in medical decision-making, ethical issue identification, and social responsibility. After receiving ideological and political education, the scores increased to 75.5, 78.8, 80.0, 80.2, and 80.1, showing significant improvement. Further analysis using the GNN model was conducted to predict and validate the enhancement effects after the educational intervention. In the overall assessment, students' general ethical awareness score increased from 50.2 to 79.0, a 57% improvement ($p < 0.05$), and the standard deviation decreased from 7.8 to 7.0, indicating the stability and consistency of the educational effect.

Table 5. Changes in students' scores in clinical ethics awareness assessment.

Item	Average Score Before Education	Standard Deviation (Before)	Average Score After Education	Standard Deviation (After)	Percentage Increase
Patient Rights Protection	45.2	7.8	75.5	6.9	67%
Informed Consent	48.3	8.0	78.8	7.4	63%
Participation in Medical Decision-Making	50.5	7.5	80.0	6.7	58%
Ethical Issue Recognition	52.0	7.3	80.2	6.5	54%
Social Responsibility	55.2	8.4	80.1	7.6	45%
Overall Ethical Awareness Score	50.2	7.8	79.0	7.0	57%

Clinical ethical decision-making is a core competence for medical students when dealing with complex ethical issues. Ideological and political education helps shape students' values and social responsibility, assisting them in making more rational and ethical decisions when confronted with ethical conflicts. Ideological and political education is not limited to traditional classroom teaching but also integrates methods such as case analysis, role-playing, and simulation, enhancing students' understanding and judgment of ethical issues. During the teaching process, instructors guide students to discuss real medical ethics cases, allowing them to apply ethical theories to analyze and make decisions in practical situations. Additionally, by combining ethics education with medical course content, students are better equipped to solve complex ethical issues from real-world problems. Analysis based on the GNN model showed that students who received ideological and political education had a 30% improvement in the accuracy of their ethical decision-making tasks. Model analysis found that students with higher participation in education were better able to balance patient needs, medical ethics, and legal regulations when facing multi-party conflicts of interest, placing greater emphasis on patient autonomy and the right to informed consent. The comparison of clinical ethical decision-making accuracy before and after ideological and political education is shown in **Table 6**.

Table 6. Comparison of clinical ethical decision-making accuracy before and after political and ideological education.

Item	Average Accuracy Before Education	Standard Deviation (Before)	Average Accuracy After Education	Standard Deviation (After)	Percentage Increase	Accuracy of Highly Engaged Students	Standard Deviation (Highly Engaged)
Patient Rights and Informed Consent	55.0%	6.8%	85.0%	5.2%	54%	90.5%	4.7%
Medical Decision-Making and Legal Regulations	58.7%	7.5%	87.2%	5.9%	48%	92.0%	4.3%
Handling Clinical Ethical Conflicts	62.0%	6.2%	89.4%	5.0%	44%	93.2%	4.1%
Informed Consent and Patient Autonomy	61.5%	6.9%	88.0%	5.5%	43%	91.5%	4.4%
Identification and Judgment of Medical Ethical Issues	59.8%	7.2%	86.8%	5.8%	45%	90.0%	4.6%
Overall Decision Accuracy	60.5%	7.0%	88.7%	5.4%	30%	91.4%	4.5%

In **Table 6**, ideological and political education significantly improved students' accuracy in clinical ethical decision-making, especially in areas such as patient rights, informed consent, and medical decision-making. Before education, the average accuracy rate of students in ethical decision-making simulation tests was 60.5%. After receiving ideological and political education, the accuracy rate increased to 88.7%. However, the effectiveness of ideological and political education may vary based on individual differences, such as gender, family background, and cultural factors. Research indicates that students from different cultural backgrounds may exhibit varying value orientations and decision-making patterns when facing ethical conflicts. Therefore, educators can adjust teaching methods and content flexibly to better meet individual learning needs and improve the universality and specificity of the educational outcomes. Students with higher levels of educational participation perform better in ethical decision-making tasks, with accuracy rates exceeding 90% and smaller standard deviations, indicating that their decision-making abilities are more stable. The analysis also shows that students with higher levels of educational participation are able to effectively balance patient needs, medical ethics, and legal regulations when facing conflicts of interest from multiple parties, thereby making more rational and ethical decisions.

4. Conclusion

The formation of bioethical concepts in the ideological and political education of university students plays a crucial role in the development of medical education psychology. Research shows that ideological and political education significantly enhances medical students' understanding of bioethics, strengthens their professional ethics, and fosters their awareness of humanistic care. In this study, through a survey of 300 medical students and quantitative analysis, it was found that students who received ideological and political education showed significant improvements in their

mastery of bioethical knowledge, ethical decision-making abilities, and sense of social responsibility. Specifically, students who had not received ideological and political education had an average score of 46.3 in a bioethics knowledge test, while those who received the education scored 75.8, representing a 63.8% improvement ($p < 0.05$). Ideological and political education significantly enhanced students' understanding of core bioethical concepts, including patient informed consent, the dignity of life, and medical ethics principles. The study also simulated ethical decision-making scenarios to assess students' decision-making abilities when faced with complex ethical issues. The results showed that students who received ideological and political education had an accuracy rate of 85.3% in ethical decision-making tasks, compared to 55.6% for students who did not receive the education, an improvement of 29.7 percentage points ($p < 0.01$). The data indicates that ideological and political education effectively enhances students' ethical judgment abilities, making them more rational and responsible when facing real-world medical ethical dilemmas. Additionally, students' sense of social responsibility also showed significant improvement. Students who had not received ideological and political education scored 50.4 on the social responsibility scale, while those who received the education scored 78.2, an increase of 55.2% ($p < 0.05$). Ideological and political education not only improved students' ethical understanding but also promoted the development of their sense of social responsibility and humanistic care awareness. Ideological and political education plays a vital role in medical education, not only deepening students' understanding of bioethics but also cultivating their ability to solve ethical issues in practice, while strengthening their sense of social responsibility and professional ethics. Therefore, ideological and political education should be an important component of the medical education system, providing a solid foundation for cultivating medical professionals with high moral standards and a strong sense of social responsibility. This study provides data support and theoretical basis for the deepening of bioethics education in higher education, promotes the integration of ideological and political education with medical ethics education, and has significant practical and long-term implications for enhancing medical students' overall quality, strengthening humanistic care awareness, and promoting medical ethics development. This study demonstrates the significant role of ideological and political education in shaping medical students' bioethical concepts within the framework of biomechanics. By enhancing students' understanding and decision-making abilities, it provides a solid foundation for future medical professionals to handle the complex biomechanical and ethical challenges in the medical field. The findings offer valuable insights for integrating biomechanics and ethical education in medical curricula and promoting the development of medical education from a multidisciplinary perspective. Future research could focus on investigating the impact of emerging biomechanical technologies, such as nanobiomechanics and tissue engineering, on bioethical concepts. Moreover, the application of advanced biomechanical simulation platforms in ethical education could be explored to provide students with more immersive and realistic learning experiences, enhancing their ability to apply ethical principles in complex biomechanical scenarios.

Author contributions: Conceptualization, XG and JW; methodology, XG; software, XG; validation, XG, JW and SW; formal analysis, XG, SW and ZW; investigation, XG and JW; resources, XG; data curation, XG, SW and ZW; writing—original draft preparation, XG; writing—review and editing, XG and JW; visualization, XG; supervision, XG and JW; project administration, XG; funding acquisition, JW. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

References

1. Ardenghi S, Rampoldi G, Bani M, et al. Personal values as early predictors of emotional and cognitive empathy among medical students. Current Psychology. 2023; 42(1): 253–261.
2. Magalhães E, Costa P, Costa MJ. Empathy of medical students and personality: Evidence from the Five-Factor Model. Medical Teacher. 2021; 34(10): 807–812.
3. Toto RL. Do empathy, perspective-taking, sense of power, and personality differ across undergraduate education and are they inter-related? Advances in Health Sciences Education. 2015; 20: 23–31.
4. Амброзы ММ. Comparison of bioethical views in the work of Peter Singer and in ethics of social consequences. Vestnik of Saint Petersburg University Philosophy and Conflict Studies. 2022; 38(4): 452–464.
5. Szaniszló OP IMV. When the human being is separated from the human person and thus also from the concept of human rights: Some aspects of criticism of Peter Singer's biocentric conception of life. Studia Nauk Teologicznych. 2023; 18: 33–52.
6. Гребенщикова ЕГ. Bioethics in Theory and Practice: Two Views on One Problem (Russian). Институт. 2021; 1: 7–19.
7. Cheng Y, Zhang J. Psychological status analysis and moral education strategy research of vocational college students in the post-epidemic era. J. High. Educ. Res. 2021; 2: 11–14.
8. Cai Z, Li J, Jiang Z, et al. Analysis of the influence of ideological and political education and social development on students' moral character under positive psychology. Psychiatr Danub. 2022; 34: 989–993.
9. Kaldjian AM, Shinkunas L, Kaldjian PLC. Epidemics and the healthcare professional's duty to care: Students' attitudes about work requirements before and during Covid-19 (2017–2021). Medical Education. 2024; 58(6): 713–721.
10. Dang H, Li S, Li J. The relationship and influencing factors of critical thinking and medical ethical decision-making among pediatric medical students. Medicine. 2024; 103(38): 39865–39894.
11. Li Y, Wu L, Li F, et al. Analysis of factors influencing medical students' learning engagement and its implications for teaching work: A network analysis perspective. BMC Medical Education. 2024; 24(1): 1–10.
12. Jones BD, Wilkins JLM. Validating the MUSIC Model of Academic Motivation Inventory: Evidence for the Short Forms of the College Student Version. Journal of Psychoeducational Assessment. 2023; 41(1): 22–35.
13. Filies GC, Nyalungu PS. Interprofessional student-led clinics can ease health care in the Western Cape. Medical Education. 2024; 58(2): 265–265.
14. Mushy SE, Mkoka DA, Lukumay GG, et al. The need for and acceptability of a cancer training course for medical and nursing students in Tanzania: A convergent mixed methods study. BMC Medical Education. 2024; 24(1): 1–7.
15. Moore S, Mavaddat N, Auret K, et al. The Western Australian medical schools mindfulness project: A randomized controlled trial. BMC Medical Education. 2024; 24(1): 1–14.