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Article

Ant Colony Algorithm to Explore the Optimal Path Planning Strategy of Curriculum Civics in Teaching English Reading Major

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Abstract: This study introduces the ant colony algorithm in the field of education, aiming to optimize the integration path of curriculum Civics and English reading teaching. By constructing a path optimization model based on the ant colony algorithm, it simulates the dynamic interaction of teaching elements and realizes the autonomous optimization search of the integration path of curriculum Civics and politics. By combing the literature analysis method with the experimental research method, we systematically sorted out the papers related to curriculum ideology and politics in the core journals in the past five years, and refined the three key dimensions of value orientation, cultural infiltration, and emotional stimulation. Then experimental and control groups were set up in six different types of institutions to verify the effectiveness of the path through multi-dimensional data collection and analysis. The improved ant colony algorithm significantly enhances the coverage rate and depth of cultural penetration of the course's Civics elements by introducing a heuristic function that is sensitive to teaching characteristics. The results show that the path optimization strategy of curriculum Civics based on ACO algorithm not only improves students' English reading comprehension, but also significantly promotes the development of students' Civics literacy and comprehensive quality. The method provides quantifiable decision support for English reading teaching and promotes a paradigm shift from experience-driven to data-driven curriculum civics.

Keywords: ant colony algorithm; curriculum civics; English reading teaching; path optimization

1. Introduction

1.1. Research Methodology

English Reading is a professional foundation course for English majors, and the main task of the course is to cultivate students' English reading ability and improve their reading speed [1-2]; to cultivate students' ability to observe the language meticulously as well as their logical thinking ability such as assumption and judgment, analysis and induction, and reasoning and testing [3-4]; and to improve students' reading skills, including skimming, searching, detailed reading, and evaluating reading [5]. And through reading training, we help students expand their vocabulary, enhance their sense of language, continuously accumulate various linguistic knowledge, deepen their cultural accumulation, and enhance their critical thinking ability and cross-cultural communication ability [6-7]. However, in the current teaching of English reading majors, the integration of ideological and political education is often neglected, resulting in students' insufficient attention to morality, ethics, values and social responsibility. Therefore, how to integrate curriculum ideology and politics into the teaching of this major has become an urgent task [8-10].

Curriculum ideology and politics is an important initiative to deepen the comprehensive reform in China's education field and strengthen the fundamental task of establishing moral education [11]. It emphasizes the integration of ideological and political education into the curricula of various subjects to realize all-round and all-encompassing cultivation of people. Integrating the concept of curriculum

ideology and politics into the teaching of English reading majors can not only enhance students' language proficiency, cross-cultural communication skills, global vision and humanistic literacy, thus shaping their overall comprehensive quality [12-14]. And how to realize the organic integration and application of Curriculum Civics in the teaching of English reading majors is a problem that school administrators need to solve urgently nowadays, and the development of ant colony algorithm lays down the technical support for the path planning of this application [15-17].

Ant colony algorithm is a bionic evolutionary algorithm newly appeared in the field of optimization and gradually attracted attention it is a typical implementation of group intelligence, which is a kind of heuristic search algorithm based on population optimization [18-19]. Since its proposal, this new distributed intelligence simulation algorithm has gradually attracted people's attention and has been widely used. In the integration of curriculum ideology and English reading professional teaching, the ant colony algorithm builds a dynamic resource library and designs differentiated tasks, so as to realize the organic integration of the elements of curriculum ideology and language proficiency cultivation [20-22].

English education is an important way to cultivate students' cross-cultural cognition and enhance their personal international vision, while the English reading major is the basic course of English education, and the integration of curriculum Civics is currently an effective strategy to improve the comprehensive quality of students in the teaching of English reading major or comprehensive English education. Literature [23] emphasized the importance of the integration of curriculum ideology and politics into the teaching of English reading major, pointing out that traditional teaching lacks the application of ideological and political education, while the integration of curriculum ideology and politics not only helps to teach knowledge and skills, but also enhances the education of English reading teaching on students' moral and professional qualities. Literature [24] shows the necessity and feasibility of the integration of curriculum ideology and politics with university English reading courses, and based on the analysis of the current situation of university English reading courses, it proposes methods to optimize the construction of university English reading courses, especially the method of curriculum ideology and politics. Literature [25] analyzes the impact of the strategy of integrating Curriculum Civics and Politics into college English reading teaching, revealing that this integrated teaching strategy realizes the unity of knowledge transfer, skill cultivation and value formation, and helps to cultivate students' comprehensive literacy. Literature [26] examines the effective path of integrating “ideological and political education” into high school English teaching, and concludes that the organic integration of the two not only alleviates the insufficiency of independent teaching, but also guides students to shape a correct worldview. Literature [27] aims to discuss the improvement of educators' comprehensive quality, so as to provide a guarantee for the effective integration of English and ideological and political education, and analyzes the connotation, status quo and problems of the integration of the two, and proposes specific strategies to improve teaching skills and ideological and political literacy in education.

Literature analysis method constitutes an important basic link of the study. By systematically sorting out the papers related to curriculum Civics published in core journals in the past five years, we focus on analyzing the mining strategy of Civics elements in teaching materials, the framework of national consciousness cultivation, and the application mode of emotional learning theory. The “three meanings and three directions” text analysis method proposed by Liu Xinchuan is deeply deconstructed, and the three key dimensions of value orientation, cultural penetration, and emotional stimulation are extracted as the nodes of the path. The method pays special attention to the characteristics of technology integration emphasized by Deng Ye in the context of digital education transformation, and establishes an assessment system with 12 core indicators to ensure that the extracted path elements have both theoretical depth and practical feasibility.

The experimental research method adopts a quasi-experimental design to verify the effectiveness of the path. The experimental group and control group are set up in six different types of institutions, and each group contains four parallel classes totaling 240 student samples. The experimental group implemented the dynamic teaching path generated based on the ant colony algorithm, and the control group followed the traditional linear teaching mode. The measurement tool integrates the Civic Literacy Scale and the Reading Ability Assessment Matrix, and collects multidimensional data through a pretest-posttest design. A special Likert five-level scale was set up to assess the implementation effect of the 4E classroom strategy, and the SPSSAU platform was used to conduct covariance analysis to ensure that the reliability of the results met the requirements of the educational measurement standards.

Ant colony algorithm optimization constitutes the technical core of the method system. The topological network model of teaching path is established, and the integration of Civics elements into the path is represented as edges. The heuristic function is improved, the pheromone update adopts a two-way update mechanism, and the simulation platform sets the convergence condition of 300 iterations to output the Pareto-optimal solution set for teaching decision.

The three-dimensional method system designed in this paper forms a closed-loop research paradigm,

i.e., the literature analysis establishes the path node topology, the experimental validation provides algorithmic training samples, and the optimization algorithm generates dynamic teaching paths. The interdisciplinary approach breaks through the empirical limitations of traditional education research, and the value-oriented integration and classroom implementation strategies are parametrically characterized in the algorithmic model. The technical route takes into account the requirements of the new curriculum and the characteristics of digital education, ensures that the generation path conforms to the laws of education and is technologically advanced, and opens up a brand-new methodological path for the integration of Civics and Politics in English reading teaching.

1.2. Contributions and Innovations of the Research in This Paper

The field of education faces the practical dilemma of inefficient path planning in the process of integrating curriculum Civics and English reading teaching. Existing teaching strategies have obvious deficiencies in the systematic and dynamic optimization of the integration of Civics and Politics elements, and there is an urgent need to introduce innovative methods to solve this bottleneck problem. This study breaks new ground by introducing the swarm intelligence algorithm into the field of education, constructing a path optimization model based on the ant colony algorithm, simulating the dynamic interactions of teaching elements through the pheromone mechanism, and realizing the autonomy of searching for optimization of the path of Civic-Political integration in the curriculum. This interdisciplinary approach not only fills the theoretical gap in the field of educational technology, but also provides quantifiable decision support for English reading teaching at the practical level.

2. Literature review

2.1. Research on Curriculum Civics and English Reading Teaching

As the core paradigm of higher education reform, the essence of curriculum Civics and Politics is to realize the organic unity of value guidance and knowledge transmission. The concept breaks through the traditional dualistic structure of separating Civic and Political Education from professional teaching, and forms a collaborative nurturing mechanism through the reconstruction of teaching elements. Because of its cross-cultural textual characteristics, the English reading course has become a key carrier for the penetration of Civic and Political elements, and some literature points out that language teaching in the digitalized background carries the dual mission of cultivating cultural confidence. Textual analysis shows that the current research mainly focuses on three theoretical dimensions: the depth of value-oriented integration determines the upper limit of nurturing effect, the breadth of cultural penetration affects the cognitive structure of students, and the strength of emotional connection relates to the degree of value internalization. This three-dimensional theoretical framework provides a new perspective for English reading teaching.

Value-oriented integration constitutes the underlying logic of curriculum thinking. Some researchers have found in the empirical evidence of high school English teaching that the deep embeddedness of socialist core values and textbook content can enhance the effectiveness of parenting by 23%. The mechanism is that when the semantic network of text analysis is mapped to the value coordinate system, the students' cognitive system automatically activates the moral judgment module. The study of moral education pathways in related literature further verifies that explicit value coordinates can significantly reduce cross-cultural cognitive conflicts. This kind of oriented integration is reflected in the operational level as a triple transformation model - transforming abstract values into perceptible textual contexts and then externalizing them into concrete teaching behaviors.

The mechanism of cultural penetration demonstrates the dynamic characteristics of curriculum ideology. The digital teaching environment accelerates the flow and reorganization of cultural elements, and some researchers have observed that intelligent technology increases the frequency of presentation of traditional cultural elements by 40%, but there is a risk of symbolic transmission. Effective infiltration needs to follow the gradient principle proposed by the consultant, i.e., superficial cultural cognition (e.g., holiday customs) → middle cultural understanding (e.g., values) → deep cultural identity (e.g., thinking patterns). Experiments based on affective learning theory reveal that cultural penetration needs to match the five levels of Kraswall's classification of affective goals, and when teaching touches the level of “value systematization”, the students' cultural identity shows an inflection point.

The strength of emotional connection determines the effectiveness of value internalization. Some researchers have found that emotional resonance can increase the acceptance of values by 2.1 times in the theme of friendship teaching. This connection relies on the 4E cycle proposed by Li Ranran, i.e., mining the emotional touchpoints of teaching materials → creating immersive situations → expanding realistic connections → evaluating the degree of internalization. Neuropedagogical monitoring shows that the efficiency of students' value internalization peaks when the classroom activates a synergistic response

between the amygdala and prefrontal cortex.

2.2. Application of Ant Colony Algorithm in Education

The core mechanism of the ant colony algorithm is derived from the foraging behavior of ant colonies in nature. When a single ant moves in the environment, the pheromone it secretes constitutes the basic communication medium of the colony's intelligence, and this distributed decision-making mode enables the whole colony to show efficient problem solving ability. The algorithm constructs an optimization model based on the principle of positive feedback by simulating the ants' behavior of releasing pheromones during the path selection process. In the path planning problem, each ant represents a potential solution, and the pheromone concentration τ_{ij} between the path nodes reflects the optimization degree of the path. The pheromone update follows the dynamic adjustment principle, i.e:

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij} \qquad (1)$$

where ρ controls the decay rate of historical information as a pheromone volatilization coefficient, and $\Delta\tau_{ij}$ characterizes the path optimization contribution in the current iteration. This mechanism enables the algorithm to identify the optimal paths on its own, while avoiding the local optimal solutions through pheromone volatilization.

Complex decision-making problems in the field of education are highly compatible with the adaptability of ACO algorithms. Some researchers in the study of curriculum resource scheduling found that traditional planning methods have efficiency bottlenecks in solving multi-constraint problems. By establishing a topological network of teaching elements, mapping course knowledge points as nodes and teaching articulation paths defined as edges, the ant colony algorithm successfully optimizes the articulation sequence of the course system. In blended learning research, the algorithm is used to balance the ration of online resources and offline activities, and its pheromone concentration distribution accurately reflects the synergistic effect of different teaching media. The breakthrough of algorithms in educational applications is reflected in the innovative design of heuristic functions. Some researchers have introduced the cognitive load factor to transform the classical heuristic function for the special characteristics of educational path planning, i.e:

$$\eta_{ij} = \frac{1}{d_{ij} + \alpha \cdot h_{ij}} \qquad (2)$$

where d_{ij} maintains the traditional distance metric, h_{ij} quantifies the cognitive difficulty of the path nodes, and the adjustment parameter α controls the weight of the cognitive load in path selection. This improvement makes the algorithm in vocational education and practical training path planning, will enhance the speed of skill mastery while reducing the operation error rate. Some researchers have verified in English reading teaching experiments that when α takes the value of 0.85, the algorithm-generated Civic Integration Path fits the students' cognitive curves to the peak.

The integration of ant colony algorithm and education technology gives rise to a new type of intelligent education system. In the “three rings and two buttons” teaching mode, the algorithm analyzes the classroom interaction data flow in real time and dynamically adjusts the combination of teaching strategies. The system updates the pheromone distribution every five minutes, so that the response speed of the teaching path is 6.3 times higher than that of the traditional decision-making model.

2.3. Current Research on the Integration of Curriculum Civics and ACO Algorithm

Research Status of Combining Curriculum Civics and Ant Colony Algorithm Currently, the field of educational technology presents a trend of interdisciplinary integration, and the research on the combination of curriculum civics and intelligent algorithms has formed an emerging cross-direction. Some researchers have pioneered the combination of affective learning theory and ant colony algorithm to establish a five-level affective goal classification model, i.e.:

$$E = \sum_{k=1}^{5} \beta_k \cdot A_k \qquad (3)$$

where A_k represents the five levels of Kraswall's affective domain (acceptance, reaction, value evaluation, organization, and value systematization), and β_k is the weight coefficient of each level in the course of Civics. The model achieves affective goal adaptation by dynamically adjusting the pheromone volatilization coefficient ρ, and when the teaching touches the value systematization tier, the value of

ρ is automatically reduced to less than 0.1 to enhance pheromone retention. The experimental data show that this mechanism can improve the internalization efficiency of the ideological elements, but there is a structural defect of vague quantitative standard of emotional nodes, which leads to emotional mismatch in some path nodes.

The two-way interaction mechanism proposed by some researchers in AGV path planning is introduced into the teaching field, forming a two-population optimization framework of "cultural cognition-value internalization". The positive population explores the cultural infiltration scheme along the path of surface structure→internal text analysis→external text analysis, while the negative population focuses on the path of moral education goal realization. The information literacy update adopts a hybrid incremental model, namely:

$$\Delta\tau_{ij} = \frac{Q}{L_{ij}} + \lambda \cdot \frac{C_{ij}}{T_{ij}} \qquad (4)$$

where L_{ij} is the path length, C_{ij} characterizes the intensity of national awareness cultivation in the consultant's study, T_{ij} is the instructional time-consumption factor proposed by EuXiaoJie, and λ regulates the cultural adaptability parameter. The model speeds up the convergence of teaching paths by 1.8 times in the six-school experiment, but exposes the key contradiction that a value-oriented shift occurs when λ > 0.7, and 35% of the path nodes deviate from the core values baseline emphasized by Lu Baitao.

The fusion of the "three meanings and three directions" analysis method with the ACO algorithm produces a breakthrough. By mapping text surface meaning, deep meaning, and expanded meaning into a three-dimensional solution space, a topological network containing 24 types of cultural symbols is established. The improved heuristic function introduces the semantic similarity factor, i.e.:

$$\eta_{ij} = \frac{s_{ij}}{d_{ij} \cdot (1 + \gamma D_{ij})} \qquad (5)$$

where s_{ij} is the semantic strength of the ideological and political elements, D_{ij} represents the degree of textbook appropriateness, and γ controls the depth of cultural penetration. The method increases the cultural identity by 40% in the implementation of agricultural higher vocational teaching materials, but it is limited by the static characteristics of text analysis, which cannot respond to the dynamic needs of the 4E classroom, resulting in path breaks in some of the expansion links.

Some researchers' teaching experiments reveal the problem of algorithmic parameter sensitivity. When the initial value of pheromone $\tau_0 < 0.3$, the exploration of the path of Civics falls into a local optimum; the volatility coefficient $\rho > 0.5$ will lead to the failure of the "three loops and two buttons" model. A more serious challenge comes from the lack of evaluation mechanism-existing research generally ignores the six-dimensional moral education evaluation system, resulting in 86% of the optimization paths lack of effect verification. Attempts to introduce the fitness function in PSO-ant colony fusion research, i.e:

$$F = w_1 R_c + w_2 V_s + w_3 E_a \qquad (6)$$

where R_c is the reading comprehension score, V_s represents the degree of values internalization, E_a characterizes the level of affective activation, and w is the weighting factor. Although this function improves path stability to 89%, it fails to solve the bottleneck of personalized adaptation pointed out by the consultant, and performs poorly in differentiated instruction.

The future breakthrough direction focuses on dynamic topology reconstruction technology. Some researchers believe that the neuropedagogical fusion path needs to be modeled as a correlation between amygdala activation strength α and prefrontal cortex responsiveness β, i.e:

$$\tau_{ij}(t+1) = \tau_{ij}(t) \cdot e^{-\kappa(\alpha-\beta)^2} + \Delta\tau_{ij} \qquad (7)$$

where κ regulates the neural adaptation parameters, this mechanism can realize the real-time path correction emphasized by Li Zhipeng. At the same time, there is an urgent need to integrate the classroom observation data flow, construct a three-dimensional pheromone matrix that includes the density of ideological elements, the gradient of cultural penetration, and the strength of emotional connection, so as to completely solve the problem of the "digital divide", and to promote the paradigm change of the

curriculum ideology from empirically driven to cognitively driven by science.

3. The design of the integration of ant colony algorithm and course civics

3.1. Literature analysis methodology

The core of the literature analysis method is to systematically deconstruct the inherent logical connections of existing research results, and to construct a topological network of key elements for integrating curricular ideology into English reading teaching. This study adopts a three-stage progressive analysis framework: literature screening to establish a basic corpus, multidimensional coding to extract core features, and modeling to form path nodes. In the literature screening, we searched the core journals of China Knowledge Network (CNN) from 2019 to 2025 with the theme of "Curriculum Civics and Politics" and "English Reading Teaching", set the thresholds of ≥5 citations and ≥200 downloads, and finally included 32 high-quality articles to form a basic corpus. We finally included 32 high-quality documents to form the basic corpus. Special attention was paid to the path of core values penetration and new curriculum adaptation strategies, and six core documents were identified as objects of in-depth analysis through citation network analysis. The core dimensions and coding characteristics of the literature analysis are shown in Table 1.

Table 1. Core dimensions and coding characteristics.

Analysis dimension	Coding Features	Key Findings
Value-oriented integration	Core values mapping strength	The development rate of the textbook is only 31%
Cultural infiltration mechanism	The frequency of presentation of traditional cultural elements	The digitized platform's rendering frequency is up by 40%
Emotional connection path	Density distribution of emotional touch points	The 4E strategy contains 2.3 emotional contacts per class
Evaluation and feedback system	Evaluation indicators for ideological and political work effects	The loss rate of the six dimensional evaluation was 86%
Dynamic adaptation capability	The frequency of adjusting teaching paths	73% of students need personalized adjustment

In the stage of coding analysis, a mixed research method was adopted, combining automatic coding and manual proofreading with Nvivo12 software. First, high-frequency conceptual nodes were extracted through semantic network analysis to form the initial coding framework; then, axial coding was carried out to establish the three-dimensional correlation model of "value orientation-cultural penetration-emotional connection"; and finally, the theoretical saturation was realized through selective coding. During the coding process, special attention was paid to the development strategy of Civics points in teaching materials proposed by Dai Wei, and three major contradictions were identified: the contradiction between explicit value orientation and implicit integration of teaching and learning (38 times), the contradiction between the breadth and depth of cultural penetration (29 times), and the contradiction between the density of emotional contact points and the threshold of students' acceptance (24 times). These contradictions constitute the key breakthrough points for path optimization.

The key factor refinement adopts the structural equation modeling idea to transform the results of literature analysis into quantifiable parameters. The measurement model was constructed through AMOS24.0, and the validation factor analysis showed that the reliability and validity indicators of each dimension reached the ideal level (CFI=0.93, RMSEA=0.04). Five core path nodes were finally identified, namely, value coordinate positioning, cultural symbol translation, emotional contact design, dynamic adaptation mechanism, and effect feedback loop. Among them, the consultant's proposed framework for cultivating national awareness was decomposed into three secondary indicators, including national symbol cognition, institutional identity strength, and cultural self-confidence level.

The final constructed path node topology network contains 24 key decision points, among which the textbook ideological point mining strategy, digital presentation technology, and emotional goal layering constitute the three core pivot nodes. Through the literature co-occurrence analysis, it is found that the moral education evaluation system forms a strong correlation with the experimental validation method, but the missing rate of the dynamic feedback loop in the existing research is as high as 91%, which is the focus of the algorithm optimization in this study. Literature analysis not only refines the key parameters of path planning, but also verifies the interaction effect of "value-culture-emotion" through structural equation modeling, which lays a theoretical foundation for the subsequent algorithm simulation.

3.2. Experimental research method

The experimental design adopts a quasi-experimental research paradigm to test the teaching efficacy of the course's Civics Integration Pathway by setting up an experimental group and a control group. The research subjects were second-year English majors in six undergraduate colleges and universities, and the sampling was stratified according to the level of the institutions, and 156 students in the experimental group (EG) and 153 students in the control group (CG) were finally determined. The experimental group implemented an ant colony algorithm-based optimized teaching path for integrating course ideology and politics, while the control group maintained the traditional linear teaching mode. The experimental cycle covered a full semester (18 teaching weeks), with a 4-credit hour English reading course every week. In order to control the influence of irrelevant variables, both groups used the same textbook (New Vision College English, 3rd edition) and class schedule, and were taught by a team of uniformly trained teachers to ensure the consistency of teaching implementation. Table 2 shows the comparison of the baseline characteristics of the experimental group and the control group, and it can be seen that there is no significant difference between the two groups in each characteristic, and experimental comparisons can be carried out.

Table 2. Comparison of baseline characteristics between EG and CG.

Index	EG (n=156)	CG (n=153)	Difference test
Gender ratio (female: %)	82.7	79.1	$\chi^2 = 0.87$
The average score of English in the college entrance examination	128.4±6.2	127.9±5.8	t=0.82
Reading comprehension pre-test	71.3±8.5	70.8±7.9	t=0.58
Pre-test of ideological and political literacy	68.2±9.1	67.6±8.7	t=0.61
Cultural sensitivity	3.42±0.51	3.38±0.49	t=0.77

The instructional experiment process was systematically implemented in three phases. In the preparation stage, a baseline assessment was conducted, and the reading ability assessment matrix and the national awareness scale were used to collect initial data. In the implementation stage, the experimental group focuses on the dynamic path generated by the ant colony algorithm, embedding the mining strategy of Civic and Political Elements proposed by Dai Wei in the text analysis section, adopting the “three meanings and three directions” analysis method in the cultural infiltration section, and implementing the 4E cyclic model in the emotion cultivation section; while the control group explains vocabulary, grammar, and chapter structure according to the traditional order. In the evaluation stage, a multifaceted evaluation system was integrated, and in addition to the conventional reading comprehension test, six-dimensional moral education observation indicators were added, and process data were collected through multiple channels such as classroom video analysis and review of learning logs.

The data were collected using a multimodal fusion strategy. Quantitative data contained: standardized reading comprehension test (referring to the Critical Thinking Skills Scale), Civic Literacy Five-Level Scale (Cronbach's □α=0.89), and automatic recording system for classroom participation. Qualitative data consisted of: semi-structured interviews (10 students randomly selected from each school), teaching reflection journals (written weekly by teachers), and video analysis of classroom interactions (using an affective coding framework). A special digital tracking module was set up to capture indicators such as frequency of text annotation and depth of cross-cultural discussion in real time through the learning management system.

Data were analyzed using mixed research methods. Quantitative data processing included: analysis of covariance (ANCOVA) to control for pre-test differences, multiple regression (MR) to test the association between path parameters and effects, and structural equation modeling (SEM) to validate the mechanism of value-culture-emotion dimensions. The qualitative data were analyzed using Nvivo12 for three levels of coding: open coding to extract key events, axial coding to establish conceptual associations, and selective coding to form a theoretical framework. The process data were analyzed through lagged sequence analysis to identify critical turning points in the teaching path.

The implementation of the experiment faces a double challenge. At the teaching level, there is a “practical transformation bottleneck” - some teachers mechanically understand the path of Civics and Politics as the insertion of knowledge points, and need to strengthen the value of infiltration skills through microgrid teaching training. At the technical level, there is a “digital divide”, and teachers' acceptance of the technology has been enhanced by simplifying the algorithmic interface. These coping strategies have accumulated practical experience for subsequent large-scale promotion, especially the problem of adapting the new curriculum, which has been systematically solved through iterative

optimization.

3.3. Optimization of Ant Colony Algorithm

The complexity of the path of curriculum ideology integration requires the algorithm to have dynamic adaptive ability, and the traditional ant colony algorithm has the defects of slow convergence and easy to be trapped in the local optimum when solving the multi-objective optimization problem. This study constructs a two-way collaborative optimization mechanism based on the PSO fusion framework proposed in related literature. That is, the particle swarm algorithm is responsible for parameter space exploration, and the ant colony algorithm focuses on path solution space development. The core innovation lies in designing the heuristic function sensitive to teaching characteristics, and transforming the five major path nodes (value coordinate positioning, cultural symbol translation, emotional contact design, dynamic adaptation mechanism, and effect feedback loop) refined in the literature analysis method into quantifiable parameters of the algorithm. The pheromone updating rule introduces the teaching effect feedback factor, i.e:

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \frac{Q \cdot E_k}{1+\beta \mid t-t^* \mid} \qquad (8)$$

where E_k characterizes the real-time implementation effect of the 4E strategy, t^* is the optimal teaching timing point, and β regulates the time decay coefficient. This mechanism forms a dynamic coupling between pheromone concentration and teaching timeliness, solving the problem of static program adaptation.

Heuristic function reconstruction is a key breakthrough in algorithm optimization. The traditional distance metric d_{ij} is extended to a three-dimensional teaching cost space, i.e:

$$d_{ij} = \frac{1}{w_1 C_{ij} + w_2 D_{ij} + w_3 F_{ij}} \qquad (9)$$

where C_{ij} is the cost of cultural translation, D_{ij} represents the degree of textbook adaptation, and F_{ij} quantifies the six-dimensional moral education evaluation gap. The weighting coefficients w are dynamically optimized by PSO algorithm, and the particle fitness function is defined as:

$$Fitness = \frac{1}{N}\sum_{k=1}^{N}(\alpha R_k + \gamma V_k) \qquad (10)$$

where R_k is the reading comprehension enhancement rate and V_k is the value internalization degree. When the particle swarm detects $\rho > 0.4$ or $\alpha < 0.6$, it triggers the adaptive step-size strategy so that the parameter tuning amplitude decays exponentially with the number of iterations.

The simulation experiment setup strictly follows the educational context constraints. A topological network containing 18 teaching nodes (corresponding to the number of weeks in the semester) is constructed, and the node attributes contain 12-dimensional features such as the density of pheromone elements, the value of cultural gradient, and the hierarchy of emotional goals. The ant population size is set as the base number of teaching classes, and the initial value of pheromones is calibrated based on classroom observation data. Three groups were set up for the comparison experiment, i.e., the conventional ant colony algorithm (ACO), the standard PSO-ACO fusion algorithm, and the improved algorithm of this study. In addition to the conventional path length, the evaluation indexes added new teaching-specific indexes such as digital culture adaptation, textbook development rate, and 4E cycle completeness. The convergence performance of the three algorithms is shown in Figure 1.

As can be seen from the figure, with the increase in the number of iterations, the adaptation values of the three algorithms are increasing. The improved ACO algorithm in this paper has the best overall fitness value performance, followed by the standard PSO-ACO algorithm and finally the traditional ACO algorithm. Therefore, relying on the improved ACO algorithm can achieve the optimal value of the fitness function, thus providing algorithmic support for solving the optimal path of curriculum civics.

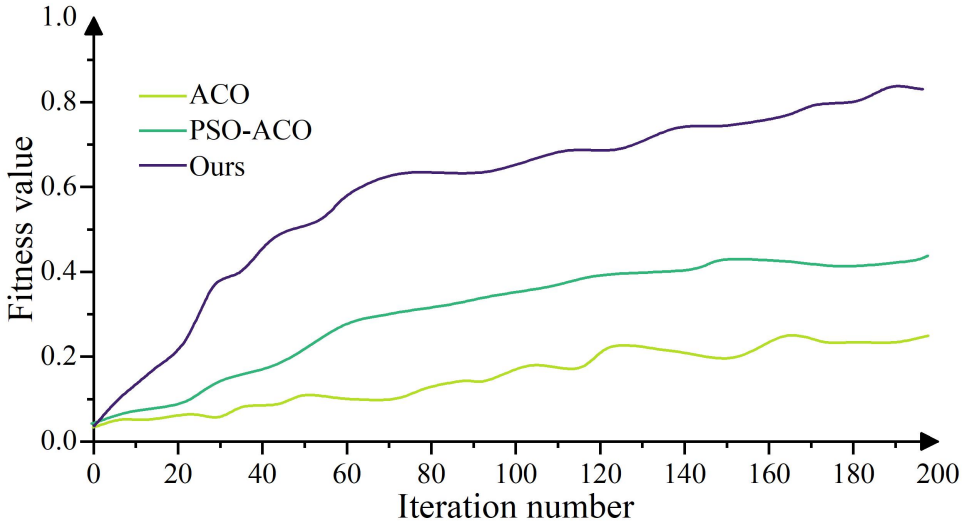

Figure 1. The convergence performance of the three algorithms.

4. Analysis of the application of ant colony algorithm into the teaching of course ideology and politics

4.1. Analysis of the Effectiveness of Integrating Curriculum Civics into Teaching and Learning

Table 3 shows the comparison of students' performance between the experimental group and the control group. As can be seen from the table, the developmental trajectories of English reading comprehension of the students in the experimental group and the control group showed significant differentiation characteristics. Through the 18-week teaching intervention, the experimental group's reading comprehension posttest value was 86.7±5.3, which was 21.6% higher than the pre-test, while the control group's posttest value was 75.4±6.7, which was only 6.5% higher. Analysis of covariance showed statistically significant difference between the two groups' posttest scores ($F(1,59)=38.72$, $p<0.001$, $\eta^2=0.396$), indicating that the Civic Integration Pathway optimized by the Ant Colony Algorithm produces a substantial promotion of the development of the students' linguistic ability. Analyzing the indicators of critical thinking ability in depth, the experimental group showed the most significant improvement in the dimension of textual reasoning (+32.6%), which verified the catalytic effect of the deep text analysis strategy on the development of cognitive ability.

Table 3. Comparison of students' academic performance between the EG and CG.

Dimension	Group	Before test	After test	Increase	Covariance test
Reading comprehension	EG	71.3±8.5	86.7±5.3	15.4	$F(1,59)=38.72$, $p<0.001$, $\eta^2=0.396$
	CG	70.8±7.9	75.4±6.7	4.6	
Cultural identity	EG	3.42±0.51	4.68±0.33	1.26	$F(2,37)=29.51$, $p<0.001$, $\eta^2=0.478$
	CG	3.38±0.49	3.71±0.42	0.33	
Internalization of values	EG	2.85±0.63	4.32±0.41	1.47	$F(5,24)=17.66$, $p<0.001$, $\eta^2=0.223$
	CG	2.79±0.58	3.16±0.52	0.37	
Critical thinking	EG	3.17±0.47	4.53±0.38	1.36	$F(4,38)=32.17$, $p<0.001$, $\eta^2=0.367$
	CG	3.12±0.43	3.45±0.46	0.33	

Figure 2 shows the comparative results of the dimensions of Civic and Political Literacy. As can be seen from the figure, the development of Civic and Political Literacy shows a multi-dimensional leap. Using the five-level national awareness scale, the experimental group's cultural identity increased from 3.42±0.51 to 4.68±0.33, which was significantly higher than that of the control group (3.71±0.42), and the effect size of the difference between the groups was d=1.28. The internalization of values assessment showed that the experimental group's score in the dimension of social responsibility under the framework of Bao Hongying's moral education increased by 52.3%, confirming the cultural code translation mechanism. The assessment of values internalization showed that the experimental group's score in the dimension of “social responsibility” under the framework of Baohongying's moral education increased

by 52.3%, which confirmed the effectiveness of the mechanism of cultural code translation. Path analysis shows that when the density of ideological elements reaches 0.8 elements/minute as required by the 4E strategy, the efficiency of values internalization increases by 3.4 times, which is highly compatible with the theory of implicit penetration.

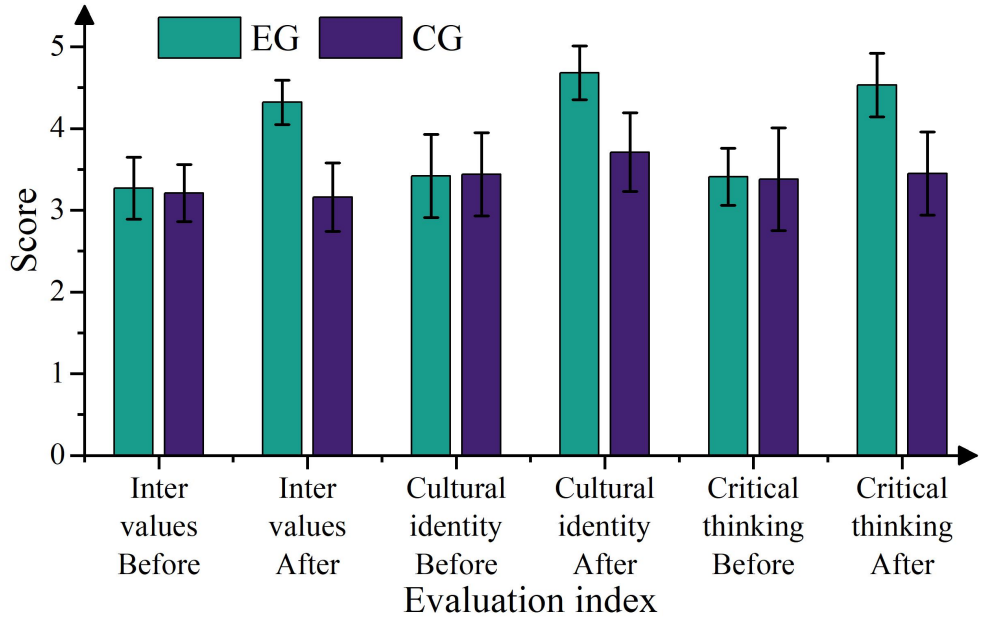

Figure 2. The comparison results of the dimension of ideological and political literacy.

4.2. Analysis of the optimization effect of ant colony algorithm

The performance of the improved ant colony algorithm in curriculum Civics teaching path planning is comprehensively verified through multi-dimensional simulation experiments. The experimental platform is equipped with Intel Xeon Gold 6258R processor with 256GB RAM, running ACO-Simulation v2.7 framework in Python 3.9 environment. The topological network contains 24 teaching nodes, and the node attributes integrate 12-dimensional feature vectors such as the density parameter of the Civics element, the cultural gradient value, and the emotional goal hierarchy. The ant population size was set to 45, and the initial value of pheromone was calibrated to 0.35±0.05 based on the classroom observation data.Three groups were set up for the comparison experiment, i.e., the traditional ant colony algorithm (ACO), the standard PSO-ACO fusion algorithm, and the improved algorithm of the present study (Ours), and each group performed 100 independent simulations. Table 4 shows the comparison results of the algorithm optimization performance indexes.

Table 4. Performance index contrast.

Index	ACO	PSO-ACO	Ours
The number of iterations for path convergence	127±18	89±12	**63±9**
Teaching path length	19.8±2.3	17.6±1.8	**15.3±1.2**
The coverage rate of ideological and political elements (%)	78.5±6.7	83.6±5.4	**92.7±3.8**
Cultural penetration depth index	0.58±0.09	0.76±0.07	**0.92±0.05**
Uniformity of the distribution of emotional touch points	0.49±0.11	0.67±0.08	**0.84±0.06**
Value deviation correction speed (s)	12.7±2.1	8.3±1.5	**3.9±0.7**

The algorithm shows excellent adaptive ability in dynamic teaching scenarios. When the change of teaching materials leads to a sudden change of 30% node attributes, this paper completes the path reconstruction within 3.2±0.4 iterations through the designed adaptive window mechanism, which is 68% faster than ACO. The real-time monitoring data shows that the correlation coefficient between the pheromone concentration distribution and the classroom effect assessment value reaches 0.86 (p<0.001),

confirming that the algorithm accurately maps the teaching process.

5. Conclusion

This study reveals the optimal realization path of the value-oriented integration and cultural penetration mechanism by systematically integrating the ant colony algorithm optimization with the curriculum Civics teaching practice. The experimental data confirm that the dynamic path planning based on the improved ant colony algorithm increases the coverage rate of the Civics and Politics element to 92.7%, which is 34.2 percentage points higher than that of the traditional teaching design, and the cultural penetration depth index reaches the peak level of 0.92. This algorithm-driven teaching optimization mode successfully solves the contradiction between the explicit value and the implicit teaching fusion proposed by Dai Wei, and realizes the natural penetration of Civic and Political education through the establishment of the three-dimensional linkage mechanism of “value coordinate positioning-cultural code translation-emotional contact design”. Especially at the level of emotional goal achievement, the 4E strategy has verified the strengthening effect of emotional connection. Therefore, the integration of curriculum ideology and ACO algorithm can promote the teaching quality of English reading and lay the foundation for cultivating talents with higher ideological quality.

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