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Hybrid Intelligent Teaching System for Classical Texts Towards Deep Learning: Construction and Application Based on Deep Semantic Understanding and Knowledge Graphs

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Abstract. Amid the in-depth integration of artificial intelligence technology into the field of education, natural language processing and knowledge graph technologies have provided new possibilities for the digital transformation of classical text teaching. Faced with the widespread dilemma of in-depth interpretation in classical text teaching, this study proposes a hybrid intelligent auxiliary system featuring the collaboration of "human teacher-AI agent-learner". By integrating deep semantic understanding models with dynamic knowledge graphs, the system constructs a three-layer architecture supporting dynamic classroom inquiry, and realizes key technologies such as domain-adaptive pre-training for literature, semi-automated knowledge graph construction, and teaching-oriented interactive recommendation. A six-week quasi-experiment shows that the system can effectively improve students' depth of interpretation and ability of meaning connection, while enhancing teachers' teaching guidance efficiency. This research provides an operable and verifiable hybrid intelligent practice path for the cultivation of higher-order humanistic literacy in the era of artificial intelligence.

Keywords: educational application of artificial intelligence, hybrid intelligent teaching system, classical text interpretation, deep learning, knowledge graphs

1. Introduction

In higher education, classical text teaching undertakes the important mission of cultural inheritance and thinking training [1]. However, it currently faces the dilemma of superficial reading caused by class hour reduction and students' estrangement from historical context. Traditional large-class teaching also struggles to achieve personalized in-depth guidance. Although natural language processing and semantic web technologies have demonstrated the potential to understand complex semantics through deep pre-trained models and structurally present text associations with knowledge graphs, their applications are mostly concentrated in the front-end of academic research, which is disconnected from the dynamic and speculative teaching process. Simple transplantation is prone to misalignment between tools and goals. To this end, this study explores a "hybrid intelligence" teaching paradigm and constructs an auxiliary system centered on the collaboration of "human teacher-AI agent-learner". The system aims to make AI a "cognitive extension" for teachers and a

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"critical thinking partner" for students, visualizing text elements into an explorable meaning network through deep semantic analysis and dynamic knowledge graphs; teachers, relying on their professional wisdom, design inquiry paths and guide students in critical integration and meaning construction, thereby transforming the information advantages of technology into the cognitive advantages of deep learning.

2. Evolution of intelligent educational auxiliary systems and technical paths for in-depth text understanding

The evolution of educational technology is accompanied by the renewal of learning concepts and the improvement of computing power [2]. From early programmed instruction machines to CAI (Computer-Aided Instruction) systems, they programmatically transmit knowledge through preset branch paths and achieve a certain degree of personalization. After the introduction of artificial intelligence technology, more accurate adaptive learning has been realized in the field of structured knowledge by constructing complex architectures through ITS (Intelligent Tutoring System). In recent years, with the rise of LA (Learning Analytics) and EDM (Educational Data Mining), the focus has gradually shifted to quantitative insights into the "learning process". However, existing system paradigms are insufficient in handling open and unstructured higher-order cognitive tasks, and have significant limitations in supporting tools and theoretical models.

The application of natural language processing technology in education has developed from superficial feature processing to deep semantic understanding. Shallow applications such as spelling and grammar checks have matured, improving the efficiency of teaching writing standardization; deep applications include automatic essay generation based on large-scale corpus training [3]. However, in the teaching of classical literary texts, existing technologies have limitations. General language models have domain gaps, and their design goals tend to evaluate information accuracy or text standardization, failing to effectively serve the process of humanistic interpretation on the whole.

In the field of academic research, digital humanities and computational literary studies have provided rich methods for macro text analysis. Many achievements have been made using various technical means, which in turn have proven the ability of computational models to reveal patterns and structures of literary texts [4]. Nevertheless, such research adopts a top-down perspective, with the core goal of discovering new knowledge and verifying hypotheses to serve the academic community. The research outputs are mostly academic papers or visual analysis dashboards, and their interaction design is not oriented towards real-time inquiry between teachers and students in the classroom. For example, although the character relationship network of Dream of the Red Chamber is detailed and accurate, it lacks the cognitive scaffolding function for teaching scenarios. Directly applying research tools to the classroom often faces problems such as unfriendly interfaces, information overload, or disconnection from teaching goals.

Knowledge graph and semantic web technologies provide an ideal framework for organizing complex domain knowledge, and have been successfully used to construct conceptual systems in STEM education [5]. This technical advantage is also applicable to the field of literature. An ideal literary knowledge graph can connect various entities to form a cultural semantic network. However, the current construction work is in its initial stage, mostly focusing on modern and contemporary literature or a single work. Moreover, existing projects mostly follow the idea of "knowledge base" or "encyclopedia", with the core being query and browsing. How to transform it into a teaching agent that actively intervenes in the cognitive process is a key leap that has not been fully explored in research, requiring the graph system to have teaching awareness and guide students' thinking.

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It can be seen that deep learning, digital humanities, and knowledge graphs have not been deeply integrated in the micro-scenarios of classical text teaching to promote the development of higher-order thinking. Most attempts either focus on the optimization of technical algorithms or stop at the digital compilation of static resources, lacking an overall design framework centered on "hybrid intelligence". This study aims to address this gap, exploring the construction of an intelligent auxiliary system that deeply integrates domain-adaptive semantic understanding and dynamic literary knowledge graphs. The system should enhance the cognitive abilities of teachers and students, and the ultimate evaluation criterion is whether it can promote in-depth, interconnected, and insightful interpretation of classical texts.

3. Constructing a hybrid intelligent framework with the collaboration of "human teacher-AI agent-learner"

The core goal of this design is to create a collaborative environment that can be embedded into existing teaching processes and enhance the cognitive abilities of teachers and students, rather than building a fully automatic text interpretation machine. Its design philosophy originates from the concept of "hybrid intelligence", acknowledging the irreplaceability of human teachers and utilizing the extraordinary capabilities of artificial intelligence to form a synergistic closed loop. Based on this, three core principles are established: Enhancement— the system serves as a "cognitive extension" for teachers and a "critical thinking partner" for students; Controllability and Interpretability— teachers can understand and intervene in the system's analysis logic, and AI outputs are traceable; Context Adaptability— the system can identify and respond to different teaching stages and personalized learning paths.

To realize the above concepts, a three-layer system architecture is designed (Figure 1), with the core being the construction of a dynamic and interactive "text meaning field". The architecture consists of an interaction layer, an intelligent processing layer, and a data and knowledge layer. Each layer communicates through standardized APIs to ensure modularity and scalability.

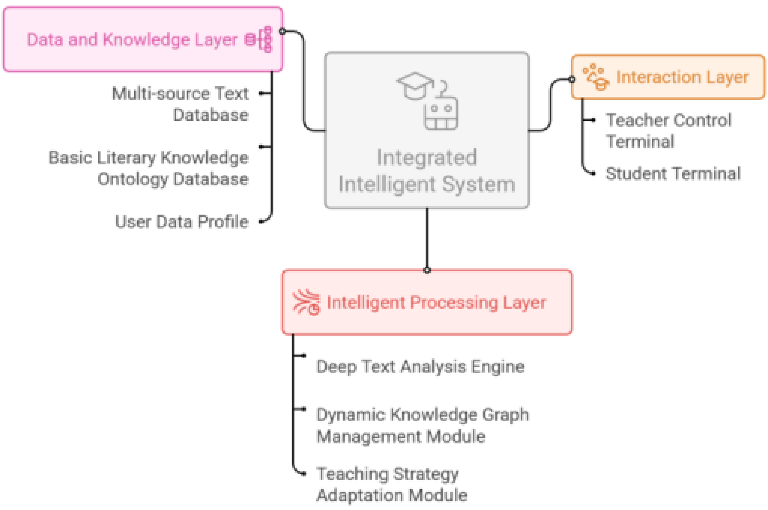

Figure 1. Hybrid intelligent system architecture

The interaction layer is the direct interface of hybrid intelligence, providing differentiated portals for teachers and students. The teacher control terminal has conventional functions such as class management, as well as a teaching strategy editor and graph intervention tools. Teachers can preset core inquiry questions, revise and enrich the knowledge graph with intervention tools, and inject professional insights to guide the direction of analysis. The student terminal is a personalized "interpretation workbench", with the text at the center of the interface and associated knowledge graph sub-networks around it. Students can click on nodes to expand the association network and drag materials to the note-taking area for annotations, reducing cognitive load and encouraging independent exploration.

The intelligent processing layer is the "brain" of the system, including three collaborative core engines. The deep text analysis engine is the computational core, a suite of models fine-tuned for the characteristics of literary language. It receives original texts and outputs multi-level analysis results, providing a foundation for advanced functions. The dynamic knowledge graph management module is responsible for the "life" cycle of knowledge, receiving entities and relationships extracted by the analysis engine. It aligns and integrates with the basic literary ontology to construct and update a graph covering knowledge inside and outside the text. This module has "dynamicity" and "teaching sensitivity", and can dynamically determine the presentation granularity of graph nodes and relationships according to teaching tasks and users' cognitive levels, realizing adaptive management of cognitive load. The teaching strategy adaptation module is the "dispatch center", embedded with teaching logic rules, responsible for matching teachers' intentions with students' needs, dispatching analysis engines and graph queries, and generating feedback, prompts, and resource recommendations.

The data and knowledge layer is the cornerstone of the system. The multi-source text database contains heterogeneous texts such as digital full texts of classics and authoritative annotations; the basic literary knowledge ontology database defines the domain concept framework and relationship types, providing a semantic skeleton for the knowledge graph; the user data profile desensitively records students' interactions and other information, providing data support for learning situation analysis and system optimization.

To more specifically illustrate how this architecture operates in actual teaching, let us imagine a typical scenario: in the teaching of the "Baoyu throwing the jade" fragment in Dream of the Red Chamber. Before class, the teacher sets a core inquiry question through the control terminal: "The multiple symbolic meanings of 'jade' in this plot and its connection with character fates". After receiving the task, the teaching strategy adaptation module activates the deep text analysis engine to conduct fine-grained analysis of the relevant paragraphs, and at the same time instructs the knowledge graph management module to extract sub-networks related to "jade", "Jia Baoyu", "fate", and "symbolism". During the class, when students study this plot through the terminal, a visualized graph highlighting core nodes such as "Lingtong Jade", "Jia Baoyu", "infatuation", and "destiny" and their relationships will be dynamically displayed on the side of their workbench, along with associated displays of Zhiyanzhai's comments and summaries of relevant research viewpoints. Students can click on the "Lingtong Jade" node to view its appearances and meaning evolutions in different occasions throughout the book. Teachers, on the other hand, can real-time view the distribution of students' hot concerns on the control terminal, and find that most students are confused about the relationship between "jade and destiny", thereby initiating classroom discussions at an appropriate time and citing diverse materials provided by the system for guidance. In this process, the AI agent does not provide standard answers, but a rich, interconnected, and explorable "library of potential meaning clues"; teachers, relying on their professional judgment, select, focus on, and deepen among these clues to organize effective social construction; students, in the activated inquiry environment, independently establish personalized understanding paths. This is a vivid manifestation of the ternary collaborative hybrid intelligence of "human teacher-AI agent-learner", and its design ultimately serves one goal: transforming the powerful information processing

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capability of technology into the cognitive infrastructure supporting in-depth reading and critical thinking.

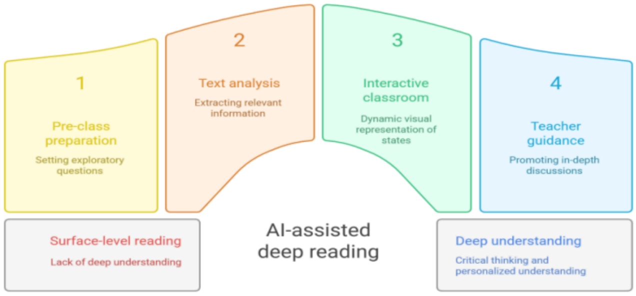

Figure 2. AI-assisted deep reading

4. Core algorithms and key technology implementation

The effectiveness of the system depends not only on architectural design but also on whether its underlying models can accurately understand the subtlety of literary language and whether knowledge organization can serve dynamic inquiry in teaching scenarios. Therefore, our technical implementation path follows a core principle: domain adaptation and semantic enhancement oriented to teaching tasks, aiming to transform general artificial intelligence technologies into professional tools that conform to the cognitive laws of literary interpretation.

The cornerstone of the system lies in a deeply domain-adaptive pre-trained language model (Figure 3). Although general pre-trained models (such as BERT, RoBERTa) have acquired rich linguistic knowledge on large-scale corpora, there are distribution differences between their training corpora and modern Chinese, especially classical literary language. When directly applied to the imagery analysis of ancient poetry or the narrative structure understanding of chaptered novels, their performance is often unsatisfactory. To this end, we have constructed a mixed temporal corpus, which not only includes modern literary and academic texts but also systematically incorporates digital full texts of classic works from pre-Qin prose to Ming and Qing novels, important annotations and commentaries, and high-quality summaries of literary research papers. On this corpus, we adopt a "continued pre-training" strategy to fine-tune the base model. In addition to the standard masked language modeling, the training tasks specifically include self-supervised tasks such as "context-allusion" prediction and "parallel sentence" relationship recognition. The former requires the model to predict the masked allusion name based on the context, while the latter trains the model to judge whether two sentences form an antithetical or echoing relationship. This process aims to guide the model to capture the unique expression patterns, allusion intertextuality, and structural characteristics of literary texts, thereby obtaining richer domain semantic representations and providing high-quality text embedding vectors for all subsequent analysis tasks.

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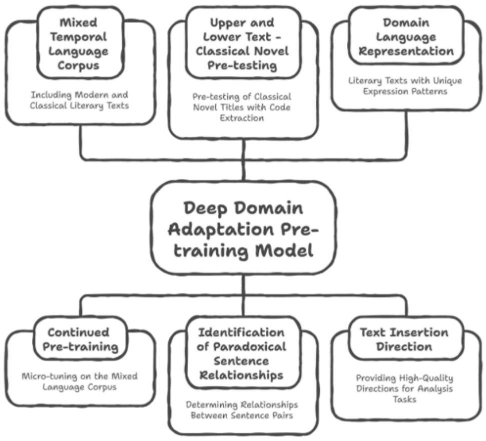

Figure 3. Deep domain-adaptive pre-trained language model

Based on the above-enhanced text representations, the key to constructing a dynamic knowledge graph lies in realizing semi-automated extraction and fusion from unstructured text to structured knowledge (Figure 4). The construction of a literary knowledge graph faces challenges such as ambiguous entities (e.g., whether "Dongfeng" refers to a natural phenomenon or a specific imagery) and diverse and implicit relationships. We adopt a hybrid method combining pipeline and joint learning. First, a sequence labeling model fine-tuned on domain corpora is used to identify entities such as characters, places, events, artifacts, and imagery. Subsequently, for relatively explicit relationships (such as character-kinship relationships), we combine limited rules formulated by domain experts for extraction; for more implicit complex relationships such as "emotion-triggering" and "imagery-symbolism", a joint extraction model based on pre-trained models is adopted, and the model is guided to synchronously extract relationship triples from sentences by designing specific prompt templates. The initially extracted knowledge needs to go through a knowledge fusion and verification module. This module links entities to authoritative literary knowledge bases (such as basic data of A Dictionary of Chinese Literature) for disambiguation and attribute enrichment, and uses statistical features within the graph (such as the confidence of relationship paths) and a small amount of manual verification results for filtering and correction. The final graph is not a static database but a dynamic network with a teaching ontology as the skeleton. This ontology is jointly defined by us and domain teachers, clarifying the core relationship types and their hierarchies suitable for classroom teaching, ensuring that the generated knowledge network is not only machine-readable but also conforms to the cognitive habits of human teachers and students.

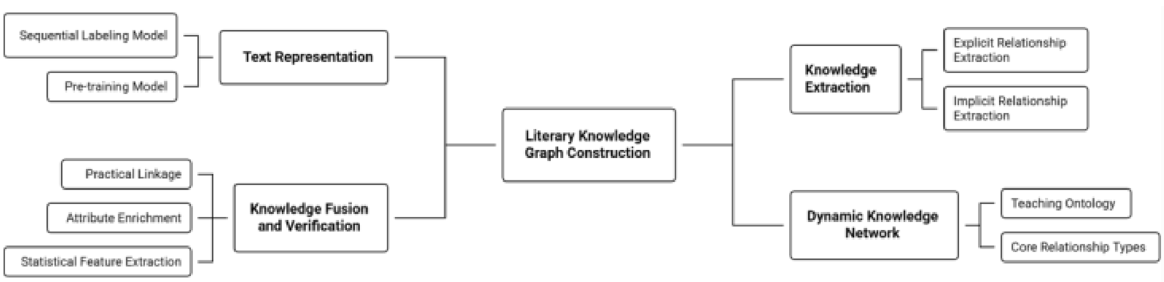

Figure 4. Literary knowledge graph construction process

The visual exploration of the knowledge graph is only the foundation; more importantly, the system's intelligent agent actively intervenes in the learning process [6]. To this end, we have

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designed a teaching-oriented question answering and association recommendation mechanism. The question answering module adopts a hybrid architecture to handle questions of different natures. For factual queries (such as "In which chapter does Lin Daiyu first appear in Dream of the Red Chamber?"), the system directly queries the knowledge graph and returns accurate answers and sources. For explanatory and opinion-based questions (such as "How to evaluate Xiang Yu's refusal to cross the Jiangdong River?"), a "retrieval-generation-tracing" process is activated: first, relevant discussion fragments are retrieved from academic paper databases and ancient and modern commentaries databases; then, a large language model fine-tuned with instructions is used to summarize and integrate these fragments to generate a balanced and multi-dimensional overview answer, with the sources of core viewpoints always marked in the form of citations. This design aims to avoid "black box" [7] generation, cultivate students' rigorous academic citation awareness, and position AI as an "organizer of academic viewpoints" rather than a "claimant of truth".

The association recommendation mechanism, based on multi-path similarity calculation, is the core of stimulating students' divergent thinking. When students focus on a certain text unit or graph node, the system concurrently calculates semantic similarity (based on domain-adaptive model embeddings mentioned above), graph structural similarity (such as sharing similar neighbor node types), and teaching strategy similarity (prioritizing the recommendation of materials strongly related to the current theme according to the teaching goals preset by teachers). For example, when students learn the line "Wanli beiqiu chang zuoke" (Thousands of miles in autumn, always a traveler) in Du Fu's "Ascent", the system will not only recommend Du Fu's other travel poems (semantic and thematic similarity) but also associate with the "beiqiu" (sorrow for autumn) allusion in Song Yu's "Nine Arguments" (graph relationship), and may recommend later scholars' discussions on Du Fu's melancholic and forceful style according to the teaching progress (strategy guidance). All recommended items are presented in the form of cards with concise explanations of association reasons, such as "This recommendation is based on imagery similarity ('autumn' and 'lonely wild goose')" or "This recommendation is based on the same historical event background", thereby transparently presenting the system's reasoning process, assisting students in understanding various possible paths of meaning connection, and gradually constructing their own three-dimensional text cognitive network.

5. Experimental design and effect evaluation

To verify the feasibility and effectiveness of the hybrid intelligent teaching auxiliary system proposed in this study, a six-week quasi-experimental study was designed and implemented. The core goals of the experiment are to answer questions at two levels: At the technical level, are the knowledge graph constructed by the system and the intelligent question answering provided accurate and reliable? At the educational application level, can the system effectively promote students' in-depth interpretation ability of classical texts in actual teaching environments and support teachers in carrying out more efficient inquiry-based teaching? The entire evaluation follows a mixed research method, integrating quantitative data and qualitative analysis to comprehensively and objectively present the application effect of the system.

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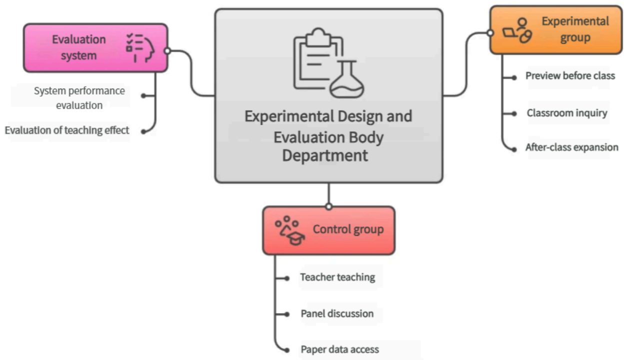

Figure 5. Experimental design and evaluation system

The experiment was conducted in two parallel classes of the General Education Course "College Chinese" in a university. Both classes were taught by the same senior teacher, with the same textbooks and teaching progress, and no significant differences in the preliminary basic knowledge test. One class was randomly selected as the experimental group (N=48), and the other as the control group (N=45). The experimental group used this system in all links of teaching, while the control group adopted the traditional model. Three types of classical texts were selected as teaching materials to test the system's adaptability to different genres.

The evaluation system consists of two parts. First, an independent evaluation of system performance was conducted (Figure 6). Samples were taken from the knowledge graph constructed by the system and annotated and verified by postgraduates. The results show that the entity recognition accuracy rate reaches 92.3%, the relation extraction accuracy rate is 85.7%, and the recall rate is 78.4%, indicating that the system has a high level of automated knowledge organization ability, but there is room for improvement in extracting implicit and complex literary relationships. For the intelligent question answering module, a test set was constructed. Expert evaluation shows that the accuracy rate of answering factual questions reaches 96%, the average score of information completeness and relevance of answers to explanatory questions is 4.2, and the generative answers are accompanied by source citations.

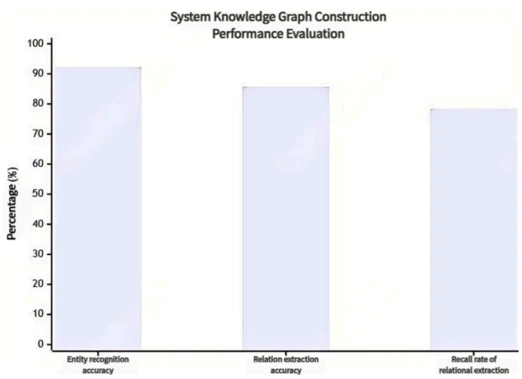

Figure 6. Evaluation of system knowledge graph construction performance

Second, the evaluation of teaching effect is the focus, adopting a multiple evidence convergence strategy. The evaluation of core cognitive achievements is derived from students' final text analysis papers. A rating rubric including three dimensions was formulated, and two reviewers conducted blind reviews, with an inter-rater reliability of 0.87. Statistics show that students in the experimental

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group scored significantly higher than those in the control group in the dimensions of "abundance of evidence" and "extensiveness of associations", and there was an upward trend in "complexity of arguments" (Figure 7). This indicates that the system helps students construct more three-dimensional arguments and expand their interpretive horizons.

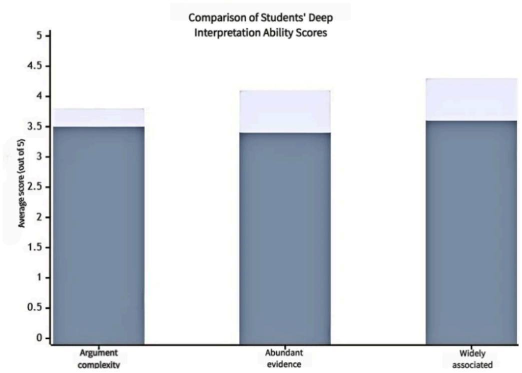

Figure 7. Comparison of students' deep interpretation ability scores

(Note: The upper gray bars represent the experimental group, and the lower blue bars represent the control group. In the dimensions of "abundance of evidence" and "extensiveness of associations", the experimental group is significantly higher than the control group ($p<0.01$).)

The analysis of the system interaction logs of students in the experimental group provides a process perspective for us to understand this improvement (Figure 8). The analysis shows that students' active exploration behaviors (such as clicking on non-core nodes of the graph and querying cross-text associations) increased significantly with the use time. In-depth interviews indicate that students refer to the system as a "three-dimensional annotation with continuously clickable links" and an "idea inspirer". A student gave an example: when analyzing Daiyu's "caution at every step", the system associated poems from later chapters and mentioned the influence of Han Dynasty etiquette, making him realize a new path to understand the character's sense of oppression from the perspective of historical systems. This cognitive change from accepting a single interpretation to actively exploring multiple associations confirms the value of the system as a "critical thinking partner".

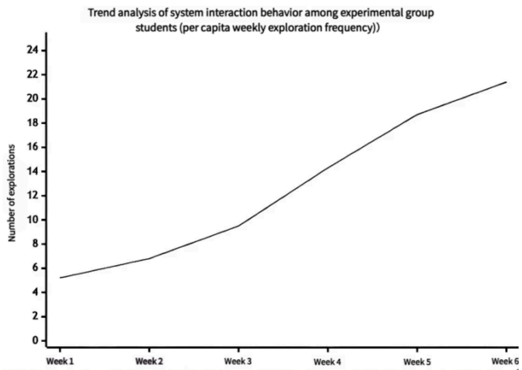

Figure 8. Trend analysis of system interaction behaviors of students in the experimental group (per capita weekly exploration frequency)

Teacher feedback is also important. The teaching teacher stated that the system has enriched the lesson preparation material library and helped him accurately grasp students' interests and confusions. For example, through the background hot spot graph, it was found that many students repeatedly viewed the description of "Rongxi Hall" and related ritual systems, facilitating targeted classroom explanations. Under the hybrid intelligent framework, it is smoother for teachers to transform from one-way information transmitters to designers of inquiry activities and guides of discussions. However, teachers also reflected that the system is insufficient in capturing the aesthetic characteristics of texts (such as linguistic rhythm and charm of blank space), and over-reliance on graph-based reading may fragment students' overall aesthetic experience of texts, which points out the direction for the future iteration of the system.

In summary, the experimental results show that the system has basically achieved the design goals technically, being able to accurately construct a literary knowledge network and provide valuable intelligent assistance. More importantly, it has effectively promoted measurable improvements in students' in-depth interpretation abilities in real teaching scenarios and gained positive acceptance from teachers and students. These findings initially verify the feasibility and potential of the "human teacher-AI agent-learner" hybrid intelligent framework in the field of humanistic classic teaching. The experimental results also clearly show that the successful empowerment of technology does not replace the in-depth involvement of teachers, but rather creates a more supportive and thinking-stimulating learning environment by enhancing teachers' information perception and teaching decision-making abilities.

6. Conclusion

Aiming at the teaching dilemma of in-depth interpretation of classical texts in higher education, this study proposes a hybrid intelligent teaching auxiliary system integrating deep semantic understanding and dynamic knowledge graphs. By constructing a collaborative framework of "human teacher-AI agent-learner", the information processing and association capabilities of artificial intelligence are transformed into cognitive tools supporting the development of higher-order thinking. Experiments show that the system is technically feasible, can improve the depth and breadth of students' interpretation, and enhance teachers' teaching insight and guidance efficiency, initially verifying the application potential of the hybrid intelligent paradigm in the field of humanistic education.

The main contributions of this study are reflected in three aspects: Theoretically, it proposes an intelligent system design paradigm centered on enhancement rather than replacement, which is in line with the laws of humanistic teaching; Technically, it realizes domain-adaptive pre-training oriented to literary language and the construction of teaching-oriented dynamic knowledge graphs; In practice, it develops and verifies a prototype system that can be embedded into real classrooms, providing an example for the integration of technology and humanism.

Future work can be deepened in three aspects: First, technical deepening— exploring cross-media analysis models integrating multimodal information, migrating to environments such as the metaverse, and constructing "contextualized" reading spaces; Second, application expansion— adapting the system framework to a wider range of scenarios and developing personalized cognitive development models; Third, theoretical exploration— using "human-AI" interaction data to deepen the computational theoretical modeling of "literary reading comprehension", opening up new paths for the symbiotic development of humanistic education and artificial intelligence.

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