Research on Shared Mental Models for Learning in Team Collaborative Information Search: Post-print

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Abstract

[Purpose/Significance] This study conducts in-depth research on collaborative information search to provide insights and references for the optimization and construction of professional collaborative information search system platforms.

[Method/Process] Focusing on the information search behavior of learning teams, with university students as the research sample and shared mental model as the entry point, this study adopts grounded theory methodology to explore the construction process of team shared mental model in collaborative information search.

[Results/Conclusions] Four core stages are identified—individual perception and exploration, team task analysis, team information collection, and team information integration—along with the cognitive activities and content elements of the shared mental model in each stage.

Full Text

Preamble

Title: Research on Shared Mental Models in Collaborative Information Search in Learning Teams

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Abstract:
[Purpose/Significance] This study provides in-depth investigation of collaborative information search to offer insights and references for the construction

and optimization of professional collaborative information search system platforms. [Method/Process] Focusing on the information search behavior of learning teams, with university students as research samples and shared mental models as the entry point, this study employs grounded theory methodology to explore the construction process of team shared mental models in collaborative information search. [Result/Conclusion] Four core interlinked elements are identified: individual perception and exploration, team task analysis, team information collection, and team information integration, with the cognitive activities and shared mental model content elements of each stage clarified.

Keywords: collaborative information seeking; team cognition; shared mental model; construction process
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The new economic era has brought numerous market-driven, technology-driven, information-driven, and innovation-driven tasks to enterprises, universities, and research institutions. These tasks often exhibit complex characteristics such as being interdisciplinary, cross-domain, cross-organizational, and cross-cultural, far exceeding individual cognitive capacity and typically requiring teamwork for completion. Successful teamwork demands high levels of collaborative and communication abilities from team members. Therefore, as talent cultivation institutions, universities should emphasize the development of students' teamwork capabilities, communication skills, and team spirit, encouraging them to participate in course projects, extracurricular activities, and various competitions in team formations while guiding them in collaborative learning. To acquire new knowledge and solve complex problems, university student teams must adapt to the collaborative learning required by the knowledge era. From a cognitive perspective, the entire task process represents the gradual dynamic construction of team shared mental models. This study focuses on the information search behavior of learning teams, using university students as research samples and shared mental models as the entry point, employing grounded theory methodology to investigate the construction process of shared mental models in school teams during collaborative information search activities, aiming to provide insights and references for the construction and optimization of professional collaborative information search system platforms.

2. Related Research Overview

2.1 Collaborative Information Search

Collaborative information search research spans multiple fields including Information Science (IS), Information Retrieval (IR), Human-Computer Interaction (HCI), and Computer-Supported Cooperative Work (CSCW), with no unified definition yet established. Scholars have interpreted the concept from different research perspectives: (1) From a technical perspective, P. Hansen et al. consider collaborative information search behavior as information acquisition activities

conducted through explicit or implicit collaboration to solve specific problems [?]; R. González-Ibáñez et al. define it as behavior where multiple individuals collaborate synchronously or asynchronously, co-located or remotely, to accomplish common goals through communication and interaction [?]. (2) From a behavioral process perspective, J. Foster defines it as systematic and practical research on systems that enable users to move from individual to cooperative information seeking, searching, and retrieval [?]; Han Yi views collaborative information search behavior as information exchange activities where actors share search processes and results with others based on common interests or tasks, with knowledge sharing as its essence [?]. Overall, collaborative information search refers to interactive cooperative information acquisition activities consciously conducted by multiple participants based on shared search goals, emphasizing joint searching with others.

Existing collaborative information search research tends to focus more on small-scale explicit cooperation. As early as 1968, the library and information science field identified cooperation phenomena in search processes [?], but this did not attract widespread attention. Until the late 1990s, advances in information technology strongly promoted collaborative information search development, expanding research domains to military [?], medical [?], education [?], agriculture [?], and scientific research [?]. Current collaborative information search research remains in a developmental stage, with two primary perspectives: technical and behavioral. The technical perspective focuses on collaborative information retrieval technology and applications, including algorithm model optimization [?] and system development design [?]. The behavioral perspective examines user collaborative information search behavior in different contexts, with foreign research concentrating on behavioral models, influencing factors, and user cognition. Behavioral model studies typically improve upon individual search stage models, with typical examples including C. Shah' s three-stage model [?] and A. Karunakaran' s three-stage model [?]. Research on influencing factors is relatively rich, with relevant factors summarized as collaboration triggers [?], behavioral subjects [?], search tasks [?], and collaborative environments [?].

Collaborative information search cognition research mostly focuses on individual users' cognitive states during collaborative information search, such as C. Shah' s examination of how cognitive context affects individual users' collaborative information search behavior and retrieval effectiveness [?]. Han Yi also points out that current collaborative information search research from an individual cognitive perspective improves single users' cognitive structures and intelligence levels, while neglecting potential cooperation issues in information seeking and retrieval processes [?]. Drawing on P. Ingwersen' s holistic cognitive perspective, he embeds cooperative information seeking and retrieval processes to construct a socio-cognitive model of information seeking and retrieval, detailing its operational mechanisms.

Domestic collaborative information search research started relatively late. Since Chu Jun' s 2003 analysis of cooperative information seeking behavior and de-

velopment trends [?], it has gradually attracted domestic researchers' attention, focusing mainly on collaborative information search behavior models and influencing factors. Jin Yan and Li Yuyao analyzed collaborative information behavior processes among scientific research team members, constructing a model with collaborative information needs, collaborative information seeking and acquisition, collaborative information utilization, and collaborative information sharing as elements [?]. Dai Jun and Guo Shixin studied contextual factors triggering collaborative information search behavior from the perspective of "remedial strategies after personal information search failure" [?]. Han Yi conducted comprehensive research on influencing factors of collaborative information search behavior, finding cooperation willingness as the core influencing element, information needs as the direct driving factor, and self-literacy, team atmosphere, topic interest, and cooperative information use as constituting team behavior contextual factors [?].

Overall, collaborative information search behavior research covers extensive content involving behavioral models, influencing factors, and psychological cognition. Behavioral model research is relatively limited, typically improving upon individual search stage models or based on specific contexts. Cognitive research on collaborative information search has gradually gained attention, but most studies focus on individual cognition of collaborative members, neglecting potential cooperation issues in information seeking and retrieval processes. Further in-depth research is needed to examine collective processing and behavioral cognitive mechanisms from the overall team level.

2.2 Shared Mental Models

Mental models are psychological mechanisms based on people' s understanding and experience, used to describe system goals and forms, explain system activities, observe system states, and predict future system states [?]. In 1993, J. A. Cannon-Bowers et al. discovered that individual mental models interact at the team level and first proposed the concept of Shared Mental Models [?], defining them as knowledge structures jointly possessed by team members about task contexts that enable consistent understanding and expectations of team tasks, thereby coordinating behaviors to adapt to team tasks and other members' needs. Shared mental models, also called team mental models by some researchers, have attracted widespread attention from scholars in industrial and organizational psychology, social psychology, management, and cognitive psychology. M. T. Maynard and L. L. Gilson believe team-level shared mental models represent the overlap or convergence of members' mental representations about team and task aspects, representing agreements or common knowledge about internal and external environmental dimensions [?]. A. T. Denzau and D. C. North consider shared mental models as emerging from communication and knowledge sharing among individuals with similar mental models within teams, suggesting cognitive science can help understand shared mental models' characteristics and dynamic processes [?]. Most shared mental models research

emphasizes establishing overlap or convergence among individual mental models, noting that shared mental models enable members to share the same cognitive and understanding level about teams and tasks, thereby improving performance and overall efficiency.

J. A. Cannon-Bowers et al. studied the structural dimensions of shared mental models [**?**], summarizing them into four dimensions: equipment/technology, team task, team interaction, and team members. In team activities, people must first understand or master knowledge about equipment or technology needed to complete tasks; second, they need to analyze and understand the team task itself, including task characteristics, focus, processes, and strategies; then assess their own capabilities, clarify what subtasks they will undertake in completing team tasks, and what interactions may occur with other members; finally, they need to understand teammates' needs, preferences, capabilities, and relevant knowledge. All four dimensions of shared mental models require dynamic achievement through member interaction. J. E. Mathieu et al. further summarized them into two dimensions: task-related and team-related [**?**].

As psychological representations of team cognition, shared mental models have been widely applied in research on emergency room teams, construction safety teams, product development temporary teams, and other multi-domain teams, becoming key factors in explaining and predicting outcome variables such as team effectiveness, team performance, team creativity, and team innovation performance, involving direct effects, moderating effects, and mediating effects. A. K. Gardner et al., studying surgical teams, found that shared mental models facilitate team coordination and knowledge sharing behaviors, thereby improving team performance [**?**]; Y. Zhou and E. Wang, studying construction project planning teams, found that shared mental models positively moderate the relationship between team process variables and team performance [**?**]; Xu Ke et al., using survey data from 234 new product development teams, verified the partial mediating role of team task models and team interaction models in the relationship between swift trust and temporary team performance, with team interdependence negatively moderating the relationship between team interaction models and temporary team performance, and positively moderating the relationship between team task models and temporary team performance [**?**].

These studies demonstrate the importance of shared mental models for collaborative cooperation in different domains (e.g., medical, management), highlighting that team cognition plays an irreplaceable role in team collaborative effectiveness. However, in the collaborative information search domain, no research has yet analyzed and discussed shared mental models in learning teams. Learning teams primarily consist of university researchers, a group characterized by large information needs and frequent information behaviors, typically with experience in teamwork and obvious collaborative information behavior features. Many questions remain worthy of in-depth research, such as the content, formation mechanisms, and effects of learning team shared mental models.

In summary, collaborative information search, as a team task, emphasizes multi-

user collaboration, embodies the social characteristics of collaboration, and is essentially a knowledge sharing process based on team cognition. Shared mental models, as team cognitive representations, help team members coordinate behaviors to adapt to team tasks and other members' needs. Clearly, studying the construction process of shared mental models in learning teams during collaborative information search activities is crucial.

3. Research Design

3.1 Research Method

This study employs grounded theory methodology to explore the construction process of team shared mental models in collaborative information search activities. Grounded theory, first proposed by B. Glaser and A. L. Strauss in the 1960s [**?**], is a classic qualitative research method whose basic principle is avoiding "preconceived notions" and emphasizing theory development from raw data through a bottom-up analytical approach.

The main reasons for adopting grounded theory are twofold: First, there is limited research on shared mental models in collaborative search activities, with few available results for reference, making it suitable for exploratory research using qualitative methods. Second, information collaborative search activities under collaborative learning represent a complex dynamic interaction process, with strong uncertainty and exploratory nature in the team shared mental model construction process itself. Grounded theory' s bottom-up inductive analysis based entirely on raw data helps discover unexpected theories, making it suitable for exploring such dynamic and uncertain research questions. Therefore, this study conducts collaborative information search user experiments, using think-aloud protocols and group interviews to obtain team cognitive data, following grounded theory methodology through open coding, axial coding, and selective coding to analyze data layer by layer, discovering the shared mental model construction process and related cognitive activities of learning teams in information search activities.

3.2 Experimental Design

Collaborative information search differs from traditional individual information search. Its search tasks are no longer traditional question-answering tasks, nor simple navigation or fact-finding tasks, as these have clear or unique answers where users simply read data without further information utilization or processing, typically satisfied by individual search. Collaborative search tasks should be open-ended, more complex and multi-faceted, requiring simultaneous satisfaction of different users' information needs, with some tasks even being interdisciplinary, cross-domain, and cross-organizational.

Search tasks under collaborative learning activities focus more on exploratory tasks, which aim at learning and investigation, belong to open-ended tasks, and

exhibit characteristics of multi-facetedness, dynamism, evolution, and uncertainty, representing a process of knowledge discovery and knowledge construction. In the initial search stage, due to users' lack of information space and contextual knowledge about a topic, information needs are often vague, with task clues only obtainable through continuous searching, learning, and understanding. As exploration and learning deepen, users gradually become familiar with the topic, and their information needs may change, with corresponding changes likely occurring in cognitive elements such as perception, thinking, and knowledge structure, though the overall state gradually becomes clearer.

Based on these task characteristics, this study designed a "thematic presentation" task scenario, where each team could independently choose presentation topics. The task scenario and assignment format are shown in Table 1 .

This study uses think-aloud protocol analysis and cognitive interviews to capture and analyze team cognition. Generally, in individual cognition research, the think-aloud method requires participants to verbally express their thinking processes while performing tasks. In team research, N. J. Cooke et al. consider team communication as a form of think-aloud that can serve as a general method for assessing team cognition [**?**]. Since team members need to express how they think for teammates to understand their ideas and generate new ones, this study selects face-to-face communication as the communication channel for learning teams, encouraging participants to express their ideas as much as possible during communication. To further obtain cognitive data from participants and supplement think-aloud content, this study employs in-depth interviews after task completion, asking participants to recall and describe their thoughts at key points.

3.3 Data Collection

The experiment was officially conducted from May 10, 2018 to July 20, 2018. Following purposive random sampling principles, this study recruited 24 university students from a university in Nanjing, randomly forming 8 teams (each containing 3 members), designated as G1-G8. The gender ratio was basically balanced, with males accounting for 41.7% and females 58.3%. Grade levels covered undergraduate, master' s, and doctoral students across all age groups. In terms of colleges and majors, participants came from 5 colleges involving 13 majors, with liberal arts majors accounting for 75% and science majors 25%. Information search abilities were relatively strong, with 75% of participants having previous collaborative information search experience.

With participants' consent, this study collected user experiment data through video recording, screen recording, and audio recording, using think-aloud protocols and interviews to collect collaborative search team cognitive data, and screen/video recording to collect team member behavioral data, obtaining 8 think-aloud audio files, 8 interview audio files, and 24 screen recording video files. After the experiment, all participants' think-aloud and interview record-

ings were transcribed into text, yielding 8 groups of think-aloud text data and interview text data as raw materials for grounded theory methodology.

Sample data collection details are shown in Table 2 .

4. Data Analysis and Discussion

4.1 Grounded Coding Analysis

The coding data totaled 40,000 characters. Following grounded theory methodology guidance, this study conducted three-level coding operations manually: open coding, axial coding, and selective coding. This study used think-aloud and interview records from 6 teams for detailed coding analysis, with records from the other 2 teams used for theoretical saturation testing.

Open coding refers to the analysis process of extracting and summarizing concepts and their connotations, attributes, and dimensions from raw data. Concepts abstractly represent important objects, events, behaviors, or activities discovered in raw data. To avoid subjective influences, researchers did not preset any theoretical hypotheses, coded as freely as possible to fit raw data, and formed 16 categories (A1-A16) on this basis.

Axial coding builds upon open coding by discovering and establishing various relationships among concepts and between concepts and categories, conducting continuous comparison and analysis to excavate connections among categories and link independent categories to abstract higher-level main categories. Axial coding and open coding are not completely independent, as relationships among concepts sometimes emerge during open coding. This study conducted axial coding at two levels: (1) based on conceptual hierarchy, and (2) based on time sequence. Accordingly, the 16 categories were further summarized into 7 main categories: individual perception, task planning, individual information search, task structure construction, collaborative information search, information sharing, and information integration, as shown in Table 3 .

Selective coding is the final step in grounded theory—theoretical construction. Based on relational coding, it further excavates core categories from main categories, systematically analyzing relationships among core categories, main categories, and other categories, describing behavioral phenomena and contextual conditions in "storyline" form, presenting research findings theoretically, and developing theoretical frameworks.

Combining video/screen recording behavioral data (considering sequence), this study systematically and deeply analyzed the seven main categories and their subcategories formed during the axial coding stage, constructing the team shared mental model construction process in collaborative learning information search activities, as shown in Figure 1 [Figure 1: see original paper]. The team shared mental model construction process in collaborative learning information search activities can be divided into four stages: individual perception

and exploration, team task analysis, team information collection, and team information integration.

The individual perception and exploration stage occurs when learning teams first encounter tasks. At this point, team members prioritize independent thinking and perception, identifying information needs and task perception based on prior knowledge and previous experience with task topics, while team shared mental models have not yet formed. Based on individual perception results, members initiate initial discussions to enter the team task analysis stage. First, team task planning is conducted, with the primary task ensuring every member understands task objectives and the team' s current knowledge level, realizing that current team knowledge cannot solve target problems, making new knowledge acquisition urgent. To improve team work efficiency, teams conduct task process planning and search strategy planning. The team task planning stage is relatively short, lasting about 30 seconds to 2 minutes. During this period, team shared mental models begin to form.

Subsequently, teams return to the individual exploration stage, where each member conducts independent exploratory information searches to preliminarily understand task topic-related knowledge, without mutual communication during this period. The individual exploration stage lasts longer, but time spent varies significantly among teams, ranging from 5-7 minutes (e.g., G2, G5, G6, G7, G8) to 17-25 minutes (e.g., G1, G3, G4). In teams with relatively shorter individual exploration durations, once members discover information helpful for solving target problems, they share it within the team and initiate discussions on task topic structure construction. Basic information sharing serves as a trigger for teams to re-enter the task analysis stage. If a member' s proposed task topic structure based on searched information cannot gain other members' recognition, the team returns to the exploration stage for individual information searches, continuing to share other basic information discovered until a team-agreed task structure is preliminarily established (see cognitive loop in Figure 1). In teams with relatively longer individual exploration durations, members independently collect large amounts of task topic-related information, and once they believe they have collected sufficient information, they initiate team discussions to jointly establish task topic structure. During task structure construction, members continuously share and compare discovered basic information until a team-agreed task structure is preliminarily established (see cognitive loop in Figure 1). At this point, team shared mental models are further developed.

Then, teams officially enter the information collection stage, launching collaborative information searches. Based on the preliminarily established task structure from the previous stage, teams conduct task division, quickly clarifying member responsibilities. During information searches, members share task intersection information; during the search process, members also share serendipitously discovered information; after information searches, members share their search results. In information search activities, members perceive teammates' search

scope, information source selection, and search progress through observation and communication, providing references for personal information search adjustments. During information search processes, members learn, understand, judge, and absorb searched information. As knowledge continuously accumulates, teams adjust, expand, and refine original task structures, searching for corresponding information based on updated task structures (see cognitive loop in Figure 1). Finally, in the team information integration stage, teams assign a member to integrate team search results, forming final documentation.

4.2 Shared Mental Model Construction Process

4.2.1 Individual Perception and Exploration Individual perception and exploration includes two phases: individual perception and individual exploration, belonging to individual cognitive activities. In this stage, team shared mental models have not yet formed.

Individual perception refers to the psychological cognitive activities conducted by learning team members when first receiving presentation tasks, including information need identification and team task perception. Facing specific tasks, members self-assess their understanding of selected topics based on prior knowledge, preliminarily perceive task difficulty, and analyze topic focus. After realizing knowledge gaps, members' initial information needs emerge at the cognitive level. To bridge the "gap" between prior knowledge and problem-solving needs, members contemplate information search strategies, hoping to acquire new knowledge through information searches. Additionally, members consider team work strategies based on previous similar task experiences, thinking about how to complete tasks from a team perspective.

Facing unfamiliar topics, all teams adopt basically consistent behavioral strategies, with each member conducting independent exploratory information searches to preliminarily understand task topic-related knowledge, without mutual communication during this period. Team members adopt basically consistent initial search strategies, typically using task topics (e.g., "Differences and similarities between classic and new Hollywood") directly as search terms or extracting key concepts from topics (e.g., "classic Hollywood") as search terms. This phenomenon is particularly obvious in information search tasks under collaborative learning activities, lasting relatively longer.

4.2.2 Team Task Analysis Team task analysis refers to learning team members conducting mental interaction through communication to establish shared understanding about presentation tasks, including task objectives, task structure, and task strategies. In this stage, team shared mental models begin to form. The team task analysis stage under collaborative learning activities lasts relatively long, representing a core cognitive stage consisting of task planning and task structure construction.

Task planning refers to preliminary planning conducted by teams around search

tasks to clarify task direction and improve work efficiency. Learning teams first clarify task objectives, mainly including four aspects: (1) task topic, i.e., the presentation topic in the task scenario; (2) goal positioning, i.e., presentation positioning in the task scenario; (3) task completion duration, i.e., estimated time to complete the task; (4) task result presentation format, i.e., search result display and submission format. Subsequently, learning teams conduct team knowledge perception, i.e., understanding each member' s current knowledge level about selected topics through communication. Based on team knowledge perception results, teams conduct task strategy planning, mainly including two aspects: (1) task process planning, i.e., preliminarily clarifying the behavioral activity sequence for task completion, telling team members what to do currently; (2) search strategy planning, i.e., analyzing topic focus, indicating search direction, telling team members what can be searched.

Task planning stage cognitive activities occur at the team level, including task goal cognition, team knowledge perception, and task strategy planning. During this stage, team leaders begin to emerge (possibly), typically being those who first initiate team communication. Team members basically follow leaders' suggestions, quickly reaching consensus, with team shared mental models beginning to form and achieving consistency in task objectives, task strategies, and member knowledge.

Task structure construction is not accomplished overnight but is a gradual improvement process. First, teams internally share basic information that helps establish common topic understanding and can provide 启发性或参考性作用. Through self-reading, understanding, and absorbing this information, members reach consensus on topic foundational knowledge, such as key concept meanings like "classic and new Hollywood," "Arab Spring," "social networks," and "blockchain." Second, based on analysis and understanding of these basic information' s writing logic or argumentation angles, individual members propose basic ideas or concepts, which other team members can choose to follow, supplement, improve, or offer alternative opinions on, refining and expanding topic structure aspects, ultimately reaching a team-approved topic structure framework. During this process, team members may propose some creative ideas to expand and refine topic structure, which can originate from rational logical thinking analysis or from concept association, inspiration, or intuition. Additionally, as later information searches deepen, team members gradually clarify task topics, continuously refining structure content. If original topic structures deviate from facts, teams will revise and adjust them.

Task structure construction belongs to team cognitive activities, with influencing factors including two aspects: subjective and objective factors, as shown in Figure 2 [Figure 2: see original paper]. Objective factors mainly consist of team-shared basic information whose writing logic or argumentation angles can serve as reference or inspiration for learning teams building task structures. Subjective factors mainly consist of team members' thinking forms, including association, inspiration, intuition, and rational logical analysis. In this stage, team leaders

gradually emerge, playing crucial roles in effectively assisting teams in task structure construction and gradually clarifying each member' s role positioning within the team. Regarding tasks, members achieve consensus on foundational knowledge and task structure elements.

4.2.3 Team Information Collection Team information collection refers to the process where team members acquire needed information through cooperation, including collaborative information search and information sharing activities. First, learning teams must clarify collaboration patterns, i.e., assign each member' s search tasks according to the preliminarily established task topic structure. Through observation, during collaborative information search processes, members have some communication and observation behaviors, mainly involving three aspects: search scope, information sources, and search progress. Among these, search progress receives the most attention and is most frequently discussed in team communication. In interviews, respondents explicitly stated, "I care about teammates' search progress; if others search faster than me, I feel search pressure" and "I worry about holding others back and affecting team progress." Second is search scope, with respondents explaining, "I' m concerned about duplicate work" and "I want to know what everyone has searched to see if anything is missing." Information sources receive relatively less attention, with members only seeking help from the team when encountering obstacles and unable to obtain applicable information, expecting to learn teammates' information search channels. Respondents described this as, "I originally wanted to find something from formal papers but couldn' t. I was looking for current status, but most content discussed future applications and technical aspects that didn' t seem relevant to me, so I asked them where they found materials and also looked at web pages."

Collaborative information search stage cognitive activities remain at the team level, mainly including collaboration strategy cognition and team search perception. As shown in Figure 3 [Figure 3: see original paper], team shared mental models are strengthened and grow in this stage. First, regarding search tasks, team consensus on task structure is further strengthened, forming consistent understanding of task progress. Second, regarding team interaction, teams achieve consensus on collaboration patterns and member division, with understanding of role positioning further strengthened.

Information sharing refers to team members sharing their respective search results. By information utility, shared information in the team information collection stage can be divided into three types: intersection information, serendipitous information, and results information. (1) Intersection information refers to information related to subtask overlapping parts, typically shared before or during collaborative information searches. (2) Serendipitous information refers to information accidentally discovered during searches that is relevant to teammates' search tasks, typically shared during collaborative information searches. (3) Results information refers to members' search results after division of labor,

typically shared after collaborative information searches.

4.2.4 Team Information Integration Team information integration refers to the process where teams summarize, categorize, and delete search result information to form final representations. Through observation, information integration is not necessarily a team activity. Among the eight teams, three teams (G1, G5, G8) had one member integrate information alone after completing information searches, while the other two members terminated tasks without participating in information integration activities. The other five teams (G2, G3, G4, G6, G7) had one member responsible for document information integration with real-time feedback on integration processes, while the other two members provided targeted integration suggestions. For teams treating information integration as a collective activity, team shared mental models regarding task structure knowledge were further strengthened during information integration processes.

4. Summary and Outlook

Based on collaborative information search user experiments and grounded theory methodology, this study gradually explored the team shared mental model construction process in collaborative learning information search activities, organizing and summarizing cognitive activities and cognitive results (shared mental model content elements) of each stage.

(1) Regarding shared mental model content, collaborative learning team shared mental models can be divided into two dimensions: taskwork model and teamwork model, consistent with Mathieu' s classification [**?**]. The taskwork model represents team consensus on task aspects, including task objectives, task strategies, task structure, task foundational knowledge, and task progress. The teamwork model represents team consensus on team interaction and members, including collaboration patterns, member division, role positioning, and member knowledge.

(2) Regarding shared mental model construction process: In the individual perception and exploration stage, learning team members conduct preliminary perception and judgment of personal information needs and team tasks based on past knowledge and experience, and perform individual information exploration. In the team task analysis stage, learning team members conduct mental interaction through communication to establish shared understanding of search tasks. This stage involves task planning and task structure construction, with cognitive loops existing in task structure construction that require continuous return to individual exploration until team-agreed task structure is preliminarily established. In the team information collection stage, learning team members conduct collaborative information searches and information sharing, with possible cognitive loops returning to task structure construction to expand, adjust, and refine original task structures. In the team information integration stage,

exploratory task learning teams summarize, categorize, and delete search result information to form final representations.

Due to objective constraints, this experiment' s sample mainly consisted of university students, with insufficient sample variety and potentially significant limitations in representativeness, which can be expanded in future research. Additionally, the grounded theory methodology used in this study is based on empirical data induction, making the analysis process inevitably somewhat subjective.

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Author Contributions

Yan Duanwu: Proposed research topic, research framework, and revised final manuscript.
Zhang Xinyue: Data collection and manuscript writing.
Tang Jiali: Questionnaire and interview design and data analysis.
Su Qiong: Data organization and verification.

Note: Figure translations are in progress. See original paper for figures.