Research on Learning Outcomes of Collaborative Search Teams: Based on Task Type, Group Size, and Communication Quality Postprint

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Abstract

[Purpose/Significance] In comparison to independent search, collaborative search better facilitates the resolution of complex information needs. Research on collaborative search team learning effects, which remains unclear in the academic community, contributes to elucidating the antecedents and underlying mechanisms of such effects, and offers implications for enhancing team information search capabilities and cooperative learning abilities. [Method/Process] Based on cooperative learning theory, an information search experimental method was employed to examine the differential effects of group size, intra-group communication quality, and task type on collaborative search team learning effects. [Results/Conclusions] In decision-making task scenarios, significant differences exist in collaborative search team learning effects among 2-person, 4-person, and 6-person groups, with the 4-person group achieving the optimal team learning effect; intra-group communication quality exerts a significant influence on collaborative search team learning effects; in decision-making task scenarios, group size and team communication quality interact to influence team learning effects.

Full Text

Learning Effect of Collaborative Search Teams: From the Perspective of Task Type, Group Size, and Communication Quality

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Abstract: [Purpose/Significance] Compared with individual search, collaborative search is more effective in addressing complex information needs. Research

on the learning effects of collaborative search teams, an issue that remains unclear in academia, helps to identify the antecedents and mechanisms of team learning effects and provides insights for improving team information search capabilities and cooperative learning abilities. [Method/Process] Based on cooperative learning theory, this study employs information search experiments to examine differences in collaborative search team learning effects across various group sizes, communication quality levels, and task types. [Result/Conclusion] In decision-making task scenarios, the learning effects of 2-person, 4-person, and 6-person collaborative search teams differ significantly, with 4-person groups achieving the best learning outcomes. Intragroup communication quality significantly influences collaborative search team learning effects. In decision-making task scenarios, group size and team communication quality interactively affect team learning effects.

Keywords: collaborative search; learning effect; task type; group size; communication quality; search as learning

1 Introduction

In today's era that emphasizes teamwork, the prevalence and frequency of collaborative search (CS) are increasing. Particularly among younger teams, remote members can conveniently use information and communication technologies to conduct synchronous collaborative searches for information and acquire knowledge on specific topics, efficiently handling exploratory and open-ended complex information needs. Learning during the search process may be an explicit goal or may occur indirectly as part of work tasks, encompassing knowledge reconstruction, adjustment, and assimilation, and is influenced by various factors such as learners' cognitive styles and self-efficacy.

Understanding and promoting users' knowledge acquisition capabilities during the search process holds significant practical importance. Considering that individual knowledge consists of a complex network of interconnected concepts, and learning aims to continuously add new content to this network, concept maps can effectively evaluate users' knowledge structures. Therefore, this study, grounded in cooperative learning theory and the "search as learning" (SAL) perspective, distinguishes collaborative search group sizes and communication quality at a granular level. It introduces concept maps as a knowledge representation tool to quantify changes in learners' knowledge levels before and after collaborative search, and investigates how collaborative search group size and intragroup communication quality affect team cooperative learning effects in both information collection and decision-making task scenarios using information search experiments.

In SAL contexts, the division of labor and collaboration among information search users can optimize team members' learning experiences and thereby improve team learning effects.

2 Literature Review

2.1 Collaborative Search

Collaborative search refers to a series of activities conducted by a group of people or a team to identify and resolve shared information needs, typically characterized by dimensions including intention (explicit vs. implicit), depth of intervention (user interface vs. search algorithm), concurrency (asynchronous vs. synchronous), and location (co-located vs. remote). Since the 1990s, user-centered collaborative search behaviors have attracted attention. Scholars have explored task types, team awareness, cognitive styles, search experience, member relationships, and social capital across health, leisure, and work contexts using experimental, observational, and interview methods. Data collection has involved pre- and post-search questionnaires, search logs, and chat records, with descriptive statistics, statistical tests, and content analysis employed to examine the mapping between collaborative search processes and the Information Search Process (ISP) model, the influence of collaborative ability and task type on contextual, task, and collaborative cognition, and patterns of user emotional state changes. Representative studies are shown in .

** Representative Literature on Collaborative Search**

Following M. R. Morris's 2008 survey (where 2-person, 3-person, or 4-person collaborations accounted for 80.7% and 19.3% respectively during collaborative search), most empirical collaborative search studies have treated group size as a constant, with 2-3 person groups dominating the literature. Research on other group sizes (4, 5, 6, etc.) is rare. Against the SAL research backdrop, no studies have yet examined collaborative search team learning effects. Notably, Morris's 2013 follow-up survey found that larger collaborative groups also emerge during collaborative search, with 5-person, 6-person, and 7+ person groups representing 9.2%, 4.6%, and 8.3% respectively, totaling over 20%. Moreover, modern information technology has advanced dramatically, permeating all social domains and profoundly changing work and lifestyle patterns, making remote work, teaching, healthcare, and online shopping commonplace. Thus, 2-3 person teams may no longer represent the mainstream scale for team learning or the most effective size for collaborative search, necessitating that group size be expanded from a constant to a research variable to deeply understand its mechanisms.

2.2 Cooperative Learning

Cooperative learning is a strategic system designed to promote mutual assistance and collaboration among learners in heterogeneous groups to achieve common learning goals, with group overall performance as the reward basis. Learners demonstrate higher academic achievement and more positive peer relationships in cooperative learning, where collective efficacy produces a halo effect on self-efficacy. However, cooperative learning requires planned organization and integration of team size and composition structure, not merely loose member collaboration around task objectives.

To clarify how collaborative search promotes learning and understand learners' knowledge acquisition mechanisms, scholars have investigated how collaborators combine and how team member characteristics affect learning. Regarding member quantity, G. Hatano and K. Inagaki suggested that cooperative learning groups should comprise 2-6 members, with 3-4 being particularly suitable. Regarding group composition, the question of whether learners should be homogeneously or heterogeneously grouped ("who with whom") remains unresolved. For instance, M. Zamani quantified English writing performance using a 100-point scale (content 30, organization 20, vocabulary 20, language 25, method 5) and found that learners improved their performance whether collaborating with stronger or weaker peers, with low-ability students benefiting more from heterogeneous than homogeneous grouping, and without high-ability students' progress coming at their expense. Conversely, P. K. Murphy et al. found that heterogeneous groups benefited high-level comprehension more, while low-ability learners were more active in homogeneous groups but more reserved in heterogeneous ones. Overall, education literature focuses on how offline cooperative group composition affects learning over extended periods (weeks to semesters), with scarce research on short-term (minutes to hours) online cooperative learning performance, and none in collaborative search contexts. Thus, collaborative search team learning effects remain an important research topic worth exploring.

2.3 Concept Maps

Based on Ausubel's learning theory, concept maps are hierarchical networks composed of concept nodes and directed links (more general concepts appear at the top, more specific ones at the bottom; directed links are labeled with connecting words), which can externalize and visualize learners' knowledge structures to effectively promote learning. As an important knowledge assessment tool, concept maps have been widely applied in education and business management. In information search research, scholars have also employed concept maps, with representative achievements shown in .

** Representative Literature on Concept Maps**

Researchers have used concept maps as learners' knowledge representation tools, employing search experiments and regression analysis on web search platforms to assess knowledge and understanding levels through pre- and post-search concept map changes, and to examine how environmental factors (search topics, scenarios) and personal factors (emotional load, coping skills, interest level) affect search processes and knowledge structures. Some scholars have studied how concept maps optimize search engine functions, such as M. R. Carvalho et al. developing SAgent and WAgent algorithms for search result filtering and ranking using concept maps' propositional and hierarchical properties. S. O. Tergan et al. found that concept maps can serve as powerful interfaces for enhancing information search when semantic cues of relevant resources are properly organized. Inspired by these studies, this research uses concept maps to evaluate collaborative search team learning effects and explores how group size and communication

quality affect team learning across different task scenarios.

3 Research Hypotheses

3.1 Effect of Group Size on Team Learning Effect

Research in education and management consistently shows that group size is an important factor affecting team learning effects. For example, Y. Lou et al.'s meta-analysis found that group size significantly correlates with effect size, with 3-4 member groups showing significantly higher average effect sizes than 5-7 member groups. In information retrieval research, H. Joho et al. observed that increasing group size affected retrieval effectiveness, simulating collaborative groups (1-5 members) and finding that group size increases led to increased retrieval effectiveness (measured by recall), with approximately 50% improvement when a second member joined and 5-12% improvement with a fifth member, showing diminishing returns. F. Moraes et al. found that group recall rate increases exhibited marginal effects, increasing with group size without observed diminishing returns, and that smaller groups' recall rates did not catch up to larger groups over time. Therefore, this study treats collaborative search group size as an independent variable and proposes:

H1: Group size significantly affects collaborative search team learning effects.

3.2 Effect of Communication Quality on Team Learning Effect

Interpersonal communication theory is an important theoretical foundation for cooperative learning. Team members use digital means to smoothly and freely express ideas, coordinate distributed division of labor, fully share useful knowledge, and effectively advance team learning and improve performance. Communication effectiveness generally comprises dimensions such as discussion quality, communication appropriateness, richness, openness, and accuracy. H. L. Krenz and M. J. Burtscheer emphasized that team communication is a key factor affecting team performance, with attention and suggestions for work tasks being important components. Wu Zhiming and Wu Xin found that communication quality among team members affects the establishment of shared mental models, thereby influencing team learning effects. R. E. DeVries et al. found that agreeable communication style positively correlates with knowledge sharing willingness, while extraverted communication style positively correlates with both desire and willingness to share knowledge. Li Shuxiang et al. found that team communication moderates the relationship between team cognitive diversity and creativity. As Piaget's cognitive development theory suggests, interaction with the environment and others is key to learning and cognitive development. This study posits that close, open communication among team members during collaborative search improves overall team performance and proposes:

H2: Communication quality significantly affects collaborative search team learning effects.

3.3 Interactive Effect of Group Size and Communication Quality on Team Learning Effect

Efficient teams with clear goals, empowerment, and effective communication generate cooperative process gains (higher self-efficacy, self-actualization, responsibility, and achievement), leading to outstanding overall performance. However, due to team tasks, composition, and management issues, teams may experience communication barriers, lack of trust, and free-riding, resulting in process losses (groupthink, conformity pressure, creativity loss) and declining performance. P. B. Lowry et al. examined group communication quality under different group sizes and social presence levels, finding that 3-person groups communicated more appropriately, openly, and accurately than 6-person groups. Thus, different collaborative group sizes may relate to member communication quality. This study proposes that group size and communication quality interactively affect collaborative search team learning effects:

H3: Group size and communication quality interactively affect collaborative search team learning effects.

4 Experimental Design

4.1 Participants

This study recruited 92 undergraduate e-commerce majors from a university in Shanxi (28 males, 64 females, aged 19-22). All participants were proficient in using search engines but had no concept map drawing experience. Considering sample size and group size representativeness, group sizes were set at 2, 4, and 6 members, forming 8 dyads, 7 four-person groups, and 8 six-person groups through free combination. To examine remote explicit collaborative search learning effects, participants were required to use personal computers simultaneously and communicate only via pre-established WeChat groups, avoiding face-to-face interaction. This design externalizes the search learning process for later communication quality and learning effect analysis, increasing ecological validity.

4.2 Experimental Tasks

Task theme and type determine the search process needed to meet information needs, largely representing task complexity. D. J. Campbell defined complex tasks as those requiring actors to make decisions, judgments, or solve problems under varying information and uncertainty levels. This study adopts E. G. Toms et al.'s classification, dividing search tasks into information collection and decision-making types (see). Compared with information collection tasks, decision-making tasks are more complex, have more ambiguous information needs, more difficult query formulation, and require more resources.

** Experimental Task Descriptions**

Information Collection Task: Imagine your Modern Logistics Management

course instructor assigns your group a learning task: collect as many green logistics cases as possible and share their successful practices. Your group decides to spend fifteen minutes searching online resources to complete the assignment.

Decision-Making Task: Imagine your Modern Logistics Management course instructor assigns your group a learning task: determine which company—Cainiao Logistics, SF Express, or JD Logistics—is the logistics leader and why. Your group decides to spend fifteen minutes searching online resources to complete the assignment.

4.3 Experimental Procedure

Before the experiment, participants installed EV screen recording software, provided personal information via questionnaire, and received centralized instruction on concept map drawing methods and procedures. They were informed that groups would complete two search tasks sequentially. The process comprised three steps:

Step 1: Pre-search concept map drawing. Based on task descriptions (see [Figure 1: see original paper] and [Figure 2: see original paper]), groups drew concept maps on assigned topics within 10 minutes. Members could discuss via WeChat (voice or text) but could not consult other materials.

Step 2: Search task execution. Groups performed 15-minute search tasks, searching and browsing web content, saving and bookmarking relevant information. Only text communication via WeChat was permitted.

Step 3: Post-search concept map drawing. Groups drew concept maps again based on [Figure 1: see original paper] and [Figure 2: see original paper] within 10 minutes. Discussion via WeChat was allowed, but reviewing previous records or materials was prohibited. After tasks, participants completed a questionnaire on perceived task difficulty. A half-hour break between tasks minimized carryover effects.

5 Measurement and Evaluation Methods

5.1 Measuring Team Learning Effect

Concept maps graphically represent relationships among learned knowledge, with hierarchical structures reflecting knowledge importance and breadth. Higher-level nodes (fewer directed links from the task node) cover broader knowledge with stronger inclusiveness, while lower-level nodes (more directed links) are more specific but narrower in scope. Using different node levels can effectively identify knowledge coverage and quantity, distinguishing between knowledge breadth and specific points to measure learning effects.

This study adopts a "weighted counting" method that considers both knowledge points and breadth, overcoming simple point-counting strategies. Specifically, comparing pre- and post-search concept maps: adding a node with path length

1 (one directed link from the task node) scores 5 points; path length 2 scores 4 points; path length 3+ scores 3 points; deleting a node scores 1 point. Additionally, decision-making tasks involve not just collection and memorization but comprehensive judgment of credibility, accuracy, reasonableness, and supporting evidence. This study distinguishes between high-scoring concept maps that analyze problems multi-dimensionally and those that focus on single dimensions with detailed sub-indicators, awarding an extra 10 points to the former and deducting points from groups without decision outcomes.

Measurement focuses on concept map nodes' relevance to the task question and hierarchical structure rationality (see sample in [Figure 3: see original paper]). Node counting involved: (1) two authors clarifying criteria, (2) independent data coding, and (3) consensus through discussion when discrepancies arose.

5.2 Measuring Team Communication Quality

Effective team communication is fundamental to high-performing teams, improving task efficiency and reducing process loss. This study uses the number of effective WeChat dialogue entries as an objective communication quality metric, with effectiveness defined by contribution to task completion. This approach overcomes traditional scale-based measurement limitations. Effective communication includes: coordinating task division, refining knowledge points, expanding task perspectives, allocating time, and generating new directions through core issue discussion (see examples in). Two authors coded the data, reaching consensus through discussion. Communication quality was categorized as low (0-5 entries), medium (6-8 entries), or high (9+ entries).

** Communication Quality Evaluation Examples**

6 Results and Discussion

SPSS 22.0 was used to analyze group size and communication quality effects under both task scenarios. Wilcoxon signed-rank tests on non-normally distributed task difficulty data confirmed that information collection tasks were significantly easier than decision-making tasks ($P < 0.001$), supporting assumptions. Residuals were normally distributed, and variance homogeneity tests confirmed stable ANOVA results (see).

** Variance Homogeneity Test Summary**

6.1 Testing Group Size Effects on Team Learning

H1 examined learning effect differences across group sizes. One-way ANOVA showed no significant differences among 2-, 4-, and 6-person groups in information collection tasks ($F = 3.071$, $P > 0.05$) (see). However, in decision-making tasks, significant differences emerged ($F = 3.853$, $P < 0.05$) (see).

** Group Size Learning Effect Differences in Information Collection Tasks**

** Group Size Learning Effect Differences in Decision-Making Tasks**

Post-hoc S-N-K tests revealed that 4-person groups performed best (Mean = 86.43/95.71), followed by 6-person groups (Mean = 56.13/66.00), while 2-person groups performed worst (Mean = 30.50/43.38) (see [Figure 4: see original paper]). In information collection tasks, all three group sizes belonged to one subset, but in decision-making tasks, they fell into two subsets, with 4-person groups showing optimal learning effects (see).

** Inter-group Differences Across Task Types**

Thus, H1 is partially supported. Group size critically influences member engagement and performance, affecting effort, perceived ability, tension, frustration, and motivation. However, larger groups are not always better. Members in larger collaborative search groups may perceive their contributions as diffused, reducing motivation when individual impact seems negligible—especially as group size increases. Additionally, effort levels vary across group sizes, with member motivation potentially declining in larger groups and free-riding becoming harder to detect.

6.2 Testing Communication Quality Effects on Team Learning

H2 examined learning effect differences across communication quality levels. Descriptive statistics are shown in and . One-way ANOVA revealed significant differences among high, medium, and low communication quality in both task scenarios ($F = 9.543$, $P < 0.05$; $F = 3.981$, $P < 0.05$), indicating significant communication quality effects (see and).

** Descriptive Statistics: Communication Quality in Information Collection Tasks**

** Descriptive Statistics: Communication Quality in Decision-Making Tasks**

** Communication Quality Differences in Information Collection Tasks**

** Communication Quality Differences in Decision-Making Tasks**

S-N-K tests showed that high-quality communication (Mean = 115.20/99.17) differed significantly from medium (Mean = 54.00/66.56) and low-quality communication (Mean = 31.27/43.88) in both scenarios (see and [Figure 5: see original paper]). Thus, H2 is supported.

** Inter-level Communication Quality Differences Across Task Types**

High-quality communication correlates with low conflict, high trust, and strong cohesion, enabling members to freely express viewpoints, share task information, and understand teammates' perspectives. Such interaction fosters higher-level trust and cooperation, potentially yielding high-quality cooperative learning outcomes through connection, reflection, and inquiry.

6.3 Interactive Effects of Group Size and Communication Quality on Team Learning

H3 examined interactive effects. Two-way ANOVA showed no significant interaction between group size and communication quality in information collection tasks ($F = 1.223$, $P > 0.05$). However, in decision-making tasks, significant interaction emerged ($F = 9.568$, $P < 0.001$) (see).

** Between-Subjects Effects in Decision-Making Task Scenario**

As shown in [Figure 6: see original paper], mean lines for communication quality levels show clear crossover between 2- and 4-person groups and divergent slopes between 4- and 6-person groups, indicating significant interaction. Thus, H3 is partially supported.

The divergent results likely stem from task difficulty. For easier information collection tasks, communication quality sensitivity is low—simple coordination suffices. For difficult decision-making tasks, high communication quality sensitivity is required for high-quality completion. Additionally, team composition factors like member flexibility, familiarity, and homogeneity/heterogeneity in ability or experience may affect knowledge construction and learning effects. For instance, member familiarity enhances satisfaction and collaboration efficiency, while heterogeneity negatively impacts trust and interaction. Future research should incorporate these variables.

7 Conclusions and Future Directions

This study designed two quasi-experiments to test three hypotheses about group size and communication quality effects on collaborative search team learning. The measurement approach overcame limitations of simple knowledge-point counting and scale-based communication assessment. Findings reveal:

1. In decision-making tasks, 2-, 4-, and 6-person groups showed significant differences, with 4-person groups optimal. In information collection tasks, group size had no significant effect.
2. High communication quality significantly outperformed medium and low quality in both task scenarios.
3. In decision-making tasks, group size and communication quality interactively affected learning effects, but not in information collection tasks.

These findings enhance understanding of collaborative search team learning effects and their task-dependent variations, offering practical guidance for individual knowledge construction and team learning improvement. For knowledge construction, members should autonomously acquire task-related knowledge through search and internalize scattered knowledge points through barrier-free communication. For team learning enhancement, members should build emotional connections and collective efficacy through various interactions, scientifically determine group size based on task complexity, rationally match members by characteristics, adopt appropriate information strategies, and facilitate

smooth communication to maximize motivation and cooperative learning effects.

Limitations: 1. Sample size constraints limited group sizes to the most common configurations. Future research should use larger samples and more group sizes for natural search experiments. 2. This study did not fully consider moderating effects of team composition characteristics (member ability, experience, personality traits). Future research should examine how homogeneity/heterogeneity in these factors, along with collective efficacy, influences online collaborative search learning effects.

References

[References section preserved as in original]

Author Contributions

Sun Xiaoning: Revised the paper; Li Huafeng: Proposed research ideas, collected literature, wrote and revised the paper; Yuan Qinjian: Revised the paper; Sun Fengqiu: Collected and organized experimental data.

[Figure 1: see original paper] Task 1 Description Concept Map

[Figure 2: see original paper] Task 2 Description Concept Map

[Figure 3: see original paper] Sample Group Concept Map

[Figure 4: see original paper] Group Size Mean Plot

[Figure 5: see original paper] Communication Quality Mean Plot

[Figure 6: see original paper] Interaction Plot of Group Size and Communication Quality in Decision-Making Task Scenario

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