Research on Online Knowledge Collaboration Behavior: The Influence of Team Member Intimacy and Collaboration Tendency (Postprint)

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Abstract

[Purpose/Significance] To help scholars gain an in-depth understanding of how team member intimacy and collaboration tendency influence small-scale online knowledge collaboration behaviors, as well as the behavioral patterns of small-scale users in online knowledge collaboration. The research findings can be applied to domains such as online education and scientific research collaboration, providing references for improving online knowledge collaboration tools and platform functionalities.

[Method/Process] Through user experiments, five types of behaviors in small teams—task planning, information retrieval, information sharing, information utilization, and communication—were analyzed to investigate the impact of team members on these behaviors.

[Results/Conclusion] Intimacy exhibits a significant positive effect on strategy formulation, particularly collaborative strategy formulation behavior; groups with high intimacy but weak collaboration tendency are more inclined to develop time schedules. Groups with both high intimacy and strong collaboration tendency are more likely to share retrieval strategies, especially retrieval experiences. Under conditions of weak collaboration tendency, groups with high intimacy demonstrate higher frequencies of communication behaviors compared to those with low intimacy, and "dual-high" groups have all explored novel communication methods. Collaboration tendency significantly influences personal information retrieval behavior; under low intimacy conditions, groups with weak collaboration tendency engage in personal information retrieval more frequently. Under high intimacy conditions, groups with strong collaboration tendency share information and edit group outcomes more frequently.

Full Text

Preamble

Online Knowledge Collaboration Behaviors: The Influence of Team Member Intimacy and Collaboration Tendencies

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Abstract: [Purpose/Significance] This study aims to help scholars deeply understand how team member intimacy and collaboration tendencies influence small-scale online knowledge collaboration behaviors, as well as the behavioral patterns of small user groups in online knowledge collaboration. The research findings can be applied to fields such as online education and scientific research collaboration, providing references for improving online knowledge collaboration tools and platform functionalities. [Method/Process] Through user experiments, this paper analyzes five types of behaviors in small teams: task planning, information retrieval, information sharing, information use, and communication, exploring the impact of team members on these behaviors. [Results/Conclusions] Intimacy has a significant positive impact on strategy formulation, particularly collaborative strategy formulation. Groups with high intimacy but weak collaboration tendencies are more inclined to develop time plans. Groups with both high intimacy and strong collaboration tendencies are more likely to share retrieval strategies, especially retrieval experiences. Under conditions of weak collaboration tendencies, groups with high intimacy exhibit higher frequencies of communication behaviors than those with low intimacy, and "double-high" groups have explored new communication methods. Collaboration tendency significantly affects personal information retrieval behaviors; under low intimacy conditions, groups with weak collaboration tendencies engage in personal information retrieval more frequently. Under high intimacy conditions, groups with strong collaboration tendencies share information and edit group outcomes more frequently.

Keywords: collaborative information seeking; collaborative sensemaking; team composition; team intimacy; collaboration tendency
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Knowledge collaboration is a process through which knowledge is shared, transferred, reorganized, and activated among organizational members. On one hand, it enables individual members to acquire needed new knowledge; on the other hand, it allows members to engage in joint learning and knowledge sharing to create collective benefits that exceed the sum of individual effects, ultimately co-creating new knowledge [1]. Collaborative information behavior is an important component of knowledge collaboration, differing from personal information behavior in three main aspects: interaction with others, complexity of information needs, and the role of information technology [2]. A. Karunakaran, M.C. Reddy,

and P.R. Spence compared the two and established a collaborative information behavior model consisting of three stages: problem formulation, collaborative information seeking, and information use [3], while other scholars have deconstructed the collaborative information behavior framework into three dimensions constituted by different variables: knowledge, cognition, and society [4].

An important component of collaborative information behavior is collaborative information seeking (CIS) and collaborative sensemaking (CS). CIS has group-based, interactive, and complex characteristics; its interactive process is not merely search behavior but also includes problem definition, needs analysis, search strategies, and evaluation of search effectiveness [5]. Collaborative sensemaking is a process of jointly understanding problems or topics, utilizing knowledge frameworks to organize and integrate data to form explicit knowledge representations, and continuously adjusting knowledge frameworks or data [6]. Although domestic and international research on collaborative information behavior has established a certain foundation, few researchers have used experimental methods to deeply investigate the specific factors affecting online collaborative information behavior and their mechanisms, with less attention paid to the entire process of online knowledge collaboration.

Intimacy and collaboration style are important factors influencing knowledge collaboration. H. Kelley measured intimacy from three aspects: frequency, diversity, and intensity [7]. R.J. Sternberg categorized human thinking styles into 13 types, among which the introverted style is characterized by a preference for working alone, while the extroverted style prefers working with others or in groups [8]. Individuals with introverted styles have weaker collaboration tendencies, while those with extroverted styles have stronger collaboration tendencies. Overall, current research on the influence of team member intimacy and collaboration tendencies on small-scale online knowledge collaboration remains weak. This study uses R.J. Sternberg' s Thinking Style Inventory (TSI) to measure collaboration tendencies, reflecting users' relatively stable states, to explore the patterns and characteristics of small-scale online knowledge collaboration under the influence of team intimacy and collaboration tendencies.

Accordingly, this study proposes the following research questions:

RQ1: What influence do team member intimacy and collaboration tendencies have on small-scale online knowledge collaboration?

RQ2: What are the characteristics of online knowledge collaboration patterns among groups with different intimacy levels and collaboration tendencies?

This study employs a combination of qualitative and quantitative methods to explore these research questions. The theoretical significance lies in helping scholars understand the impact of intimacy and collaboration tendencies on small-scale online knowledge collaboration, particularly in understanding the complete process, behavior types, and behavioral pattern characteristics of groups with different intimacy and collaboration tendency compositions. The practical significance is to help online knowledge collaboration platforms, online knowledge

communities, and teaching stakeholders deeply understand how team composition—intimacy and collaboration tendencies—affects users' online knowledge collaboration behaviors, providing references for improving online knowledge collaboration systems, software, and tool platforms, and offering broader and more necessary support for users' knowledge sharing and collaboration.

2 Related Research Review

2.1 Knowledge Collaboration and Team Knowledge Sharing

S. Faraj et al. defined knowledge collaboration in a broad sense as the process of knowledge sharing, accumulation, transfer, transformation, and co-creation. Knowledge collaboration in online communities includes providing one' s own knowledge to others or adding, modifying, organizing, and integrating others' contributions [9]. The knowledge collaboration process is essentially one in which individual members within a collaborative organization share and cooperate based on their dispersed, unique personal knowledge to create needed new knowledge, representing a self-organizing evolution from low-level to high-level [1]. Thanks to the development of the Internet and various tools and online platforms, knowledge collaboration is ubiquitous in various online scenarios.

Team communication and knowledge sharing refer to the exchange of ideas and information among collaborators in group activities. Knowledge collaboration requires team communication and knowledge sharing, and the ability to effectively share information is considered one of the foundations of any group activity [10]. C. Foley et al. summarized the technical implementation of knowledge sharing in existing collaborative information systems—establishing shared workspaces and providing relevant feedback to collaborators, enabling team members using the system to benefit from the diversity of the entire team. However, from the perspective of users' sensemaking, a balance needs to be found between explicit and implicit system intervention [11]. Currently, there are multiple online knowledge collaboration tools such as KnowledgeCommunity [12], Coagmento [13], Moodle [14], and "Yiqixie" (Write Together), in addition to Wiki [15], which is also a popular online collaboration tool for offline teams.

2.2 Collaborative Information Seeking and Collaboration Strategies

An important component of online knowledge collaboration is collaborative information seeking. Collaborative information seeking is a behavioral system that includes information needs generation, retrieval task organization, and subsequent utilization of retrieval results [16], requiring two or more users [17]. It includes four stages: collaborative planning, information retrieval, information sharing, and collaborative information decision-making, during which situations such as information loss, incomplete retrieval, information unavailability, and preference conflicts may occur [18]. Many domestic and international scholars have used small-scale experimental methods to study influencing factors of user collaborative information behavior such as context awareness, emotional

state, community type, task difficulty, task order, collaborative ability, and time. Some scholars have found that collaborative ability and user communication frequency are positively correlated with positive emotions, while task difficulty is positively correlated with negative emotions [13]; others have found that time constraints and search order both affect participants' confidence and experience in completing tasks, with comprehension tasks being more difficult than transactional tasks but yielding less new knowledge according to participant feedback [19-20].

He Huifen et al., through case experiential research on collaborative search platforms, believe they improve retrieval ease, real-time performance, and efficiency [21]. In current research on collaborative information retrieval systems, C. Foley et al. believe future systems should be improved by balancing awareness cues and system leadership [11], while other scholars suggest that future system research could focus on virtual communities, spatiotemporal combinations, and realistic collaborative environments [22]. Teams exhibit different collaboration strategies in collaborative information seeking. Some scholars believe there are two types of collaboration strategies: divide-and-conquer strategy, which has obvious planning and coordination with task division throughout the process; and exhaustive strategy, which has no obvious coordination during the search process and only merges at the end [23]. M. Sharples et al. divided the divide-and-conquer strategy into three types: 1) parallel strategy, dividing the work into subtasks with all collaborators working simultaneously; 2) sequential strategy, dividing the task into several stages where the output of one stage is passed to the next collaborator; and 3) interactive strategy, where members continuously adjust with each other throughout the process [24]. Some scholars believe that collaborative information queries can also be divided into individual-led and stage-discussion types, and that prioritized information, contextual information, and activity-related awareness all have positive effects on collaborative information queries [6].

2.3 Collaborative Sensemaking

Another important component of online knowledge collaboration is collaborative sensemaking. Collaborative sensemaking refers to the process where searchers with different knowledge backgrounds attempt to establish common understanding and form final expressions [6]. It has three important characteristics: prioritization of relevant information, construction trajectory, and activity awareness. The three main reasons facilitating CS are information ambiguity, role-based information distribution, and lack of expertise. Based on the above research, researchers created CoSense (a sensemaking system supporting collaborative search tasks), which enables team members to understand key strategies and roles in collaborative search tasks and uses different features to support sensemaking in asynchronous and synchronous collaboration [25-26].

Online knowledge communities are typical scenarios for collaborative sensemaking. C.M. Chiu et al. believe that the biggest challenge in cultivating virtual

communities is knowledge contribution, that is, community members'willingness to share knowledge. Factors such as social relationships, trust, reciprocity, common language, common vision, and outcome expectations all have positive or negative impacts on the quantity and quality of people's knowledge collaboration in virtual communities [27]. J. Shelby et al., by understanding the information retrieval and sensemaking strategies used by participants in two contextual collaborative search experiences (project and acquaintance contexts), believe that individual sensemaking needs to be supported before sharing results, summarizing, and contextualizing results [28].

3 Research Methods

3.1 Experimental Design

Common methods for studying collaborative behaviors include "self-report"methods such as questionnaires and interviews, behavioral log analysis recorded under natural conditions, and user experiments. Methods like interviews and questionnaires largely depend on users' subjective judgments and memories, which cannot directly and detailedly observe the collaboration process, potentially making research results somewhat subjective. While behavioral logs recorded under natural conditions are relatively ideal data sources, commercial and systematic logs for collaboration are difficult to obtain for research purposes. Therefore, collecting user behavioral logs through experiments allows for more detailed and objective observation and recording of group online collaboration processes while also facilitating variable control through experimental grouping.

3.1.1 Experimental Task This study designed two types of tasks: learning-oriented (primarily for exploring and querying information) and problem-solving-oriented (primarily for performing specific practical tasks). Taking the learning-oriented task "Internet Hospitals" as an example, the detailed description and requirements are as follows:

(1) Description: Internet hospitals represent a new application of the Internet in the medical industry, including health education, medical information queries, online disease consultation, and other forms of health medical services. Internet hospitals represent a new development direction for the medical industry, helping to resolve the contradiction between unbalanced medical resources and increasing health demands in China, and are a medical development model actively guided and supported by the Ministry of Health.

(2) Requirements: Groups need to prepare a 10-15 minute presentation on the theme of Internet hospitals. Please collaborate and complete the presentation outline and content through the collaboration platform within 45 minutes. Find the establishment time, initiator, and important timeline nodes and events in the development process of Wuzhen Internet Hospital. Clarify the differences between the main service methods of

Wuzhen Internet Hospital currently (such as registration, consultation, report queries, prescription issuance, payment, drug delivery, personal health management, etc.) and traditional hospitals.

3.1.2 Experimental Grouping This study recruited 24 participants, divided into 8 groups of 3 members each, with collaboration tasks conducted within each group. In the recruitment questionnaire, the Thinking Style Inventory (TSI) [29] was used to measure participants' collaboration tendencies, and groups were formed based on high or low collaboration tendency scores. Within groups, intimacy among members was measured using a pre-test questionnaire adapted from the Relationship Closeness Inventory (RCI) [30]. The RCI is a questionnaire measuring the degree of closeness in relationships, with the concept derived from H. Kelley' s proposal that "intimacy comes from high mutual dependence between two people in various activities," which can be mainly divided into three properties: frequency, diversity, and strength. Intimacy was measured pairwise among group members, yielding three intimacy scores, with the group' s intimacy score being the average of the three, used to divide groups into high or low intimacy (higher scores indicate higher group intimacy, 0 indicates complete strangers) (see Table 1). To ensure coverage of high and low intimacy ranges, this experiment encouraged roommates, couples, and friends to register in groups of three, with intimate participants forming high-intimacy groups, which were then divided into strong or weak collaboration tendency groups based on collaboration tendency scores. Individual registrants were directly assigned to groups by staff based on collaboration tendency scores, but their group intimacy was relatively low. All 24 recruited participants were students from the Department of Information Management at Peking University, including 6 males and 18 females, comprising 16 undergraduates, 6 master' s students, and 2 doctoral students.

Table 1 Experimental Grouping Results

Group	Collaboration Tendency	Intimacy Scores (Low, Low, High)	Intimacy Mean
A	High, High, High	Low, Low, Medium	69.33
B	High, High, High	Low, Low, High	37.33
C	Low, Low, High	High, High, High	79.83
D	High, High, High	Low, High, Low	-
E	High, High, High	Low, High, Low	-
F	High, High, High	Low, High, Low	-
G	High, High, High	Low, High, Low	-
H	High, High, High	Low, High, Low	-

3.1.3 Experimental Process All 8 groups completed two tasks. To exclude the influence of task order on experimental results, the task sequence differed for the two groups of each type. Before tasks began, researchers introduced

experimental requirements to participants and familiarized them with the web version of Youdao Cloud operation, after which collaboration was completed in this software. After the experiment officially began, participants had 45 minutes to read and complete tasks. After task completion, participants were interviewed to understand group collaboration strategies.

3.2 Data Collection This study used the user research and usability testing software Morae [31] to record participant behaviors, enabling video marking, analysis, and rapid chart generation. The experiment recorded 24 participants completing two tasks each, yielding 48 video datasets. The web version of Youdao Cloud Collaboration [32] was used as the collaboration tool, allowing users to independently or jointly edit documents, communicate in real-time, and view each other' s editing progress. The experiment retained collaboration outcome files and group chat records.

3.3 Data Analysis This study adopted qualitative content analysis, combined with existing research theories and findings in the collaborative information behavior field, to construct and gradually refine an online knowledge collaboration behavior framework and coding system [18]. First, 6 videos of Group A' s two tasks were selected. Taking the group as the unit, descriptive coding was performed on all group members' behavioral actions, speech, and interview records. Behaviors were then summarized and classified to determine coding standards. Second, the above process was followed for subsequent video coding, while the behavior framework and coding system were supplemented and updated, with coding results undergoing secondary verification. Three researchers participated in coding after training to ensure unified and correct understanding of the coding work.

Through experimental observation and induction, this study found that small-scale user online knowledge collaboration mainly includes five behaviors: collaborative planning, information retrieval, information sharing, information use, and communication. Collaborative planning refers to groups developing strategies for task completion after tasks begin; information retrieval is conducted during tasks to obtain needed information; information sharing refers to maintaining the exchange of ideas and information to complete tasks; information use refers to using shared information to form individual and group outcomes; communication runs through the entire knowledge collaboration process, facilitating task completion. The detailed classification of these five main behaviors and sub-behaviors is shown in Table 2 .

Table 2 Coding of User Online Knowledge Collaboration Behaviors

Category	Code	Behavior Description
Collaborative Planning	P1	Develop collaborative strategy
	P11	Develop information retrieval strategy
	P12	Develop information sharing strategy

Category	Code	Behavior Description
	P13	Develop information use strategy
	P15	Develop group outcome integration strategy
Information Retrieval	Q1	Select retrieval tool
	Q2	Conduct personal information retrieval
	Q21	Input search terms
	Q3	Help others with information retrieval
	Q31	Share retrieval strategy
	Q34	Share retrieval content
Information Sharing	L1	Share retrieval strategy
	L11	Share retrieval tool
	L12	Share retrieval experience
	L13	Share background knowledge
	L2	Share retrieval content
	L21	Share search terms
	L22	Share URL
	L23	Share relevant information
	L3	View group history
	L31	View chat records
Information Use	U1	Edit personal outcomes
	U2	Use member-shared information
	U21	Use shared retrieval tool
	U22	Use shared search terms
	U23	Click shared URL
	U24	View shared relevant information
	U3	Edit group outcomes
	U31	View group outcomes
	U32	Integrate group outcomes
	U33	Edit group outcomes
Communication	C1	Determine communication method
	C3	Group decision conflict occurs
	C4	Group decision conflict ends
		Communication without response/delayed response

4 Experimental Results

4.1 Overview of Small-Scale User Online Knowledge Collaboration

This study coded and analyzed knowledge collaboration behaviors in 16 tasks across 8 groups. Figure 1 [Figure 1: see original paper] shows the frequency of knowledge collaboration behaviors in each group. As seen in Figure 1, Group B (high intimacy, strong collaboration) had the highest behavior frequency at 473 times, followed by Group C (low intimacy, weak collaboration) at 465 times, while Group E (low intimacy, weak collaboration) had the lowest frequency at 337 times. Statistics for the five types of collaboration behaviors are shown in

Figure 2 [Figure 2: see original paper].

As shown in Figure 2, information retrieval behaviors (Category Q) were most frequent (1,067 times), followed closely by information use behaviors (Category U) (1,062 times). Collaborative planning behaviors (Category C) were least frequent (197 times), while communication behaviors ran throughout the entire process.

4.1.1 Collaborative Planning In planning behaviors, strategy formulation behaviors occurred 72 times, and task division behaviors occurred 69 times, accounting for 36.55% and 35.03% of total planning behaviors respectively, indicating that strategy formulation and task division received the most attention. Data showed that collaborative strategies (28 times) and group outcome integration strategies (26 times) together accounted for three-quarters of strategy formulation behaviors, representing an important component.

4.1.2 Information Retrieval 56.25% of participants used only one retrieval tool per task, and 33.33% used two, indicating that most participants used relatively single types of retrieval tools. Participants input 319 search terms total, with 292 used for personal information retrieval and 27 for helping others, showing a preference for personal information retrieval. Participants primarily input search terms directly, with news websites (36.4%) and general websites (24.13%) being the most browsed types. Compared to personal information retrieval, helping others with retrieval showed a higher proportion of search term evolution based on group members (22.22%).

4.1.3 Information Sharing In information sharing, participants preferred sharing URLs, task-related information, and retrieval experiences, which together accounted for 83.72% of shared retrieval strategies and content. Viewing group history records occurred 183 times, with viewing chat records accounting for 164 times, indicating that participants preferred to maintain awareness of group work progress and member communication content through chat records.

4.1.4 Information Use In information use behaviors, editing personal outcomes occurred 572 times, while editing group outcomes occurred 281 times, with the latter being less than half of the former. This shows that although the task was online knowledge collaboration, group members preferred to divide tasks and complete their own work rather than collaboratively editing group outcomes. Regarding using member-shared information, directly viewing relevant information accounted for 65.15% of using shared information behaviors, showing that members preferred directly viewing shared relevant information rather than retrieval tools, search terms, or URLs. However, comparing with information sharing data revealed that shared information was not fully utilized. For example, URL sharing occurred 33 times, but clicking on shared URLs only occurred 19 times.

4.1.5 Communication Communication behaviors totaled 635 times, averaging about 39.69 times per group per task. Group decision conflicts occurred once and were resolved once, indicating that decision conflicts were rare and could be resolved.

4.2 Impact of Team Member Intimacy and Collaboration Tendency on Small-Scale Online Knowledge Collaboration

Due to the small sample size and generally non-normal distribution of experimental data, this study used SPSS 22.0 to conduct non-parametric tests (Mann-Whitney U test) on knowledge collaboration behaviors from 48 videos of 24 participants completing two tasks. Significant dependent variables (P<=0.05) and significance results are shown in Table 3 and Table 4 .

Table 3 Non-parametric Test Results for Dependent Variables Significantly Affected by Intimacy

Variable	Mann-Whitney U	Asymptotic Significance
P1 Strategy formulation behavior	181.000	0.023
P11 Collaborative strategy formulation	195.000	0.033
P4 Time planning behavior	185.000	0.018
L1 Shared retrieval strategy behavior	202.000	0.030
L12 Retrieval experience sharing	219.000	0.044
C Communication behavior	159.500	0.008
C1 Number of speeches	155.000	0.006

Table 4 Non-parametric Test Results for Dependent Variables Significantly Affected by Collaboration Tendency

Variable	Mann-Whitney U	Asymptotic Significance
Q21 Personal information retrieval	152.500	0.005
L Information sharing behavior	193.500	0.050
U33 Edit group outcomes behavior	157.000	0.006

Results show that intimacy significantly affects strategy formulation behavior, collaborative strategy formulation behavior, time planning behavior, shared retrieval strategy behavior, retrieval experience sharing behavior, communication behavior, and number of speeches. Collaboration tendency significantly affects personal information retrieval behavior, information sharing behavior, and editing group outcomes behavior.

4.2.1 Impact of Intimacy Behavior categories and frequencies affected by intimacy are shown in Table 5 .

Table 5 Behavior Categories and Frequencies Affected by Intimacy

Group Type	P1	P11	P4	L1	L12	C	C1
High intimacy, weak collaboration (A)	12	3	-	-	-	-	-
High intimacy, weak collaboration (H)	11	4	-	-	-	-	-
High intimacy, strong collaboration (B)	12	5	12	4	-	-	-
High intimacy, strong collaboration (F)	11	8	-	-	-	-	-
Low intimacy, weak collaboration (C)	-	-	-	-	-	-	-
Low intimacy, weak collaboration (E)	-	-	-	-	-	-	-

For strategy formulation behavior, intimacy has a significant positive impact ($P<0.05$). Under the same collaboration tendency, higher intimacy leads to higher behavior frequency, indicating that high-intimacy groups are more inclined to formulate group collaboration strategies. For time planning behavior within strategy formulation, under weak collaboration tendency, high-intimacy groups showed higher behavior frequency, while under strong collaboration tendency, intimacy' s impact was not significant. This shows that high-intimacy groups with weak collaboration tendencies are more inclined to develop time plans.

For shared retrieval strategy behavior, under strong collaboration tendency, intimacy significantly impacts group shared retrieval strategy behavior ($P<0.05$), while under weak collaboration tendency, intimacy' s impact was not significant. This indicates that high-intimacy groups with strong collaboration tendencies are more inclined to share retrieval strategies.

For communication behavior, under both strong and weak collaboration tendencies, high-intimacy groups showed higher communication behavior frequencies than low-intimacy groups. The "double-high" groups explored new communication methods.

4.2.2 Impact of Collaboration Tendency Behavior categories and frequencies affected by collaboration tendency are shown in Table 6 .

Table 6 Behavior Categories and Frequencies Affected by Collaboration Tendency

Group Type	Q21	L (L1, L2)	U33	C1
High intimacy, weak collaboration	-	-	-	-
High intimacy, strong collaboration	-	-	-	-
Low intimacy, strong collaboration	-	-	-	-
Low intimacy, weak collaboration	-	-	-	-

As shown in Table 6, collaboration tendency significantly affects personal information retrieval behavior ($P<0.05$). Under low intimacy, groups with weak collaboration tendencies engaged in personal information retrieval more frequently, while under high intimacy, collaboration tendency' s impact was not significant.

For information sharing behavior, under high intimacy, collaboration tendency significantly affects group information sharing behavior ($P=0.05$), with strong collaboration tendency groups showing higher information sharing frequencies than weak collaboration tendency groups, while under low intimacy, collaboration tendency' s impact was not significant.

For editing group outcomes behavior, under high intimacy, strong collaboration tendency groups showed higher behavior frequencies, while under low intimacy, collaboration tendency' s impact was not significant.

Overall, groups with high intimacy and strong collaboration tendencies are more inclined to share information and collaboratively edit group outcomes.

4.3 Analysis of Small-Scale User Online Knowledge Collaboration Patterns

Among all knowledge collaboration behaviors, collaborative planning, information retrieval for others, information sharing, editing group outcomes, and number of speeches all reflect group collaboration levels. Through analysis of the above category data and observation of experimental processes, this study found that small-scale user online knowledge collaboration has fixed patterns, which can be classified according to group division of labor and task collaboration strategies.

4.3.1 Classification by Division of Labor Through qualitative analysis of group member behaviors and quantitative analysis of video coding data, division of labor situations can be divided into three types: collaboration-dominant, division-dominant, and division-collaboration types. Quantitative data for each type is shown in Table 7 .

Table 7 Classification of Group Online Knowledge Collaboration Patterns by Division of Labor

Pattern Type	High Intimacy, Weak Collaboration	High Intimacy, Strong Collaboration	Low Intimacy, Strong Collaboration	Low Intimacy, Weak Collaboration
Collaboration-dominant		-	-	-
Division--dominant		-	-	-
Division--collaboration		-	-	-

(1) **Collaboration-dominant**: In collaboration-dominant groups, one member spontaneously acts as the leader and dominates the collaboration process, with other members actively participating in collaboration under the leader' s guidance. These groups have more interactive communication and high collaboration efficiency and effectiveness. Typical collaboration-dominant groups include low-intimacy weak-collaboration Group C and low-intimacy strong-collaboration Group G. Figure 3 [Figure 3: see original paper] shows the timeline behavior marking for Group G as a collaboration-dominant group.

(2) **Division-dominant**: Similar to collaboration-dominant groups, division-dominant groups also have a spontaneously emergent leader who dominates task decomposition but interacts less with members, with each completing tasks independently after division. Information sharing, editing group outcomes, and communication behaviors are significantly fewer than in collaboration-dominant groups. Low-intimacy strong-collaboration Group D and low-intimacy weak-collaboration Group E are obvious division-dominant groups. Figure 4 [Figure 4: see original paper] shows the timeline behavior marking for Group D as a division-dominant group.

(3) **Division-collaboration**: These groups have no obvious leader, with every member actively speaking and interacting to jointly develop collaboration strategies. In addition to completing their own tasks, members also help others with information retrieval and outcome editing, actively share task-related information, and maintain continuous attention to task progress. High-intimacy strong-collaboration Groups B and F and high-intimacy weak-collaboration Groups A and H are typical division-collaboration groups. Figure 5 [Figure 5: see original paper] shows the timeline behavior marking for Group B' s second task as a division-collaboration group.

Overall, low-intimacy groups tend to elect a group leader to organize tasks, while high-intimacy groups have no leader and members cooperate better, making collaboration tendency less influential on division-collaboration types.

4.3.2 Classification by Task Collaboration Strategy Group online knowledge collaboration patterns can be divided into four types by task collaboration strategy: parallel, parallel-sequential, responsive, and parallel-responsive.

(1) **Parallel**: Parallel groups divide tasks into subtasks at the beginning, with members working simultaneously. This is efficient but has low interaction, with final outcomes being simple concatenations of individual members' work. Except for Group F, all groups used parallel strategy for their first task. Since parallel strategy highly depends on members' execution ability, it can also negatively affect tasks. For example, in Group E' s first task, member E-2 did not complete tasks according to division arrangements and did not upload outcomes to the group folder, making no contribution to the collaboration. Figure 6 [Figure 6: see original paper] shows the parallel group collaboration strategy analysis.

(2) **Parallel-sequential**: Parallel-sequential groups divide tasks in parallel, but some subtasks have sequential relationships. Therefore, at task start, stages are divided where one member' s output is passed to the next member to continue or serve as the basis for the next member' s task. For example, in Group D' s second task, leader D-1 first found 3 controversial points and passed them to member D-2 to find corresponding solutions. The advantage of parallel-sequential strategy is that it fully considers sequential logical relationships between tasks during decomposition, making final outcomes more coherent and logical with strong inter-member interaction. The disadvantage is potential time waste and human resource idleness. Figure 7 [Figure 7: see original paper] shows the parallel-sequential group collaboration strategy analysis.

(3) **Responsive**: Responsive groups do not divide tasks but have members jointly read materials, search for information, and edit outcomes. The advantage is that every member has comprehensive understanding of group tasks with sufficient communication and joint editing of group outcomes. The disadvantage is potential inefficiency and possible disengagement of some members. Figure 8 [Figure 8: see original paper] shows the responsive group collaboration strategy analysis.

(4) **Parallel-responsive**: Parallel-responsive groups combine division and collaboration. In the experiment, there were two situations: two members responsible for the same question, or one member joining the collaboration of two other members after completing their own part. The parallel-responsive strategy combines advantages and disadvantages of parallel and collaborative strategies, clarifying task division while ensuring members' overall grasp of group tasks and interaction levels, fully utilizing human resources but possibly with some members contributing less to group outcomes. Figure 9 [Figure 9: see original paper] shows the parallel-responsive group collaboration strategy analysis.

Overall, all 8 groups used parallel collaboration strategy for their first task (ex-

cept high-intimacy weak-collaboration Group F, which used both responsive and parallel strategies). Five groups optimized their collaboration strategy for the second task: high-intimacy strong-collaboration Group A, high-intimacy weak-collaboration Group B, and low-intimacy weak-collaboration Group H adjusted to parallel-responsive strategy; low-intimacy strong-collaboration Group C adjusted to responsive strategy; low-intimacy weak-collaboration Group D adjusted to parallel-sequential strategy; Groups E, F, and G made no adjustments and remained parallel. Therefore, intimacy and collaboration tendency had no significant impact on collaboration strategies and changes.

5 Conclusions and Discussion

This study found that small-scale user online knowledge collaboration mainly includes five types of behaviors: collaborative planning, information retrieval, information sharing, information use, and communication, with information retrieval being most frequent and collaborative planning least frequent. Regarding behavior frequency, groups with higher intimacy and stronger collaboration tendencies showed higher behavior frequencies, similar to Wu Dan et al.' s [33] findings that more cohesive groups have more recommendation behaviors and more diverse collaboration methods.

Through non-parametric tests on behavior frequency data, this study found that team intimacy has a significant positive impact on collaborative strategy formulation and intra-group communication behaviors. High-intimacy groups are more inclined to share retrieval strategies, especially retrieval experiences. Even under weak collaboration tendency conditions, high-intimacy groups actively communicate. This study also found that collaboration tendency significantly affects personal information retrieval behavior: under low intimacy, weaker collaboration tendency leads to more frequent personal information retrieval; under high intimacy, stronger collaboration tendency leads to more frequent information sharing and group outcome editing, consistent with Qiu Jin et al.' s [34] finding that groups with stronger collaborative abilities tend to cooperate and share more.

Building on Li Fenglin et al.' s [6] research, this study further refined group division of labor situations into three types: collaboration-dominant, division-dominant, and division-collaboration. Low-intimacy groups tend toward the first two types that generate leader-led groups, while high-intimacy groups tend toward division-collaboration groups without leaders, making collaboration tendency less influential on division-collaboration types. Building on M. Sharples et al.' s [24] research, this study refined and supplemented task collaboration strategies, dividing them into four types: parallel, parallel-sequential, responsive, and parallel-responsive.

This research has theoretical and practical value. Theoretically, it helps scholars further understand the impact of intimacy and collaboration tendency on small-scale online knowledge collaboration, refining and supplementing previ-

ous research on online knowledge collaboration processes, behavior types, and pattern characteristics. Practically, findings can be applied to online education and scientific research collaboration, such as grouping members in online teaching according to familiarity and collaboration tendency to maximize collaboration and communication, helping members fully utilize shared resources and improve team collaboration efficiency. It also provides references for designing and improving online knowledge collaboration platforms and communities, such as developing forms or functions that strengthen team interaction and providing adaptive communication and sharing mechanisms based on team collaboration strategies to offer broader and more necessary support for user knowledge sharing and collaboration.

6 Limitations and Future Directions

In experimental design, for research observation and data collection convenience, groups were required to use Youdao Cloud knowledge collaboration software. However, due to participants' low familiarity with the software and Youdao Cloud' s poor real-time notification functionality, group communication was somewhat affected. Additionally, due to poor stability of the user research software Morae, one group's data could not be read and required re-experimentation, also affecting results. Regarding experimental user samples, although intimacy and collaboration tendency were strictly controlled, variables such as gender ratio and education level were not controlled, which may affect results. The small sample size may also affect the generalizability of conclusions. Furthermore, the relationship between task completion quality and team composition was not explored.

Future research directions could continue examining the impact of team composition on small-scale knowledge collaboration outcome quality, further expand research samples, expand influencing factors, and conduct in-depth research using combined qualitative and quantitative methods.

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