Exploring Role-Based Knowledge Co-Construction in Social Annotation with Epistemic Network Analysis

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Abstract. Social annotation has emerged as a promising approach to fostering social reading and collaborative learning. However, the implementations of social annotation vary in pedagogical depth, with some lacking structured support for deep knowledge co-construction. To address this issue, role assignment—defined as the intentional allocation of predefined roles among students—has been widely adopted to guide learner participation and foster purposeful engagement. Prior research, however, has largely relied on traditional content analysis to quantify isolated knowledge co-construction behaviors without capturing how these behaviors interrelate or unfold over time in social annotation activities. To close the gap, this study employs Epistemic Network Analysis (ENA) to reveal how three assigned roles (facilitator, synthesizer, and summarizer) contributed to students' knowledge co-construction in social annotation activities in a university-level class. Course-wide ENA revealed that both summarizers and students without assigned roles consistently linked three core practices (*Externalization, Quick Consensus Building, and Integration-Oriented Consensus Building*), whereas facilitators and synthesizers consistently engaged with these three practices along with *Elicitation*. Building on course-wide ENA, stage-specific ENA across early, middle, and late stages further illuminated how each role's co-construction patterns evolved over time. The results underscore the need for structured guidance and intentional instructional support to foster deeper collaborative engagement in social annotation.

Keywords: Social Annotation, Role Assignment, Knowledge Co-Construction, Epistemic Network Analysis.

1   Introduction

Social annotation, which refers to the use of web-based annotation tools to support collaborative commentary on digital texts, has emerged as a promising pedagogical strategy for facilitating social reading [23, 24]. By embedding an interactive interface within

digital texts [20], social annotation creates a collaborative space that encourages critical reading, interpretation exchange, and meaningful peer dialogue with a sense of community [11]. Such an environment affords valuable opportunities for knowledge co-construction—the collaborative process through which learners co-create new, shared understandings beyond individual cognition [1].

Despite evidence supporting social annotation's effectiveness in facilitating collaborative knowledge construction [3, 10], many existing implementations remain superficial, often limited to generic posting and replying requirements that are rarely conducive to productive contexts needed for deep engagement [24]. To foster more meaningful participation, scholars have called for the use of intentional pedagogical scaffolds, among which role assignment has received considerable scholarly attention. Defined as the deliberate design of functions or responsibilities that guide individual behavior and regulate group interaction [18], role assignment has been implemented in various forms—such as social tutor [2], synthesizer, and summarizer [4, 22]. The impact of role assignment on knowledge co-construction has been investigated, primarily through content analysis and statistical modeling. Findings from various contexts suggest that such role-based designs can effectively enhance knowledge co-construction [7, 14, 15, 16, 24].

However, while prior work has established the value of assigned roles, key methodological limitations remain in how their effects are evaluated. Most studies have relied on traditional content analysis to quantify isolated behaviors—such as the frequency of students' initiation, negotiation, or reflection [2, 24]—without revealing how these practices interrelate to scaffold deeper collaborative discourse or accounting for their temporal progressions.

This methodological gap is particularly critical in the context of social annotation, where learners engage in iterative cycles of reading, annotating, and responding, thereby creating a dialogic space in which ideas are shared, negotiated, challenged, and refined. Shared understanding does not arise from isolated moves but from how students build on one another's contributions—through practices such as externalizing ideas, eliciting peer responses, aligning with peers, and extending or challenging peers' ideas [21]. This dynamic interaction of behaviors underpins collaborative meaning-making and highlights the necessity of examining behavior interactions rather than calculating mere frequencies. Moreover, knowledge co-construction behaviors do not simply accumulate over time. Rather, they unfold within distinct thematic threads following certain temporal sequences, highlighting the need for analytical methods capable of modeling thread-based, temporally ordered interactions.

To address these limitations, this study employs Epistemic Network Analysis (ENA) in the context of social annotation activities in a university course to uncover course-wide role-based knowledge co-construction patterns and to examine how role-based co-construction patterns evolve across different course stages. ENA quantifies patterns of code co-occurrence and projects these high-dimensional relationships into visual networks [17]. By modeling how code connections develop across successive discourse windows, ENA accounts for the temporal progression of role-driven knowledge co-construction, thereby capturing the interrelated and unfolding nature of role-based knowledge co-construction. Moving beyond simple code tallies, this study leverages ENA to elucidate the nuanced, evolving knowledge co-construction networks

that emerge under different assigned roles in social annotation activities. Building on this foundation, this study addresses the following research questions:

RQ 1: What role-based knowledge co-construction patterns emerged in social annotation activities in the course?

RQ 2: How did students' role-based knowledge co-construction patterns in social annotation activities evolve across different stages of the course?

2 Background

2.1 Social Annotation and Knowledge Co-Construction

Social annotation—the application of web-based annotation technologies to support social reading in educational contexts—has emerged as a prominent pedagogical practice [23, 24]. By embedding comments directly within shared online documents, social annotation anchors discussions in the annotated text, engendering an interactive layer on any web document to foster collaborative engagement [20]. Specific web annotations offer diverse affordances, including providing visible traces to guide reader attention, expressing reactions, and expanding dialogues beyond the document [12].

These affordances create an online collaborative space in which learners are encouraged to read critically, exchange interpretations, and engage in meaningful discourse with a sense of community [11]. In this context, social annotation offers a powerful foundation for knowledge co-construction, which is defined as the collaborative process whereby learners interact to construct new, shared understanding that transcends individual cognition [1]. Such knowledge co-construction is not simply having students to talk with one another, but includes key practices such as *Externalization*, *Elicitation*, *Quick Consensus Building*, *Integration-Oriented Consensus Building*, and *Conflict-Oriented Consensus Building* [21]. Several studies have documented the promise of social annotation in supporting knowledge co-construction by engaging learners in connecting ideas, making sense of key concepts, seeking clarification, and negotiating shared understanding [3, 10].

Despite these promising findings, there is room to further improve the design of social annotation activities to go beyond generic posting requirements and offer pedagogically rich scenarios for deep engagement [24]. To this end, scholars have called for the integration of structured scaffolds—such as role assignment—that purposefully scaffold learners' knowledge co-construction.

2.2 Role Assignment and Its Impact on Knowledge Co-Construction

As defined by Strijbos and Weinberger [18], roles are "more or less stated functions or responsibilities that guide individual behavior and regulate group interaction" (p. 491), while scripted roles are intentionally "designed to improve both learning processes and outcomes" (p. 492) and are deliberately assigned to learners to structure the collaborative process. Given the critical influence of assigned roles on group dynamics [8], assigned roles have garnered substantial scholarly interest within the CSCL community, with a major focus on investigating how role assignment can scaffold knowledge co-

construction. Scholars have developed various roles to support this aim: socially oriented roles (e.g., the social tutor, who provides socio-emotional support) [2]; content-oriented roles (e.g., the importer, who introduces information) [22]; and summative roles (e.g., the synthesizer and summarizer, who produce coherent summaries or syntheses of the group's evolving discourse) [4, 22].

With the development of diverse participation roles, extensive research has examined how role assignment impacts students' knowledge co-construction by comparing their cognitive engagement levels in co-construction across roles [14-16, 24]. Predominantly, scholars have applied content analysis to derive discourse codes reflecting different levels of knowledge co-construction, and then compared these code frequencies across roles using descriptive statistics [24], ANOVA [14], or multilevel modeling [15, 16]. Some studies have further incorporated time as a variable to trace how students' co-construction engagement evolves across different stages of discourse [14, 24].

Despite extensive research on role-based knowledge co-construction—primarily within online asynchronous discussion forums—few studies (except [24]) have explored how roles shape discourse dynamics in social annotation. In social annotation, comments explicitly build on prior contributions, giving rise to thematic threads in the discourse space. Reporting aggregated code frequencies, demonstrated in prior work, neglects the relational and temporal structures through which knowledge co-construction unfolds. Using the same "code-and-count" paradigm to evaluate participation roles would limit our understanding of how roles shape collaborative meaning-making. To address these gaps, this study employs ENA to model course-wide and stage-specific patterns of key knowledge co-construction practices across roles. This approach captures relational patterns and accounts for the unique temporal unfolding of knowledge co-construction, offering insights beyond traditional frequency-based analyses.

3   Methods

3.1   Research Context and Participants

This study was conducted in a university course focused on dance traditions from Africa and the African Diaspora [24]. The course included thirteen students, with twelve identified as female and one as male. From week 1 to 11, each week students engaged in a week-long structured social annotation activity, joined two 90-minute online discussions (on Tuesdays and Thursdays), and completed a reflective writing assignment.

Each Thursday after class, the instructor uploaded one or two assigned readings to the course platform (Canvas). By Sunday evening, students were required to read the material and post at least two annotations on Hypothesis—an open-source online social annotation platform for collaborative highlighting and commenting [13]. They were also expected to reply to peers' annotations by next Thursday. Social annotation was an essential part of this writing-intensive course, as it promoted close reading, critical analysis, and thoughtful peer interaction to prepare for writing.

To structure participation and support meaningful engagement in the annotation activity, the course instructor introduced three rotating roles, facilitator, synthesizer, and summarizer. Each role was designed to guide students in contributing to collaborative reading and discussion and taking responsibility for group learning.

Facilitators supported active engagement by prompting timely responses to questions, identifying related ideas, and applying consistent tags to standardize and clarify annotation purposes. Their role spanned from Thursday to the following Thursday. Mid-week, synthesizers distilled insights from the annotations and crafted discussion prompts to support the subsequent social-annotation activity. They posted a synthesis on Canvas each Tuesday evening that summarized key points, identified unresolved questions, and highlighted links among comments. Summarizers contributed at the week's end by writing a brief overview of the discussion, due Saturday, to support reflection and closure of the annotation cycle. Students were expected not only to engage with course content individually, but also to participate actively in collaborative learning through annotation.

3.2   Data Processing and Coding

An initial review of the dataset confirmed no missing entries. Duplicate entries were identified and removed to avoid distortion in the analysis. In ENA, the conversation variable defines the boundaries within which co-occurrence of discourse codes is calculated, grouping all relevant annotations into discrete interactional units [17]. To operationalize the conversation variable, we created a derived variable—thread—that assigns each annotation to its corresponding discussion thread, thereby delineating segments of discourse tied to the same source text. This procedure preserves the natural adjacency and relational structure of participants' contributions, ensuring that co-occurrence counts reflect authentic conversational boundaries.

To capture the interactive processes through which students collaboratively construct knowledge, Weinberger and Fischer's [21] framework of knowledge co-construction was adopted as the initial coding scheme for this study. This framework includes five key practices—*Externalization*, *Elicitation*, *Quick Consensus Building*, *Integration-Oriented Consensus Building*, and *Conflict-Oriented Consensus Building*.

Two researchers with qualitative research experience then applied an inductive–deductive coding approach (Fereday & Muir-Cochrane, 2006) to the social annotation data. Beginning with the theory-driven categories of Weinberger and Fischer [21], they refined the framework to incorporate emerging themes, context-specific patterns, and additional codes. The final coding scheme is presented in Table 1.

To establish the reliability and consistency of the qualitative coding process, the researchers first met to review and clarify the coding scheme to reach a shared understanding. They then independently coded an initial set of 100 randomly sampled lines using a binary coding system. Inter-rater reliability (IRR) was assessed using Cohen's Kappa (κ). This procedure was repeated for two additional rounds, each involving independent coding of a new set of 100 lines. After each round, discrepancies were addressed through a social moderation process [9], which resulted in a refined and agreed-upon coding framework. After the third round, the researchers achieved agreement across all codes ($\kappa > 0.7$). One researcher then coded the remaining dataset using the finalized coding scheme. Within the QE community, $\kappa > 0.7$ is considered an acceptable threshold for IRR and has been used widely in prior QE work (e.g., [19]). While $\kappa > 0.7$ does not imply complete agreement on every coded line, it indicates sufficient

consistency for reliably applying the coding scheme. We therefore adopt $\kappa > 0.7$ as an acceptable and practical threshold for IRR in this study.

Table 1. The knowledge co-construction codebook

Codes	Description	Examples
Externalization	Articulating thoughts to their peers without any explicit or implicit references to previous contributions.	"It's really interesting to me how one thing can be categorized into so many different categories."
Elicitation	Questioning or provoking a reaction from peers.	"I wonder if there was opposition to this "improvement" by other capoeiragem practitioners?"
Quick consensus building	Accepting the contributions of peers without any modification or indication that the peer perspective has been taken over by the learner.	"Yes [Student A], this is a good point to consider!"
Integration-oriented consensus building	Taking over, integrating and applying the idea of their peers, significantly differing from a juxtaposition of perspectives, but indicating a further development of the idea from a learning partner.	Student B: "…Many popular musical artists would use Black women vocalists within their songs, most times with little credit or no recognition…" Student C: "…This idea of taking the vocals of black women is similar to what [Redacted] was saying about taking things from black bodies and putting it on white people to receive more credit..."
Conflict-oriented consensus building	Challenging, modifying, or expanding upon the original ideas presented in the posts. Including rejection (replacement, modification, and supplementation), exclusion, and critical evaluation of peers' contributions.	Student D: "…Hurston was quite critical about Dunham visiting so many places in such a short period of time, questioning whether what Dunham was learning was 'enough'…" Student E: "…I also wonder how much of Hurston's harsh criticisms can be attributed to the jealousy that was discussed previously…"
Sharing external resources	Sharing external information such as YouTube videos to facilitate collaborative discourse	"…here is a great one from one of my favorite artists right now, [Video Link]"

3.3   Epistemic Network Analysis

ENA was used to explore knowledge co-construction by modeling the co-occurrence of thematic codes within annotation episodes [17]. ENA is particularly suited for this type of analysis, as it allows researchers to visualize and quantify how each practice occurs together over time and shows the development of shared meaning.

The unit variables used for both course-wide and stage-specific analyses were constructed to create the epistemic networks. In ENA, a unit variable specifies the unit of aggregation for co-occurring coded behaviors [17]. For course-wide epistemic networks, the unit variable combined assigned role and student ID, allowing us to track

each student's knowledge co-construction patterns across the entire course while accounting for role differences. For stage-specific epistemic networks, the unit variable included assigned role, course stage, and student ID, allowing for a finer-grained analysis of how role-based co-construction patterns unfolded across the early (Weeks 1–3), middle (Weeks 4–7), and late (Weeks 8–11) stages of the course.

Conversation segments were grouped by week, reading assignment, and annotation thread. An annotation thread refers to a series of connected annotations focused on the same original text. Each thread thus constitutes a thematically focused discussion unit that reflects how learners interact around a shared textual reference. All annotations within the same thread, reading, and week were grouped and treated as a single conversation segment. The stanza size was set to infinite, meaning that each annotation's connections were computed relative to all preceding lines within the same conversation. This approach functions like a moving window without an upper limit of previous lines, allowing each annotation to be interpreted in the context of the entire preceding discourse. We set the nodes equally spaced to enhance visual clarity, facilitating comparison of the relative connection strengths of practices across different networks.

4 Results

4.1 Role-Based Knowledge Co-Construction Patterns Across the Course

Distinct patterns of knowledge co-construction emerged for each role, as evidenced by ENA network structures and edge weight (ew) profiles. Figure 1 illustrates these role-specific networks—Figure 1a for students without roles, and Figures 1b–d for the Facilitator, Synthesizer, and Summarizer conditions, respectively.

The epistemic network without assigned roles (Fig. 1a) showed three dominant practices: *Externalization*, *Quick Consensus Building*, and *Integration-Oriented Consensus Building*, with the strongest links occurring between them. This pattern suggests that students frequently acknowledged peers' ideas—for example, by saying "This is a good point to consider!" in response to others' contributions (*Externalization – Quick Consensus Building*). Students also frequently responded to their peers' ideas by integrating and building on them (*Externalization – Integration-Oriented Consensus Building*). For instance, one student noted that all cultures are subject to external influence, and another extended the concept of cultural influence to include both "current" and "historical aspects". Moreover, students without roles frequently acknowledged peers' contributions before extending or integrating them (*Quick Consensus Building – Integration-Oriented Consensus Building*). For instance, an unassigned student acknowledged a peer's contribution by stating, "That is a really important thing to consider," and then extended the peer's discussion of the tension between creating "the art that you want to make" and "being able to support yourself" by introducing an important explanatory angle: "the role of the audience in a dance artist's career."

By contrast, the Facilitator network (Fig. 1b) retained these three core practices but incorporated *Elicitation* via multiple high-weight edges, resulting in a network where all four practices were strongly interlinked. The strongest link between *Externalization* and *Elicitation* across all roles (ew = 0.36, compared to 0.27 for unassigned students,

0.33 for synthesizers, and 0.24 for summarizers) indicates that facilitators most often followed their own or peers' externalizations with questions or prompts to facilitate discussion. For example, one facilitator proposed a viewpoint, "…police violence is being met by opposing violence…This situation seems to build on itself, leaving no clear end in sight," (*Externalization*), and then prompted, "It makes me curious to discuss the end goal…and whether a final, definable solution exists" (*Elicitation*).

They also frequently elicited further ideas after peers' contributions. For instance, after one student suggested the artist chose a gradual exposure of Black diasporic culture over a "strong Black attitude" to gain wider acceptance (*Externalization*), one facilitator responded with an elicitation: "…if she had decided to at least one more time use her 'strong Black attitude'…would there have finally been some movement or would she be back at square one again?" (*Elicitation*).

 The Facilitator network also showed the strongest connection between *Externalization* and *Sharing External Resources* among all roles (ew = 0.07, compared to 0.04 for unassigned students, 0.01 for synthesizers, and 0.02 for summarizers), indicating that facilitators most often used external materials, especially video content, to support both the externalization of their own ideas and responses to peers. For example, one facilitator explained "ginga motion" as "a side‑to‑side movement with bent knees used in mock fighting." (*Externalization*) and included a video link for illustration (*Sharing External Resources*), thereby anchoring the discussion to a concrete multimedia resource and providing peers with an immediate reference for further exploration.

Within the Facilitator network, although the absolute weight of edges linked to *Conflict-Oriented Consensus Building* remained moderate, the node co-occurred more frequently with *Externalization*, *Quick Consensus Building*, *Integration-Oriented Consensus Building, and Elicitation* than in other networks (see specific edge weights in Figs. 1a–d). This suggests that facilitators were more likely to challenge peer ideas in ways that pushed the discussion forward. In one example, a facilitator challenged a peer's claim that Cuban dance is valued because professionals inspire youth by arguing that the value comes from a cultural norm that involves everyone (*Conflict-Oriented Consensus Building)*. This contribution led another student to add a new explanation—the role of government funding—showing continued conflict-oriented discussion.

The Synthesizer network (Fig. 1c) also linked four key practices—*Externalization*, *Quick Consensus Building*, *Integration-Oriented Consensus Building*, and *Elicitation*—mirroring the pattern observed under the Facilitator condition. Similar to the Facilitator network, edges involving *Conflict-Oriented Consensus Building* in the Synthesizer network, though moderate in absolute weight, appeared stronger than those in the No-Role and Summarizer networks, suggesting a greater tendency to critically assess, challenge, or refine peers' ideas as part of collaborative dialogue.

Despite the similarities, notable differences emerged. A key distinction lay in the minimal presence of *Sharing External Resources*, indicating that synthesizers rarely incorporated external materials to support collaborative discourse (all edges connecting to *Sharing External Resources* had line weights ≤ 0.01). In contrast, the edge between *Externalization* and *Integration-Oriented Consensus Building* (ew = 0.45) was stronger than that in the Facilitator network (ew = 0.35), suggesting that synthesizers more often expanded on and integrated peers' ideas compared to facilitators. For instance, after a

student proposed that making a living from art during the Great Depression required "much hard work" for an artist (*Externalization*), a synthesizer built on this by linking it to the broader historical experiences of the Black American community, "These questions seem to be ones that the whole of the Black American population were grappling with at the time" (*Integration-Oriented Consensus Building*).

The network of the Summarizer role (Fig. 1d) was structurally similar to that of the No-Role condition (Fig. 1a), with key nodes and patterns largely overlapping. However, the majority of the edge weights in the Summarizer network were lower than those observed in the No-Role network (see specific edge weights in Fig. 1), suggesting that although similar types of knowledge-co-construction actions were present, they co-occurred less frequently. In particular, the connection between *Externalization* and *Integration-Oriented Consensus Building* in the Summarizer network was the second lowest of all roles (ew = 0.37, compared to 0.51 for unassigned students, 0.35 for facilitators and 0.45 for synthesizers). The *Quick Consensus Building* and *Integration-Oriented Consensus Building* link was the weakest of all roles (ew = 0.27, compared to 0.42 for unassigned students, 0.32 for facilitators, and 0.33 for synthesizers). These reductions suggest that summarizers were markedly less inclined to transform peers' externalized ideas into deeper, integrative consensus and to progress beyond quick peer alignment, reflecting a more limited engagement with collaborative meaning-making processes.
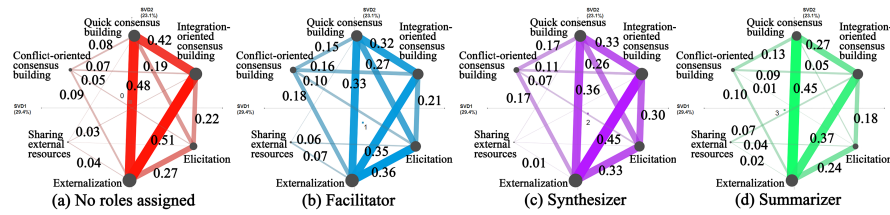

Fig. 1. Course-wide role-based knowledge co-construction patterns

4.2 Role-Based Knowledge Co-Construction Patterns Across Course Stages

Building on the course-wide networks, we next present the stage-specific epistemic networks for four role conditions (see Fig. 2). The stage-by-stage visualization allows us to examine how knowledge co-construction patterns for each role unfolded over time and how the connections between key practices evolved across the three course stages.

For students without assigned roles (Fig. 2a–c), early and middle-stage networks showed a consistent triangular pattern connecting three core practices: *Externalization, Quick Consensus Building*, and *Integration-Oriented Consensus Building*. These nodes formed the most prominent connections in the network, mirroring the pattern observed in the course-wide No-Role network described in Section 4.1. At the late stage, however, the network took on a different form. *Elicitation* formed strong links with each of the three core practices, suggesting that *Elicitation* played a more central role in the later part of the course and co-occurred more frequently with other core practices.

Similar to the course-wide Facilitator network (see Section 4.1), the stage-specific networks for facilitators (Figs. 2d–f) consistently linked four core practices—*Externalization*, *Quick Consensus Building*, *Integration-Oriented Consensus Building*, and

Elicitation—across all three stages. Notably, connections to *Conflict-Oriented Consensus Building* remained relatively strong at each stage but showed an overall gradual decline, pointing to a reduced role of "conflict" in supporting discussion and conceptual development as the course advanced (see edge weight changes in Figs. 2d–f).

A similar downward trend was observed for edges involving *Sharing External Resources*, indicating that facilitators became less inclined to draw on outside materials to support collaborative discourse. In contrast, the connection between *Externalization* and *Elicitation* strengthened over time, increasing from 0.27 at the early stage to 0.29 at the middle stage, and reaching its peak at 0.54 at the late stage, highlighting that facilitators increasingly responded to peers' contributions with questions or prompts aimed at encouraging engagement.

Mirroring the Facilitator networks described in Section 4.2, the stage-specific Synthesizer epistemic networks (Figs. 2g–i) consistently featured the strongest interconnections among *Externalization*, *Quick Consensus Building*, *Integration-Oriented Consensus Building*, and *Elicitation* across all stages. Connections involving *Conflict-Oriented Consensus Building* in Synthesizer epistemic networks exhibited a downward trend similar to the Facilitator networks.

One key distinction is that the connections between *Externalization* and *Integration-Oriented Consensus Building* in the Synthesizer networks remained both strong and stable across all three stages (ew = 0.44, 0.51, 0.35). These connections appeared stronger and more consistent than those in the stage-specific Facilitator networks (ew = 0.27, 0.41, 0.31), which indicates that synthesizers more often expanded and developed peers' contributions throughout three course stages compared to facilitators. In contrast, edges involving *Sharing External Resources* remained weak across all stages, with only a minor link with *Quick Consensus Building* observed during the early stage. This trend suggests that *Sharing External Resources* played a minimal role in the knowledge co-construction process for students in the synthesizer role across all stages.

The stage-specific Summarizer epistemic networks (Figs. 2j–l) closely mirrored No-Role networks across all stages. In both groups, the early and middle stages featured a similar triangular structure linking *Externalization*, *Quick Consensus Building*, and *Integration-Oriented Consensus Building*. At the late stage, *Elicitation* became more integrated into the network, forming a quadrilateral pattern, suggesting a late-stage shift toward more frequent use of *Elicitation* to foster collaborative discourse.

In sum, while all roles shared three foundational practices across stages—*Externalization, Quick Consensus Building, and Integration-Oriented Consensus Building*—each role showed distinct temporal patterns. *Elicitation* was integrated as one of the core knowledge co-construction practices across all stages for both facilitators and synthesizers. While facilitators showed an increasing reliance on *Elicitation* over time, synthesizers consistently maintained a strong connection between *Externalization* and *Integration-Oriented Consensus Building*, suggesting steady engagement in integrating and developing peers' contributions to facilitate collaborative knowledge construction. Summarizers, on the other hand, largely mirrored the No-Role condition, with only a modest increase in the use of *Elicitation* at the late stage. These differences underscore how assigned roles shaped the evolution of students' knowledge co-construction behaviors across different course stages.
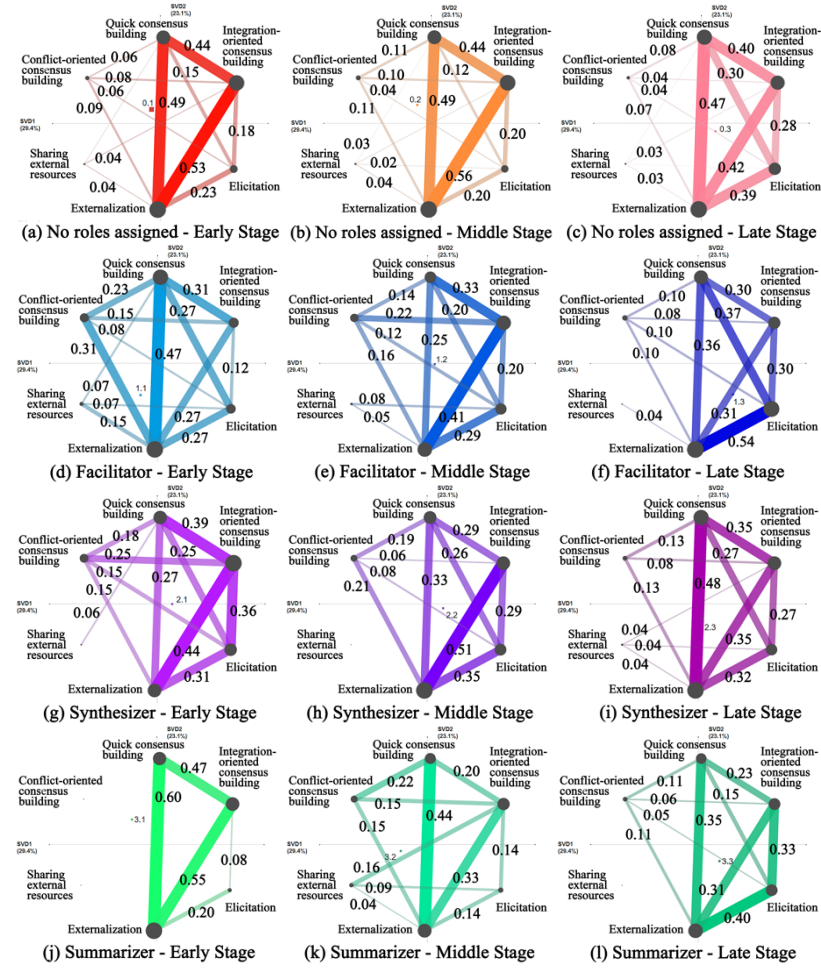
Fig. 2. Role-based knowledge co-construction patterns across different course stages

5   Discussion

To explore how the assigned roles (facilitator, synthesizer, and summarizer) influenced knowledge co-construction in social annotation activities, this study used ENA to examine role-based patterns across the entire course (RQ1) and their evolution across the early, middle, and late course stages (RQ2).

The course-wide ENA uncovered clear distinctions in knowledge co-construction patterns across roles. Both the Facilitator and Synthesizer networks linked four core knowledge co-construction practices—*Externalization*, *Quick Consensus Building, Integration-Oriented Consensus Building*, and *Elicitation*—and demonstrated the strongest interconnections among these nodes. This indicates that students in these roles tend

to frequently acknowledge peers' contributions and actively extend and deepen them while maintaining dialogic momentum through prompting and questioning.

However, facilitators' practices were especially oriented toward prompting peer responses. They frequently followed their own and peers' idea externalizations with provocative questions, references to external materials, and critical engagement with peers' ideas to prompt responses. These strategies align closely with their assigned role to "encourage and advance peer engagement" and suggest that facilitators internalize and enact their responsibilities. Our study extends Zhu et al. [24]'s work by illuminating concrete strategies facilitators employ to foster peer engagement. While they associate facilitators' frequent participation with the depth of class-level knowledge co-construction, we identify three specific tactics—posing provocative questions, incorporating external resources, and critically evaluating peers' ideas—that facilitators employ to sustain and deepen collaborative discourse.

In our study, synthesizers prioritized deepening and integrating peers' ideas, as indicated by a strong link between *Externalization* and *Integration-Oriented Consensus Building* and minimal use of external resources. Rather than introducing new external content, synthesizers appeared more inclined to engage deeply with ongoing thematic threads, integrating and extending others' ideas. This deep and integrative engagement aligns with Zhu et al.'s [24] findings that synthesizers tend to contribute more responses than regular participants and summarizers and play a key role in sustaining connected, in-depth discussions. Such tendencies likely reflect their commitment to producing meaningful and conceptually rich syntheses that largely draw on refining, extending, and connecting peers' contributions, consistent with their mid-week synthesizing duties.

Summarizers, in contrast, exhibited patterns similar to students without assigned roles, with the strongest interlinks observed among *Externalization*, *Quick Consensus Building*, and *Integration-Oriented Consensus Building*. Notably, most of the edge weights for summarizers were weaker than those of students without roles, suggesting that summarizers did not engage as actively. Such less active engagement likely stems from their role's timing—summarization was required only at week's end—thus they might not have perceived a need to contribute in real time and may have focused more on consolidating existing annotations than on generating new, interactive contributions.

Our finding of less active engagement contrasts with De Wever et al. [5], who found that summarizers achieved higher levels of knowledge construction. One possible reason is that summarizers in their study received more detailed instructions: they were expected to post interim summaries identifying tensions and drawing provisional conclusions throughout the discussion, in addition to a final summary. In contrast, summarizers in our study were only asked to provide an end-of-week overview. This distinction echoes prior research emphasizing the importance of specifying role responsibilities and suggests that future practice should offer more detailed guidance and support to help students understand and enact their roles [24].

Building on the course-wide analysis, stage-specific ENA revealed more nuanced temporal developments in role-based knowledge co-construction across course stages.

Notably, in both the No-Role and Summarizer networks, *Elicitation* became more central at the late stage, increasingly co-occurring with other core practices. This

change may be related to the fact that by the late stage, many students rotating into the no-role or summarizer condition had previously served as facilitators or synthesizers—two roles in which *Elicitation* featured prominently—suggesting a potential carryover effect from prior role assignments, whereby students are inclined to retain role-based behavioral patterns even after their formal role changes. Contrary to Ouyang and Chang's [14] finding that students' social-cognitive engagement levels, once established, tend to remain stable through a course, our results suggest "role inertia" that prior role experiences may foster lasting interactional habits beyond its active tenure.

For facilitators, connections involving *Sharing External Resources* declined steadily across stages, while the link between *Externalization* and *Elicitation* grew stronger over time. This trend suggests a shift toward increasingly responding to their own or peers' ideas with probing questions or prompts. Echoing Zhu et al. [24], one possible explanation is that the instructor provided sophisticated scaffolding by clearly articulating facilitation strategies and creating in-class opportunities for role-takers to discuss their experiences. This may have helped subsequent facilitators recognize the value of dialogic prompting, making them more attuned to using elicitation techniques to sustain peer engagement and deepen collaborative discourse.

Consistent with Zhu et al.'s [24] finding that synthesizers typically contribute more responses than no-role students and summarizers, our analysis also reveals their sustained engagement. We further extend this line of inquiry by showing that a substantial portion of their contribution behaviors involve consistently integrating and extending peers' ideas across all stages, thereby facilitating in-depth discussions. This frequent use of integrative approaches to building consensus among synthesizers may reflect their ongoing reflection and deep thinking in response to the role-driven demands of generating meaningful summaries, which in turn shapes their annotation behaviors.

Taken together, these findings demonstrate how different assigned roles shape students' engagement in knowledge co-construction and how the influence of these roles shifts over the progression of the course.

From a pedagogical perspective, these findings yield important educational implications. Assigning structured roles meaningfully shapes students' engagement in knowledge co-construction. However, the impact of these roles varies by role type and course stage, which highlights the need for instructors to not only design roles thoughtfully but also to support role enactment as students progress through the course. In particular, instructors should clearly define and communicate the expectations for each role. Instructors are also encouraged to implement timely pedagogical interventions that respond to evolving patterns of role engagement, thereby sustaining meaningful collaborative discourse over time.

However, several limitations merit consideration. The single-course setting and predefined role scheme may limit generalizability across domains and learning environments. Second, our ENA approach aggregates at the group level, potentially obscuring individual differences in discourse patterns. Third, we focused primarily on the process of knowledge co-construction without examining its relationship to learning outcomes.

To address these gaps, future research should leverage participant-level ENA metrics to reveal more nuanced differences in how students engage with collaborative knowledge construction. Additional analyses could include trajectory analysis across

multiple time points to trace how network structures evolve for both individuals and groups. Another important direction is to investigate how network characteristics correlate with outcomes like learning gains and discussion quality.

6   Conclusion

In conclusion, this study examined how different assigned roles—facilitator, synthesizer, and summarizer—shaped students' knowledge co-construction behaviors in social annotation. Through ENA, we uncovered distinct role-based patterns and temporal progressions of knowledge co-construction practices. The Course-wide ENA showed that facilitators prioritized eliciting peer responses, synthesizers emphasized integrative elaboration of ideas, and summarizers engaged less actively in co-construction. Over the three course stages, these role-based patterns evolved distinctly: facilitators increasingly leveraged elicitation, synthesizers consistently engaged in integrative approaches to building consensus, and summarizers continued to mirror peers without assigned roles, with only a modest increase in the use of elicitation toward the end. These findings underscore the importance of purposefully designing pedagogical scaffolds to sustain meaningful engagement in social annotation and similar learning situations.

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