

The Power of Peer Engagement: Exploring the Effects of Social Collaborative Annotation on Reading Comprehension of Primary Literature

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Abstract

In graduate education (GE), critical reading of reading primary literature (CRPL) is the principal method of learning a discipline and its practices, such as discourse about research and preparation for writing. CRPL is inconsistently taught in GE yet essential, forming a hidden curriculum advantaging the best-prepared students. In traditional reading or journal clubs, PL discourse follows a hierarchical social model, where those with the most knowledge and extroversion dominate discussions. This article reports qualitative findings explaining why online peer engagement using social collaboration annotation (SCA) with embedded prompts supported CRPL in a broader mixed-methods intervention study with doctoral participants in spring 2022. The broader study reported elsewhere was an online intervention delivered over four weeks where participants in various fields read science policy research. Qualitative data collection elicited participants' practices, experiences, and self-perceptions of CRPL in the new field while using SCA for peer-based discourse and collaboration. The findings indicated that when everyone was learning with SCA, they asked questions and learned from seeing each other's ideas in real time, thereby correcting mistakes, activating various critical strategies, and improving comprehension and confidence. Self-doubt and fear calmed down in a supportive environment without the hierarchy of traditional journal clubs. The implication is that students encountering CRPL need and benefit from explicit instruction and low-stakes peer-based discourse practice with SCA.

Keywords: higher education, online learning, peer engagement, social collaborative annotation, primary literature, discourse, critical reading, sociocultural theory, raciolinguistics

1. Introduction

1.1. Overview and context

Ongoing and deep engagement with the primary literature (PL) as a reader, researcher, and writer are essential practices as doctoral students develop into scholars [1]. The primary research literature is a unique genre of writing, not meant to be read from start-to-finish like novels, and beginning graduate students tend to be unaware of this academic norm [2]. Reading is deeply intertwined with writing and research [3]. Despite this, many higher education programs do not explicitly teach critical reading of PL (CRPL) skills, which are generally assumed and unaided [2]. As Margolis noted, whenever skills in higher education are implicit yet essential, they form hidden expectations that advantage the most prepared students [4]. How this hidden curriculum works in graduate education (GE) can be understood through doctoral persistence. Who persists is predictable by the demographic factors of age, gender, ethnicity, and marital status [5, 6]. Men are more likely to finish than women, older White students are more likely to complete than older students of color [7], and married students are more likely to graduate than single students [8, 9]. Another way to explain disparities in doctoral persistence is that the mean time-to-attrition for doctoral students of color is 23 months, a full year earlier than their White counterparts [10]. A telling example of this disparity in GE in the United States is that only 32.5% of doctoral and 46% of master's degrees were earned by students of color in 2018 [11]. What groups more likely to graduate have in common is greater social capital that provides access to essential resources and support [12, 13].

However, even the most advantaged doctoral students will struggle to persist without strong reading skills because “reading and writing do not stand in a functional relationship with inquiry [i.e., research] but are constitutive of it—essential elements of the whole” [14, p. 226]. Instructors often fail to take advantage of the interconnection between reading and writing [15] in terms of interrogating texts [16] and developing critical reading skills [17], which at the doctoral level include being able to evaluate arguments critically [2]. Instead, doctoral reading is done in isolation and without feedback, except for occasional journal clubs [18–20]. An essential aspect of literacies, whether reading, writing, or reflecting, is that they are “derived from social practices (...) are socially constructed, often with our friends, in specific contexts, for specific purposes (...) and grow (...) from schools, from work, from cultures, from knowledges, from technologies, and so on” [21, p. 70]. From this constructivist view of literacy, CRPL in isolation should hinder critical reading skill development in all students as well as the co-constructed skills of writing and research.

Previous scholarship details this hindrance. In a seminal article, Boote and Beile observed that the “dirty secret known by those who sit on dissertation committees is that most literature reviews are poorly conceptualized and written” [22, p. 4]. Problems with writing indicate that student authors are unfamiliar with the conventions that make for effective research writing, underpinned by what Matarese described as a need for “an effective approach to reading in their discipline” [23, p. 76]. In other words, weak reading leads to weak writing.

Social collaborative annotation (SCA) is a strategy for building a learning community that is impossible with individual reading activities and is exceptionally well suited for online learning environments [24, 25]. SCA is a tool for increasing learner engagement in online courses, defined as “psychological investment in and effort directed toward learning, understanding, or mastering” [26, pp. 205–206]. Despite generally positive outcomes, minimal scholarship addresses the usage of SCA in online GE [27], a context that grew 155% from 0.9 million students in 2012 to 2.3 million students in 2020, similar to online undergraduate education growth during the same period [28]. The present study addresses this gap by providing a rich qualitative explanation of how and why peer engagement with PL using SCA improved reading comprehension in an online critical reading skills intervention of reading PL in a new field [29]. This article aims to advance the understanding of online peer engagement in terms of reading and annotation skill development at doctoral level.

1.2. Theoretical and conceptual framework

Sociocultural theory provides the theoretical framework to explain findings between language and learning in higher education [30]. Learning occurs primarily from participating in discursive activities between teacher and student or between students in a collaborative discussion [31], which culminates in a written thesis at the doctoral level. Students develop and refine their thinking in GE through reading, writing, and feedback from more knowledgeable peers, professors, and advisors [31]. In online learning environments, student engagement develops through social interactions, and centering interaction with peers, instructors, and content is essential for success [26].

The traditional method to advance doctoral scholarship is the pedagogy of feedback, a form of sociocultural scaffolding aligning with Vygotsky’s zone of proximal development [30]. Advisors, serving as the more capable peer, edit rounds of writing to help doctoral students define the research topic, scope, and design of the project, gather materials, write and work through manuscript drafts, and disseminate their findings [32, 33]. This model assumes students already have CRPL skills [1]. It also leaves many research advisors feeling drained and frustrated, especially when the dissertation lags or students quit [10, 33–36]. Consequently,

many students experience challenges learning the co-constructed skillsets of reading, writing, and researching from ambiguous or avoidant feedback [37, 38], or worse, for raciolinguistically diverse students, lack of guidance or intentional mistreatment [39]. It is no surprise, then, that the pedagogy of feedback works for some, is neutral for many, and harms others [37–39].

Adequate support and mentoring to develop literacy skills are significant barriers to the progress of raciolinguistically diverse students in graduate education [38, 40]. Language is a primary way humans create racial and ethnic identities, and therefore, language is inherently related to race and vice versa, a connection highlighted in the field of raciolinguistics [41]. As a conceptual framework, a raciolinguistic perspective acknowledges the co-construction of race and linguistic varieties as part of colonialism, settler nation-state formation, and world history [42]. This perspective also acknowledges that online environments can unmask covert racism [43]. Thus, race and ethnicity data were collected in this study to contextualize participants' raciolinguistic experiences within the sociocultural framework of peer-based discourse about PL.

2. Review of the literature

SCA provides new, creative affordances that transform reading, typically an isolating activity, into socially constructed learning opportunities with generally positive outcomes [27, 30], such as improving student reading compliance and increasing engagement in course activities [44, 45]. SCA is both a pedagogy and a tool. SCA as pedagogy allows instructors to transform their courses from teacher-centered to student-centered. For example, SCA provides a low-stakes environment for asking questions and making sense of a text [27]. Instructors can use SCA to guide students through taking reading notes and making annotations shared with peers in real-time using one or more software tools [26]. For example, online software with SCA functions includes Google Suite (Alphabet, Inc; Mountainview, CA) and OneNote (Microsoft; Seattle, WA). In addition, there are dedicated SCA tools, such as Hypothes.is (San Francisco, CA) or Perusall (Austin, TX). Whichever works, SCA tools broadly provide opportunities for constructivist learning.

Sociocultural learning should go beyond the student-advisor relation to include peers and more capable others, as Brown and Renshaw described [31]. Graduate students experience and learn disciplinary and cultural norms through many sociocultural interactions, such as coursework, during lectures and presentations, conferences, and discussions of the primary literature [19, 20, 46, 47]. A study of 422 Canadian doctoral students found that interactions with other people in the program, including peers, played a role in students' persistence and was positively associated with degree completion [48]. Later research confirmed this finding [48]. Collaboration is a type of interaction with others that promotes learning, and its

essential components include the activities of resource sharing, participatory pedagogy, and peer-supported learning [49]. An annotation is a form of collaborative learning where a networked peer community blurs the distinctions between author and audience, allowing for new knowledge creation and helping to build a more participatory learning environment [50]. Thus, creating supportive peer engagement is beneficial for student learning and persistence.

SCA can promote critical reflection among learners [48, 51]. Critical reflection and critical thinking are often used interchangeably in the literature, where critical reflection is necessary for critical thinking. Dewey defined critical reflection as an active, persistent, and careful consideration of a belief or supposed form of knowledge, the grounds that support that knowledge, and the further conclusions to which that knowledge leads [52]. Annotating specifically supports content knowledge [53]. In other words, learners monitor what they know and need to know and how they bridge that gap during learning situations. SCA provides real-time peer feedback essential for monitoring [24–26, 28].

A comprehensive review of SCA in 2020 found an active field of 249 studies, of which 39 studies had empirical designs [54]. Most of these studies focused on undergraduate or K-12 classrooms; only a few focused on higher education or graduate students. SCA increased engagement with peers and course readings in two studies [24, 55]. In one study, participants exposed to SCA performed better on reading comprehension tests and reported less mental effort [55]. In another, comment analysis indicated that most of the comments were individual self-reflections (47%), followed by showing support (14%), elaborating on others' ideas (10%), and recognizing something new (7%) [24]. Many comments proposed complementary, alternative views (21%), while none offered disagreement, suggesting a significant limitation of SCA for scholarly discourse, where contradiction and disagreement are desirable.

At the graduate level, two studies compared social app tools, Slack (San Francisco, CA) and Hypothes.is (San Francisco, CA), for annotation generation and management. Both studies found increased engagement with academic texts and higher-quality discussions. Hollett and Kalir examined two cases in graduate courses using the concept of digital graphic organizers [56]. The qualitative findings showed that an online learning environment combining formal course activities with informal social media practices increased the learners' sense of agency. Similarly, Chen (2019) created a pilot course testing SCA and replaced the online discussion forum with Slack, a team communication tool, and Hypothes.is, a social annotation tool [57]. The findings showed that the social annotation tools generated a positive learning experience for the participants, with increased agency. However, participants relied more frequently on public conversations on Slack than private messages in Slack or Hypothes.is replies,

suggesting that real-time public channels generate more activity for collaborative discourse.

Finally, another significant area of research considers annotation as an active reading strategy to improve reading comprehension. In higher education, annotations can improve reading comprehension [58, 59] and mediate the internal process of reading and the external writing process [25]. When combined with new affordances of online annotation tools, several studies of social collaborative annotation (SCA) reported skill and motivation improvements in areas relevant to this study [54]. These improvements in higher education contexts included:

- increased engagement with course readings and peer discourse [24, 57];
- improvements in reading comprehension, motivation, and mental effort required to read [55, 59];
- learning gains in reading comprehension, critical thinking, meta-cognitive skills, and improved motivation and positive feelings [58, 60]; and
- evidence of group inquiry, establishing associative connections, and discerning multiple perspectives [24].

Thus, these studies showed positive learning gains associated with SCA among undergraduate and graduate students, as described by Cohn [27] as reducing mental effort and increasing motivation, engagement, and metacognitive skills in higher education; and by Bjorn (2023) as improving reading comprehension as critical reading, reading apprehension, and research self-efficacy in GE [29].

This SCA research has several implications. One implication is to challenge academic course timelines. The findings indicate the possibility of sustaining a group of collaborators across terms within the broader university system. Another implication is a digital version of the Funds of Knowledge approach, whereby the learners' formal (i.e., school) and informal (i.e., home) environments interconnect to enrich and increase learning gains [61]. A third implication is that technology acceptance is a significant factor, and models, such as the Technology Acceptance Model, should be considered seriously in planning future research [62–64].

3. Methodology

This study aimed to understand participants' experiences with peer engagement through SCA while reading PL in a new field in an online learning environment and preparing for writing. The study was part of a broader mixed-methods study investigating critical reading skills using the CERIC (claim, evidence, reasoning, implications, and context) method and SCA for discourse [29]. The approach to analysis in the study was mixed methods parallel convergent design with pre-post

testing [65–67]. The complete findings of the broader study are reported elsewhere [29].

The qualitative arm of the broader study about peer engagement with SCA yielded exceptionally rich data sufficient to warrant its report presented herein. These data were collected during the spring of 2022 and then triangulated to address multiple research questions. The treatment consisted of a free, six-module online course delivered to doctoral students over four weeks. Data from 24 participants were included in the analysis, and nine study participants volunteered and completed in-depth, structured interviews. The approach to analysis in the qualitative arm was three rounds of coding: content, pattern, and thematic. The data were then triangulated, checked with members, and quantized.

3.1. Context and participants

The context was an online eight-week professional development course offered by the National Science Policy Network (NSPN) from March 1 to April 25, 2022, as preparation for a national science policy brief writing competition. Study participants used a software ecosystem consisting of Canvas for the course and Hypothes.is for SCA. Learners had to create free accounts for each as part of the pre-session enrollment. Study participants were further instructed to choose usernames that did not reflect their names, an essential step to protect their privacy.

The study participants included only currently enrolled doctoral students in U.S. university programs. Individual doctoral students were the unit of analysis. The primary exclusion criteria were enrollment in a non-U.S. doctoral program and enrollment in programs where reading is a topic of study, such as English, Journalism, and Rhetoric. Participant recruitment occurred through convenience sampling [68]. The sponsoring organization, NSPN, contacted their nationwide membership ($n = 1574$) with an online invitation to participate. They sent invitations through their email newsletter, website posts, and social media channels. Of those who responded, 28 indicated an interest in the study, and 24 met the inclusion criteria, consented, and began the study. Four people who did not qualify were not currently enrolled doctoral students (one was an undergraduate, and three were post-baccalaureates). The completion rate for the study was 100%.

Participant profiles reflected various life and professional experiences, as shown in Table 1. Participants had doctoral experience ranging from one to six years of full-time equivalent study. Nearly half of the participants (46%) were in the pre-dissertation stage (i.e., “early” defined as years 1–3), and most studied Life Sciences (58%). Participants represented all geographic regions of the U.S., except the Northwest, and were attending research-intensive universities (R1 or R2). Most participants were ages 25–34 (88%) and identified as women (79%). No participants had formal preparation in science policy, the field that served as the intervention’s

Table 1. Study participant profiles.

Study ID	Doctoral year, field	US region	Age group	Gender	Race/ethnicity	Prior online courses (any level)
SCA01	2, Life Sciences	Northeast	18–24	Man	Asian/Asian–American	1–2
SCA02	3, Physical Sciences	Midwest	25–34	Woman	White/Euro American	0
SCA03	3, Applied Sciences (Eng)	Midwest	25–34	Woman	White/Euro American	0
SCA04	5, Life Sciences	Southeast	25–34	Woman	White/Euro American	3–5, certificate
SCA05	4, Physical Sciences	Northeast	25–34	Woman	White/Euro American	1–2
SCA06	3, Life Sciences	Midwest	25–34	Woman	Hispanic/Latino	1–2
SCA07	5, Life Science	Southeast	25–34	Woman	Two or more races	0
SCA08	4, Life Sciences	Southeast	25–34	Man	Asian/Asian–American	0
SCA09	4, Applied Sciences (Eng)	Southwest	25–34	Woman	White/Euro American	3–5, certificate
SCA10	4, Applied Sciences (Pharm)	Midwest	25–34	Woman	White/Euro American	1–2
SCA11	2, Life Sciences	Northeast	25–34	Man	Asian/Asian–American	0
SCA12	5, Applied Sciences (Eng)	Southeast	25–34	Woman	Hispanic/Latino	3–5
SCA13	3, Life Sciences	Midwest	25–34	Woman	White/Euro American	0
SCA14	2, Life Sciences	Southwest	25–34	Woman	Hispanic/Latino	0
SCA15	1, Life Sciences	Southwest	18–24	Woman	Hispanic/Latino	1–2
SCA16	3, Physical Sciences	Midwest	25–34	Woman	White/Euro American	0
SCA17	5, Physical Sciences	Midwest	25–34	Woman	White/Euro American	0
SCA18	6, Life Sciences	Southeast	25–34	Woman	Hispanic/Latino	0
SCA19	5, Life Sciences	Southeast	25–34	Non-binary	Black/African American	0
SCA20	1, Life Sciences	Southwest	25–34	Man	White/Euro American	0
SCA21	3, Life Science	Southwest	35–44	Woman	Asian/Asian–American	1–2
SCA22	4, Life Science	Southeast	25–34	Woman	Hispanic/Latino	1–2
SCA23	5, Social Sciences	Midwest	25–34	Woman	Asian/Asian–American	0
SCA24	5, Physical Sciences	Midwest	25–34	Woman	Black/African American	1–2

topic, or astrophysics, the field from which the pre-post reading assessments were drawn.

While participation by people identifying as BIPOC was not an explicit recruitment goal, the demographics were significant and reported herein for three reasons. First, the scholarship on raciolinguistics in higher education indicates significant barriers for students of color [41, 42]. Second, participants shared experiences related to race, ethnicity, and gender, and this data was significant to the findings. Third, the host organization, NSPN, tracks diversity, equity, and inclusion (DEI) outcomes in their science policy activities, where people of color are underrepresented. To these aims, participants who identified as Asian or Asian American (21%), Hispanic (17%), Black or African American (8%), and Two or More Races (4%) were more highly represented in the study than in NSPN’s membership. This data provided important feedback for NSPN about its outreach efforts.

Participants were randomly assigned unique study numbers, ranging from SCA01 to SCA24, to protect their identities. Quotations in the remaining discussion reflect only this anonymous identifier. Citing participants by study number, while nontraditional, is not proscribed [65, 66, 68] and allows for greater accuracy, synthesis, and transparency in reporting this rich and complex data set that would not be possible with traditional citation methods.

3.2. Data collection

Data collection included six sources of qualitative data: software reports, participants' SCA work products (i.e., SCA assignments with embedded prompts), written metacognitive reflections, researcher observations, and interviews. The collection tools and frequency varied by the data source. Software reports measured participation and were generated daily by Canvas and Hypothes.is. Participants' work products were generated weekly by participation in course assignments and submitted through Canvas. Metacognitive reflections were generated weekly and submitted through Canvas. Researcher observations were generated weekly using two rubrics, implementation and session observation. Interviews were completed weekly through open-ended questions and at the end of the course as an in-depth structured elicitation of participants' experiences. For the follow-up interviews, data collection occurred through audio-only calls on Zoom. The audio files were transcribed using Otter.ai and checked for accuracy. Data collection was completed in April 2022.

3.3. Data analysis

The qualitative data were analyzed using content and thematic analysis [69]. Content coding and thematic analysis of the participants' interviews were appropriate to address qualitative research questions about participants' lived experiences and understanding [70]. Specific qualitative analysis techniques included inductive coding, pattern analysis, thematic analysis, frequency (i.e., counting), and proximity analysis [70–74]. The initial analysis occurred in three rounds, content-coding, pattern analysis, and thematic analysis. Then frequency analysis regarding SCA patterns from the Hypothes.is data sets were visualized by Crowdlaers using learning analytics and quantization [69]. Additional software support for qualitative analysis came from the software NVIVO (QSR International Inc., Melbourne, Australia), which the student researcher used to code all assets digitally.

Coding qualitative data, such as interview transcripts, began with a conventional, inductive coding process [65, 70]. The researcher read each transcript line-by-line and marked the margins with impressions, ideas, concepts, words, phrases, and perceptions of emotional affect [73]. During the first coding cycle, the researcher

used a descriptive coding method to assign labels to data and then summarized those in a word or short phrase. This approach's advantage was to gain information directly from the participants without imposing preconceived notions [73]. In addition, the researcher wrote summaries after each interview and memos while coding interviews, continuously recording interactions between data and theory [74].

The first analysis round included pattern analysis and thematic coding, highlighting patterns and themes within the same participant's work over a few weeks and between participants. The second coding round was focused on coding, aiming for code saturation and testing emerging ideas with disconfirming information [73]. The final coding round was theoretical coding, building on emergent concepts to clarify relationships between codes and themes, comparing findings with theory, and generating new hypotheses.

3.4. Researcher positionality

The research paradigm that supports this research is an indigenous insider with added expertise [74, 75]. Many past and present roles position the researcher as indigenous to the academic writing and publishing community, including scientific writing instructor, coach, manuscript editor, published writer, and former researcher in life science. The researcher understands the community's perspectives, behaviors, beliefs, and knowledge through these roles. Likewise, insider status comes from holding past and present institutional affiliations, such as at Johns Hopkins University, Nature Publishing Group, *Science*, *The New York Times*, and others. Crucial for this study and collaboration with the context, NSPN, the researcher was a science policy reporter for two years with *Nature Medicine*. Thus, this community perceives the researcher as a legitimate member who can speak with authority about publishing, language, reading, writing, annotation, and science policy skills at the doctoral level.

A deeper reflection of this indigenous-insider paradigm reveals several unearned advantages [76]. First, the researcher grew up speaking "standard" English and, thus, had a raciolinguistic advantage when learning MAE. To conduct this research, the researcher did not have to unlearn, relearn, or assimilate into a new raciolinguistic identity [21, 42]. In addition, the researcher identifies as White and cis, the default norms of White Supremacy Culture (WSC) within the academy, with characteristics such as perfectionism, one right way to do things, objectivity, and obsession with the written word [77, 78]. Finally, the researcher identifies as a U.S. female teacher. The unexamined Whiteness of teaching is normalized and centered because most U.S. K-12 teachers are White women [79]. Thus, a central task of teacher preparation is to explore stereotypical racist attitudes towards students of color and minoritized groups, including assumptions about what students should

know [80]. One way to challenge WSC within academia is to make expectations explicit and offer instruction in assumed skills, a central aim of this study.

This mix of positionality exposes the researcher to name, recognize, and act to change the racism and linguicism deep in the consciousness [21]. Applied to this research study, this work means that the researcher emphasizes qualitative data (i.e., interviews and observations) as the highest priority. Qualitative data focuses on the participants' experiences and avoids the WSC trap of objectivity [65]. Also, the focus on narrative data allows for an epistemological perspective that centers on the participants' experiences [66]. After all, the researcher is an indigenous insider who identifies as an expert in the dominant raciolinguistic group. However, the researcher does not assume to know already which constructs to test, which is why the study's focus on qualitative data is essential for exploring, explaining, and generating additional hypotheses and implications for practice and research.

4. Results

As described elsewhere by Bjorn (2023), participants using the CERIC method combined with SCA for four weeks in an online intervention showed improved reading comprehension as critical reading of the primary literature (CRPL) [29]. Other statistically significant improvements in that study were in reading apprehension, research self-efficacy, confidence, and ease ($p < 0.0001$ for all pretest-posttest indicators). Given limited prior scholarship, these findings are worthy of a deeper explanation, especially because of the foundational nature of CRPL to advancing in higher education.

This article explores the impact of one factor, peer engagement, using SCA with embedded prompts as having a significant impact on critical reading and annotating skills of primary literature in a new field. Peer engagement emerged as a powerful factor for learning from thick, rich descriptions of participants' experiences. In addition, these data generated several major themes, such as seeing other people's ideas improved reading comprehension, and SCA created a low-stakes and supportive learning environment. Finally, participants identified many possible uses of SCA in higher education.

4.1. Peer engagement supported reading comprehension

Participants reported engaging with their peers using SCA in at least two ways, a passive reading of other people's annotations and an active peer response. Peers provided valuable, low-stakes checks for understanding the text (SCA09, SCA15, SSCA18, SCA21, SCA23). A participant summarized the process, "You can first annotate what you don't understand and then compare to others" (SCA09). The online and collaborative nature of the SCA tool meant that feedback on ideas about

the text was available to all participants as needed in real-time throughout the intervention, whenever participants were reading.

4.1.1. Peer engagement activities were beneficial to reading skills

The intervention benefited participants' reading skills, anxiety and procrastination, and reading in a new field. The most beneficial activities for reading skills included interacting with peers about the text using SCA (50%), learning a strategic reading method (38%), collaborating and communicating about a usually silent and internal process using SCA (29%), doing activities that promoted critical thinking (17%), having a safe online forum to develop a deeper understanding of the text (13%), and the ability to annotate from anywhere with an online tool (13%). Nearly all of the activities reported as beneficial are attributable to online peer engagement with PL using SCA.

Several participants reported that these activities worked together to improve reading comprehension as critical reading (SCA06, SCA15, SCA21, SCA24). One participant explained how:

I feel that these course activities are helping my reading comprehension [because] I get exposed to the material several times, including other people's ideas. I have a place to ask questions. Writing an annotation or two (...) further helped me retain and understand the material since I had to put the elements together, not just identify them. (SCA06)

This participant explained that multiple activities helped her improve her reading skills. The net effect is to create "a clear understanding of what I should focus on as a reader, which has been very helpful for my comprehension [of the paper]" (SCA24). Thus, it appears that the interplay of multiple activities helped to deepen the understanding of the text.

4.1.2. Seeing other people's ideas in real-time helped correct misunderstandings

Participants found great value in seeing other people's ideas about the shared reading. SCA revealed other people's "thinking about the paper" (SCA05, SCA09), which made "discussing [papers] more interesting" (SCA18, SCA09) because people had "different ideas" (SCA08, SCA07, SCA06). This process "raised questions" (SCA17, SCA02) through "peer feedback" (SCA14, SCA18) that "improved understanding" of the paper (SCA09, SCA18, SCA19). One participant described feedback from peers as the most important connection between SCA and improving reading comprehension, "I got real-time feedback from my peers while reading and annotating [with SCA], and that helps me monitor my reading skills and also my understanding of the paper" (SCA18). Real-time peer feedback helped participants correct misunderstandings in reading and monitor reading skills, which is essential for improving reading comprehension.

By comparison, feedback on a reading from professors or advisors “may take weeks or months, if it comes at all” (SCA21), during which time people may “forget their thinking” (SCA18) or erroneously “learn their mistakes [as correct] because of long waits for advisor feedback” (SCA17). Some participants reported waiting 30 days or longer for advisor feedback on shared reading if it came at all (SCA17, SCA18, SCA21, SCA23). In contrast, SCA provides immediate peer feedback, which still has value, even if the subject matter knowledge is less than that from an advisor. Value comes from transforming the reading process—from isolating to collaborative and from untimely (or never) to immediate.

4.1.3. *Peer engagement increased self-monitoring while reading*

SCA was valuable for individuals to monitor their reading skills to see what “ideas [they] missed and what ideas stood out to different people” (SCA06, SCA14, SCA18). Self-monitoring compared to peers led to questions and discussions that improved individuals’ understanding of the paper. A participant explained it this way, “I tend to ask questions when annotating, and I find this helps me get a better idea of my understanding of the paper and any gaps I need to fill in” (SCA10). This participant reminds us why social interaction is essential for learning and how discourse is a primary way to construct knowledge at the doctoral level. SCA offered social interaction and a flexible forum for discourse about research literature, which helped participants understand the PL better.

Participants noted that while an annotation is a marker for understanding, it does not replace deeper reading. One participant explained:

It’s important not to be caught up in only annotating because when annotating, I tend to just hunt for sentences and mark them up. I don’t fully process what I’m reading. It’s very important to then go back and actually read the content of what you annotated, using the annotations as markers for understanding. (SCA21)

Thus, annotation did not replace deeper reading and provided markers for understanding that the annotator must still process.

4.1.4. *A positive experience, even with no or neutral benefit to reading*

Some participants suggested that they experienced no or neutral personal benefits to reading comprehension and still experienced benefits from their experiences with SCA. Some participants had a neutral experience that “did not help reading comprehension of primary research” but did “not hurt either” and found “seeing other people’s ideas interesting” (SCA09, SCA10). One participant clarified, “I don’t think the course materials had a particularly large effect on my reading comprehension, but it has given me some interesting new ideas, some of which I

may adapt into my usual [reading] process” (SCA10). This participant used what she learned in the intervention to teach a college course on reading.

There were no study requirements for peer responses or annotations, only suggested guidance (e.g., respond to two peers, be respectful). Thus, the frequency of peer responses varied widely in this study. Some participants never responded to other’s annotations (SCA01, SCA10, SCA11, SCA13, SCA15, SCA22), while others responded ten or twelve times in a session (SCA02, SCA03, SCA05, SCA10). The peer responses that were generated created a “supportive environment” that helped participants “check [their] thinking safely” (SCA15, SCA18, SCA23). All participants who did not respond to their peers cited heavy workloads and conflicting obligations external to the intervention as a barrier to more peer response participation. The low frequency of some peers’ responses was identified as a weakness of SCA (SCA09, SCA17, SCA21).

Finally, it was challenging for participants to know what they did not know about a new field. Where participants did not mark up the shared text provided insight that informed instruction. When participants avoided annotating the section in the intervention text, for instance, about using Cronbach alpha values to validate constructs, the absence of any annotation suggested a need for support, explicit instruction, or other strategies to process the information. In response to these data, the researcher added information about Cronbach’s alpha to the weekly discussion about social science methods. Thus, SCA was also a method for improving the intervention design. In summary, SCA promoted peer engagement in two ways: passive reading of others’ annotations and active responses, which were beneficial for reading comprehension and self-monitoring.

4.2. SCA created a low-stakes and reassuring learning environment

SCA helped to create peer engagement around a shared text, but more than SCA was needed to guarantee a positive online learning environment. Other intervention components and activities combined with SCA created a low-stakes environment where people felt safe to ask questions. The combination created a reassuring and psychologically safe learning environment necessary for learning at any stage, especially with a new topic and group. Feelings of safety allowed some participants to open up and share many of the invisible experiences they faced as students of color.

4.2.1. Peer engagement with SCA reduced fears about reading PL in a new field

Peer engagement with SCA decreased participants’ fears about reading PL in a new field by creating a safe/supportive environment (71%), cooperative learning (38%), feeling like we are all learning (30%), and a flexible structure (30%). A participant summarized her experience of the interplay of these components:

When I do not have support or a sense of safety from my environment, my anxiety levels rise, and instances of imposter [phenomenon] reappear. This directly leads to higher stress levels and lower productivity, but this course was supportive and flexible and did not trigger it.” (SCA24)

Another participant shared this struggle and elaborated:

I struggle because I have trouble prioritizing tasks, and therefore, I start experiencing anxiety and procrastinate until the last minute as a result. It's the worst with reading and writing because it all just piles up. Working with others [in this course] helped because we were all learning together, and I felt supported, [which] helped me calm down and get things done. (SCA21)

No single instructional component improved participants' feelings of anxiety and procrastination. Instead, the interplay of multiple supportive components helped participants relax, focus, and get involved. These included a “cooperative” or “supportive” learning environment (SCA09, SCA10, SCA11, SCA14, SCA19, SCA22, SCA23), “empathy” and “understanding” from the instructor and group (SCA05, SCA21, SCA13), focus on “specific skills” and “strategies” (SCA04, SCA17, SA07, SCA14, SCA12), “not being expected to know” new information (SCA09, SCA21), having a “safe a way to learn” technical information (SCA19), and feeling safe to “make mistakes” as part of the learning process (SCA18).

Further, the intervention was beneficial to reading in a new field. Beneficial components included focusing on career goals that require new skills (83%), everyone being new to the field of policy research (50%), exposure to mixed methods research (46%), group discussions (38%), and instructional materials (25%). A participant identified a central issue whereby he was “trained in experimental methods, not mixed methods, but needs to know something about it to evaluate policy research” (SCA08). All participants studied experimental research methods; only one had formal learning opportunities in mixed methods. For many participants (71%), the intervention offered the first engagement in social science research methods. Another participant elaborated on how these components interacted to support reading in a new field:

Being new in the field, the unfamiliarity and lack of thorough comprehension of some of the research topics felt very intimidating, but everyone was new, too. I found the group discussions helpful in gaining an in-depth comprehension of content outside of my field and learning some new methods for policy research. (SCA21)

Thus, having productive group discussions while feeling safe to participate improved learning in a new field.

4.2.2. Peer engagement improved feelings of reassurance and confidence

Peer engagement using SCA relieved self-doubt and fears about reading and discussing PL, in part, by checking negative feelings associated with the imposter phenomenon as described by Clance and Imes [81] and improving confidence [29]. Participants reported feelings of validation and reassurance working with a social collaborative annotation group when they were:

new to the topic and “learning together” (SCA01, SCA18, SCA04, SCA17, SCA23, SCA22);

“seeing notes together and tagging” (SCA17);

“brainstorming together, keeping track of z and reflections” (SCA16);

“fumbling, struggling, and figuring it out together” (SCA23);

“noticing similar points [or ideas] in the readings” as their group members (SCA09, SCA23, SCA22);

“talking about papers together and [their] pitfalls” (SCA04);

feeling “free to ask questions” without feeling “intimated” or “afraid” (SCA05, SCA06, SCA11);

“working together with peers and helping each other (...) [this increases] my feeling of comfort, enjoyment, and engagement in the projects” (SCA13);

“exchanging [or sharing] ideas with peers” (SCA08, SCA04, SCA10, SCA14, SCA18, SCA21); and

“giving and receiving peer feedback” on annotations (SCA11, SCA10, SCA13, SCA19, SCA20, SCA22).

Thus, participating in SCA can be reassuring, especially when individuals notice the same things as their group members. A participant explained why “collaborating with others on reading is way more useful than I thought. There is value in sharing ideas, compared to reading things in isolation” (SCA23). Overcoming isolation while reading, noticing, and sharing ideas about a paper generated feelings of self-assurance. Another participant elaborated on how the course experience had an impact on deeper feelings of confidence:

In this course, we’re all kind of fumbling, struggling, learning, and figuring this out together. I found it was quite helpful working as a group. I worried less and felt more confident about my answers and the [main ideas] that I picked out from reading [the] article. (SCA23)

Learning collaboratively with SCA increased confidence, a positive factor for academic success. Specifically, SCA boosted participants' confidence in their findings and conclusions (SCA17, SCA23, SCA05, SCA21). One explained how “we could trace back questions [with SCA] and feel really secure about the information and interpretations. We could see the logic chain and were confident in our results” (SCA17). Thus, tracking shared questions with supporting information helped participants feel “less worried about not being good enough” (SCA09) and more confident in their interpretations of the paper.

By comparison, a few participants struggled with low confidence and felt reluctant to participate in a group discussion. What helped was to “remind myself that we are all learning!” (SCA05, SCA21). When everyone learns together without a hierarchy or competition, self-doubt and fear can calm down.

Other doubts are more deeply rooted. Reading research papers was just one area where participants expressed that they constantly doubted their skills and abilities, mainly because they typically read alone. Other areas of doubt included lab work, coursework, conducting literature reviews, researching, writing, public speaking, and networking (SCA01, SCA08, SCA15, SCA05, SCA10, SCA11). These skills are essential for success in doctoral programs and need to be addressed by educators if students are to succeed.

4.2.3. Positive peer engagement elicited the sharing of invisible barriers

Several participants of color felt safe enough to share their experiences of having extra challenges related to essential academic skills like reading. A participant of color explained the experience:

When I first came to graduate school, it was a heavy transition for me. There were many times that I felt I was floundering, fearful, and didn't belong. It also seemed that my other [mostly White] colleagues were okay, which made me feel worse and increased my anxiety. Of course, this is a dangerous game of comparison, which does no one any good. There is also the pressure that ‘you should just know’ something that everyone seems to know, like reading research papers, making it hard to reach out to other students to see if they are experiencing the same thing. (SCA24)

This participant described the bind of comparing herself to others while fearing she did not belong in her academic program with the added pressure of assumed skills, such as reading research papers.

Another participant of color echoed this experience when she explained how she often feels, “I am not doing enough reading and research, and I don't know enough

about the topics that I should have grasped. This is further worsened by academic bullying” (SCA22). This participant named academic bullying a reality in academic environments. A third participant of color described academic bullying as “competition [that] drives us to bash other scientists and science students. In academia, knowledge/intellect is the most valued commodity, which is why there is so much stress in being revealed as a fraud” (SCA21). The stress of being found out as a fraud had another dimension for participants of color. A participant offered this insight:

This kind of fear [of being a fraud] is often felt most strongly within groups that are underrepresented in science. This is because the feeling of impostor syndrome is often framed as students doubting their skills/talents when a lot of the time, there are many invisible barriers preventing a student’s success that do not get talked about. (SCA16)

These invisible barriers may include feeling unfairly judged on academic abilities because of personal traits, including “skin tone” (SCA16), “accent” (SCA23), intersectional identities, such as a “nonbinary and Black” (SCA19), and other harmful stereotypes, such as being a perpetual foreigner “because you look Asian, people assume you’re foreign and ask you where you’re from all the time” (SCA21). To the latter point, the participant explained how she was “never nominated for funding or awards that required U.S. citizenship because the people around me assumed I was foreign. I had to apply for everything on my own” (SCA21). These invisible barriers based on visible traits added to feelings of being unfairly judged and were only reported by participants of color. Invisible barriers were described by participants as leading to less funding, fewer nominations, slower advancement, and in some cases, quitting doctoral programs (SCA17, SCA14, SCA11, SCA21). For participants of color, positive peer engagement using SCA provided relief, in part, by providing a safe, low-stakes learning environment to check impostor phenomenon and improve confidence [81]. In summary, SCA, when structured with prompts, was a powerful tool in fostering positive peer engagement and creating a psychologically safe learning environment, especially for students of color.

4.3. Annotation is a dynamic reading practice that improves with practice and feedback

Participation in the intervention produced various impacts on annotation practices. Several rich themes emerged from the data, including a range within the group, various experiences with annotation before the course and evolving annotation practices. These themes reveal that annotation is not a static or fixed skill but a dynamic practice that changes with instruction, experience, and feedback.

Overall, annotations varied widely per participant in quantity and quality, with differences attributable to their prior knowledge and experience with annotation. In total, participants produced 810 annotations, and of these, 141 (17.4%) were in threads, meaning they were responding to peers. Of the 24 participants, 12 produced the most threads, averaging responses to 10 threads each. These participants were the most engaged with their peers throughout the intervention. In addition, a moderate correlation between SCA frequency and quality was indicated by the Spearman correlation coefficient between these two variables, $r(22) = 0.6, p < 0.05$. This finding is nuanced because participants reported that two factors, competing work demands during the intervention and prior experience with annotation, affected their SCA quality and quantity.

Some participants had taken annotation courses as undergraduates. One participant reported many years of experience with annotating research papers. However, she produced high-quality, standalone annotations with low frequency, citing a hefty workload as a barrier to participation in the intervention (SCA09). Another participant reported some experience with annotation in college, and in contrast, he produced many annotations of low or moderate quality in many threads (SCA08). There was a range of annotation experiences in the group.

In addition to a range of experience, participants also reported a range of annotation practices. Reported methods include highlighting PDFs with Adobe Reader (SCA09, SCA11), taking notes on a tablet (SCA01), using comments in Google Docs (SCA08), and sending long email chains (SCA18, SCA04). Participants reported annotating primarily for reading clubs (SCA08, SCA18, SCA04), in preparation for qualifying exams (SCA18, SCA21), for paid work (SCA09), and teaching (SCA10). Finally, one participant reported never annotating articles independently (SCA08). Thus, the range of participants' annotation experiences and practices was wide, despite all being enrolled in U.S. doctoral programs.

During this intervention, all participants reported gaining their first exposure to SCA and an online tool (i.e., Hypothes.is). Nearly all participants reported a positive first experience (83%), while some reported a neutral first experience (17%). None reported the experience as negative. There were many benefits for those with a positive first experience with SCA, such as seeing in one place "where all the ideas are happening, and what each person is thinking" (SCA08). Others liked it because "you can first annotate yourself, mark what you don't understand, and then compare to other people were saying" (SCA09) or "just have little conversations in the margins" (SCA04). About half of the participants reported using the "I" icon at the top of the annotation tool to block annotations, so they could first read an unmarked text before seeing others' ideas.

In contrast, the other half reported reading the annotations while they read the text. Some compared SCA for reading collaboratively to the same benefits as Google

Docs for writing collaboratively (SCA08, SCA04, SCA09). Another participant described having difficulty transitioning from reading articles on paper to digital articles, despite hating the paper waste. She explained how the course “introduced me to social annotations, which is very good and close to annotations on hard copies” (SCA11). For those with a neutral experience, some found that SCA was slower than their current method (SCA17, SCA19) or already had an effective annotation method (SCA06, SCA10). Nonetheless, many liked the SCA activity more than they thought, and several planned to use it again immediately (SCA17, SCA09, SCA19).

Another central theme is that annotation practices evolve with practice, instruction, modeling, and feedback. A participant explained that during her first exposure to PL as an undergraduate, she received no formal instruction and tried to “remember every detail and to understand everything” (SCA15). Then she realized that was impossible. She learned in a literature course that “annotations help you understand better, so I started annotating basic stuff that I didn’t know about the topic, like clarifying concepts” (SCA15). Now that she is in a doctoral program, her annotation practice has evolved further, such that her annotations are “mostly about doubts that I have, or how one piece of information links to another” (SCA15). Similarly, other participants’ annotation practices began with highlighting everything (SCA01, SCA04, SCA09, SCA11) and evolved to marking up texts with essential categories, such as “motivation, RQ (for research question), methods, and importance” (SCA11).

After the intervention, the participant reported that her annotation practice became more strategic. She is looking for “the paper’s main argument and any holes or gaps in the evidence” (SCA15). Likewise, other participants no longer believed that a paper’s conclusions were automatically valid because they passed peer review. They now felt they must actively analyze those claims using the evidence presented (SCA04, SCA08, SCA11, SCA17, SCA18, SCA23, SCA24). Other participants explained how the course’s repeated annotation activities helped them develop a regular annotation habit in their doctoral reading (SCA01, SCA04, SCA23). These participants’ experience conveys that annotation practices change with experience and feedback, including feedback from peers and seeing peers’ annotations. In summary, the intervention had positive impacts on participants’ diverse annotation practices, illuminating that annotation is a dynamic, evolving skill.

4.4. Many valuable applications of SCA within higher education

Most participants liked SCA and volunteered many potentially valuable applications of SCA within HE. Suggestions included communicating with advisors in real-time about papers, various types of group work, and preparing undergraduate and graduate students to pass major exams. One participant explained that she and her advisor share key papers by sending a lot of PDFs back and forth through Slack,

noting that “we don’t annotate them, but make chat comments, like ‘this is the paper and here’s what they found.’ It’s not really a conversation. I think SCA could really improve our communication” (SCA04). Others echoed this notion of SCA improving communication with advisors using SCA (SCA18, SCA14). Thus, participants suggested that SCA could improve communication about research articles in doctoral programs.

Other suggestions for SCA applications focused on improving group work where PL is central. Recommendations included coursework (SCA01, SCA17, SCA09, SCA15, SCA13), studying for qualifying exams (SCA18, SCA14), group writing projects (SCA18, SCA23, SCA06), and journal or reading clubs (SCA08, SCA18, SCA04). One of the problems with journal clubs is that “everyone just sits there and hopes that they don’t get called on with a question or ask questions” (SCA18). However, SCA overcomes reticence to share ideas by creating a forum for conversation in the margins with low social barriers to entry (SCA08). Another problem with reading clubs is long chains emailing comments on papers. “With SCA, we could go through papers together, and then if we were confused about something, we can ask in real-time rather than just chatting [texting] about it or sending a long chain of emails back and forth” (SCA04). These participants felt that SCA would encourage more participation, which is also efficient.

SCA could also replace traditional annotation for coursework and study for qualifying exams. Both situations involved writing summaries of a set of papers as a group. One participant suggested SCA instead of traditional annotation because “it’s so much easier to use, and you can see what people are thinking in each part” (SCA03). The same participant also explained how her policy writing group continued using SCA in the second part of the intervention course, even though it was not required. Her group continued using SCA “because it’s helpful, especially when you’re learning a field, to talk about and share thoughts on what we were reading” (SCA18). Thus, many participants felt that SCA would improve many aspects of studying with others using the PL.

The final suggested application of SCA was to prepare undergraduate and graduate students to read PL better and pass major exams, such as qualifying exams. Participants suggested preparing students in PL annotation as early as the second semester of undergraduate study (SCA01, SCA18, SCA15), during upper-division undergraduate courses (SCA04, SCA09, SCA23), or the first or second year of graduate school (SCA17, SCA23). Focusing on graduate school, one participant described a situation where she thought SCA would be most helpful:

There are no undergraduate standards for reading PL. The GRE doesn’t even test it. So, we bring first- and second-year doctoral students into the lab and do literature reviews every other month. Students are

required to turn in a literature review about a paper, and then we [the senior graduate students and post-docs] review it and analyze their critiques. We try to help them think critically about papers. There would be a lot of value for the new students to see some social annotation about a new paper and the important things we pull out. (SCA17)

This participant recognized no undergraduate preparation standards for PL, yet new graduate students much write literature reviews. Making reading and critical thinking about the primary literature explicit through SCA would add transparency and value to an incoming graduate student's educational experience.

Further, the underlying rationale for preparation to read primary literature reflects a reality summarized as “most people I’ve met [in graduate school] never learned how to do it, even though the professors expect us to” (SCA23). Another participant elaborated on this experience:

After a bachelor's, master's, and now a Ph.D., nobody ever taught me how to do reading for writing. I think that people feel, with reading, [that] you learn by doing, but it's not true. You can learn some reading from writing, but what helps most is being taught to read critically, like this [intervention] did. (SCA18)

This participant explained how she had never been taught to read critically, benefitted from explicit instruction, and suggested SCA as a method to better prepare students for advancement in HE. In summary, participants appreciated SCA and identified many potential applications within higher education.

5. Discussion

A predominant assumption of graduate education is that students receive sufficient preparation in critical reading of the primary literature (CRPL) from prior coursework or research experiences. However, participants' experiences reported herein illuminated why this assumption is fraught with challenges and how peer engagement using SCA can help. Participants also expressed a need for explicit instruction in CRPL at the doctoral level [29].

Participants reported that CRPL norms must be absorbed implicitly because they are rarely taught. Despite being a foundational academic skill, no participants reported formal training in CRPL at the graduate or undergraduate levels. Once students enter graduate programs, advisors and instructors may recognize insufficient preparation and informally model reading practices through reading clubs, lab discussions, shared notetaking, and assigning hundreds of reading pages.

Ultimately, students must figure out CRPL on their own. Those who cannot or take a long time to figure it out struggle most with literature research and applying reading to writing.

Consistent with prior scholarship, peer engagement in this study supported reading comprehension; specifically, SCA activities benefitted critical reading skills. This occurred because seeing other people's ideas in real-time helped participants correct their misunderstandings and increased self-monitoring while reading. The experience was positive, even when there were no or neutral benefits to reading. Participants learned from seeing their peers' annotations and having low-stakes, peer-based discourse about a text. In addition, peer engagement using SCA created a supportive and reassuring learning environment. This occurred because SCA reduced participants' fears about CRPL in a new field and improved feelings of confidence and ease. Finally, annotation was a dynamic reading-to-writing practice that improved with practice and feedback.

These findings are also consistent with the central tenet of sociocultural theory that language and learning are intertwined [30]. The sociocultural tradition emphasizes the social constructionist view of learning, focusing on discursive actions between teachers and students or between students in collaborative discussions [30]. In this tradition, social interaction is essential for human learning, and discourse is a primary way to construct knowledge at the doctoral level. SCA offered participants both social interaction and a flexible forum for discourse about CRPL, which helped the participants understand the literature better.

However, participants explained that the sociocultural tradition can break down in highly competitive academic environments and for students of color. For example, toxic comparison of self to others can generate harmful feelings of not belonging, often described as imposter phenomenon [79]. In another example, many participants felt judged unfairly because of skin tone, ethnicity, or first language. In this intervention using SCA with prompts where everyone was learning together, participants who struggled with invisible barriers felt safe enough to discuss their experiences, which were shared by others. A supportive peer-based learning environment using SCA countered these negative experiences through a shared social context, validation, and reassurance. These findings are consistent with a raciolinguistic perspective that recognizes the harms of race and linguistic discrimination as a legacy of colonialism, settler nation-state formation, and world history [41, 42, 80].

Finally, the study achieved a more extensive representation of doctoral students of color than the sponsoring association's membership. Recruitment did not specify any goals for demographic representation, such as by gender, race, or ethnicity. Nonetheless, these data were collected because adequate support and mentoring to

develop literacy skills are known barriers to the progress of raciolinguistically diverse students in graduate education [38, 40]. Indeed, half of the participants identified as students of color, 25% more than the proportion within NSPN's membership. In addition, eleven (46%) participants of color identified as intersectional, meaning a person of color and a woman or non-binary person [82]. Thus, the data set included a rich and highly diverse range of backgrounds, suggesting enhanced transferability to other contexts, especially online contexts considering diversity, equity, and inclusion issues.

6. Conclusion

Although previous scholarship indicated that explicit reading instruction and SCA discourse practice improved reading outcomes in younger students, this study elicited participants' experiences with peer-based discourse using SCA at the doctoral level with PL. Likewise, this study applied a novel intervention design using SCA in an online learning environment as part of a professional development course. Everyone was learning to read PL critically in a new field, motivated by career goals. The study also contests the conventional assumption in graduate education that students arrive prepared to navigate and critically read professional literature (CRPL). Participants noted that a lack of explicit instruction at the undergraduate and graduate levels led to difficulties understanding, thinking critically, and applying readings to writing. However, using SCA and peer engagement facilitates demonstrated positive outcomes in enhancing reading comprehension, self-monitoring, and overall confidence. While the outcomes of the SCA system might vary with a study population not intrinsically motivated to read research articles or if measured over a more extended period, the intervention effectively improved the participants' perceptions of their critical reading abilities, confidence, and annotation practices, reinforcing its value as a tool for facilitating peer engagement. Nonetheless, this CRPL intervention using SCA improved doctoral student participants' perceptions of their critical reading abilities, confidence, and annotation practices.

6.1. Implications for future practice

Overall, the study illustrated the effective use of SCA in facilitating cognitive connections and group learning, indicating the necessity to adapt instructional practices in online learning environments. Key elements of this adaptation include direct instruction, group practice, real-time peer feedback, and CRPL. These elements point to changes in instructional design that anticipate learners' challenges, particularly when understanding primary literature. This can be achieved by incorporating numerous worked examples and encouraging real-time SCA discussions to support peer-based discourse and critical thinking.

SCA's implementation revealed several teaching practice implications. The study's findings underscored the need for explicit instruction in reading primary literature to address the challenges posed by a lack of formal training. Second, it demonstrated the positive impact of SCA and peer engagement in teaching, particularly in enhancing reading comprehension and self-monitoring. Third, it emphasized the importance of early integration of instruction in critical reading of primary literature was emphasized, suggesting it should be part of both undergraduate and graduate teaching. Courses at these levels include group SCA discussions and practices that analyze research articles' methods and key concepts, aiding students in comprehending essential disciplinary ideas and practices.

The study further highlighted SCA's advantages, including its transparent approach to evaluating research articles, benefiting both expert and novice readers. The collaborative nature of SCA promotes collective learning, making it a valuable tool for reading beyond one's primary field and understanding broad social issues. SCA's utility was also demonstrated in a hybrid learning approach combined with CRPL, which could find applications in academic settings such as journal clubs, article comparison exercises, and discussing seminal articles.

Critical reflection on the peer-engagement pedagogical design was another highlighted aspect, with tools like SCA assisting in identifying areas requiring more explicit instruction. However, the study also urged caution regarding potential pitfalls of SCA, such as distraction from comprehensive text processing and ensuring active student involvement was another focus, with suggestions of using tiered prompts for peer engagement to address varied participation levels. Future implementations should consider these challenges.

Finally, the study recognized the negative impacts of competitive academic environments on marginalized students and emphasized the necessity of a positive peer-based learning environment to counter such experiences. These findings underscore the importance of building a supportive learning environment that fosters peer-engaged cooperative learning, enabling students to express their uncertainties and participate in meaningful discourse. This includes addressing challenges faced by students from marginalized groups to ensure a more inclusive academic environment. The findings urge efforts to eliminate invisible barriers faced by students from marginalized backgrounds, enhancing the inclusivity and enrichment of academic experiences. Further, research on SCA in teaching practices should explore its full potential across various academic contexts, focusing on its long-term efficacy and adaptability among diverse groups of learners.

6.2. Implications for future research

SCA adds another layer of socially constructed learning by making other people's ideas visible and creating a low-stakes forum for analytic discourse. Such discourse

is an essential aspect of critical reading and writing in a discipline. Future research should create an explicit conceptual bridge using SCA from reading analysis to writing synthesis, focusing on crucial doctoral outputs, such as literature reviews, presentations, posters, papers, and dissertations. Synthesis differs from summarizing in that synthesis is produced with analysis, while summaries can be made with skimming. The goal of synthesis is a deeper, more advanced understanding of texts that evolves the reader's understanding. Thus, SCA could serve as a peer-reviewed bridge between reading and writing by extending the learning from the reading intervention, focusing on analysis, to additional practices that prepare learners for synthesis.

For example, using an SCA discourse practice environment could serve as the basis for developing and revising a written paragraph synthesizing critical elements of several articles. SCA discourse practice in this context would allow learners to see other people's ideas, check their understanding with peers, and reduce apprehension. This line of future research could be maintained over a long term beyond a single course, such as an academic year or longer, to model disciplinary literacy spanning multiple courses.

Any future research with SCA should consider participants' prior experience with annotation, as it varied widely in this study. Assessment of prior experience could include a skills assessment or survey. Developing a validated instrument, for instance, to assess annotation experience, would be very useful for developing a field of research that includes quantitative data. Finally, future research should consider SCA plus generative artificial intelligence systems (GAI), such as GPT and Bard, as these systems can substantially alter learners' interactions with academic texts.

6.3. Limitations of SCA

Learning complex skills—such as reading, writing, and research via PL at the doctoral level—requires high levels of self-efficacy, self-regulation, and other mature learner characteristics [46]. These characteristics are more likely present collectively within working groups. However, to the extent that these properties of group learning benefit individuals, the nature of doctoral assessment through an individual thesis means that individuals also need to develop the group attributes to call on them when the group is not present. Thus, a limitation of this approach is that group benefits of collaborative social annotation at the doctoral level are insufficient unless the individual can use the experience to develop core skills further and make degree progress.

SCA has several other limitations. Kalir (2020) provides an example of discourse analysis but does not address doctoral students' specific learning needs [2]. Likewise, a pilot project by Chen combined social and collaborative annotation (SCA) in a graduate course using Slack and Hypothes.is provide an implementation model

relevant to course instruction [57]. However, the course took much work to develop and implement. Like Kalir, Chen did not focus on working with the primary research literature [25, 57]. These studies suggest an opportunity to investigate SCA for developing critical reading skills using the PL at the doctoral level, which this study did. Nonetheless, the body of research at the graduate level is limited and warrants further investigation, including combining SCA with direct instruction in other critical reading methods, such as the CERIC method [83] or the Toulmin method [84].

6.4. Limitations of the study

The major limitations of this study were time-consuming data collection and subsequent time-intensive qualitative analysis. These limitations are known in qualitative and mixed-methods research [65]. Also, the qualitative arm study was not powered for more complex statistical analyses, such as ANOVA, and thus, generalizing the findings was not a goal [85].

Other limitations reflect the nature of a voluntary professional learning setting. These limitations include participants who volunteered because they were highly motivated to learn to read in a new field (i.e., science policy research) with attendant career goals. Thus, there were no participants with low motivation for reading. Future studies should include readers with more varied motivation levels. Also, participants were heterogeneous in terms of field and year of study, and it is possible that a more homogenous sample would produce different findings. For instance, a group of less experienced readers may have improved more or revealed essential features of becoming an expert reader not reported by a more advanced academic population. Finally, the study was not longitudinal by design, and thus, it needs to be clarified how participants will use SCA over time.

Data availability statement

The author elects not to share data. Research data are not available to protect the privacy and identities of participants.

Conflict of interest

The author declares no conflict of interest.

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