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Social metacognition and the creation of correct, new ideas: A statistical discourse analysis of online mathematics discussions

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ABSTRACT

During asynchronous, online mathematics discussions, new ideas and justifications (knowledge content) and evaluations and invitations to participate (social metacognition) can influence the likelihood of a correct, new idea (CNI) in the current message. Using statistical discourse analysis, we modeled 894 messages by 183 participants on 60 high school mathematics topics on a mathematics problem solving website not connected to any class or school. Results showed that CNIs, justifications, and social metacognition (correct evaluations and questions) in recent messages increased the likelihood of a CNI in the current message. Meanwhile, more experienced participants (who had posted more messages on the website) had more CNIs, and participants who initiated topics had fewer CNIs. Applied to practice, these results suggest that teachers can facilitate students' creation of CNIs by encouraging them to justify their ideas, evaluate one another's ideas carefully, and ask questions during online mathematics discussions.

1. Introduction

Students are increasingly using asynchronous, online discussions to aid their learning (Tallent-Runnels et al., 2006), in part because these discussions allow participation at different places and times (asynchronous) – unlike traditional face-to-face discussions (Dubrovsky, Kiesler, & Sethna, 1991; Harasim, 1993). As asynchronous, online discussions allow participants more time to gather relevant information, contemplate ideas, and evaluate claims critically before responding, they often display high levels of cognition (Hara, Bonk, & Angeli, 2000; Tallent-Runnels et al., 2006).

In this study, we examine how group processes affect the creation of correct, new ideas (CNIs) during asynchronous, online discussions of high school mathematics problems by small groups of individuals. We define a CNI as an expressed idea that is both *correct* (consistent with the problem situation and the mathematics) and *new* relative to the participants' discussion of a topic. Past theoretical models have highlighted the importance of CNIs to group problem solving and suggested that groups with more CNIs are more likely to solve a problem correctly (e.g., Chiu, 2008a; Hinsz, Tindale, & Vollrath, 1997; Orlitzky & Hirokawa, 2001). Hence, understanding the online group processes that affect CNI creation can help educators improve students' online group mathematics problem solving.

In addition to finding correct answers, a productive mathematics discussion supports and reinforces desirable mathematics thinking processes such as expressing new ideas, supporting them with proofs, evaluating one another's mathematics claims, and inviting others to evaluate their mathematics relationships (Chiu, 2000a, 2008a). Through these processes, participants facilitate one another's creation of mathematics relationships that facilitate mathematics solutions. For example, Chiu's (2008a) study of face-to-face mathematics discussions showed that correct evaluations of mathematics ideas in the three most recent conversation turns raised the likelihood of a CNI in the current conversation turn. A natural extension of this research is how group processes might affect the likelihood of a CNI during online mathematics discussions.

However, past studies of online discussions typically focused on the isolated properties of each online discussion message (Gress, Fior, Hadwin, & Winne, 2010; Hara et al., 2000; Tallent-Runnels et al., 2006) without systematically examining the *relationships* among online discussion messages to characterize the group processes that affect the likelihood of CNIs. By understanding how messages in online discussions create a context that influences a student's CNI creation, educators can help students engage in beneficial group processes to aid correct outcomes.

In this study, we take a step in this direction by examining how new mathematics ideas and justifications (knowledge content) and evaluations and invitations to participate (social metacognition) in

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recent messages facilitate or hinder CNI creation during online discussions about mathematics problems. The useful knowledge content of a message includes its new ideas and justifications. Discussants monitor the correctness of the knowledge content in previous messages and use this information to influence the local discussion context and the knowledge content of subsequent messages through social metacognition (Chiu & Kuo, 2009). Whereas individual metacognition is monitoring and control of one's own knowledge, emotions, and actions (Hacker & Bol, 2004), *social metacognition* is defined as group members' monitoring and control of one another's knowledge, emotions, and actions (Chiu & Kuo, 2009). For example, students working on a problem together often agree or disagree with one another's ideas (monitoring) and use questions or commands to influence one another's actions (control).

This study contributes to the research literature in three ways. First, we introduce hypotheses regarding how knowledge content and social metacognition in recent messages might influence the likelihood of a CNI in the current message during online mathematics discussions. Second, we explicated a new method to model online conversations across multiple topics. Our coding framework consisted of mutually exclusive and exhaustive categories, sufficiently comprehensive to test our hypotheses. Meanwhile, the multi-dimensional simplicity facilitates the coding for large sample-size statistical analyses. Lastly, we applied this new method to analyze high school students' small group mathematics discussions from an online discussion community not related to any class or school.

2. Theoretical perspective

Past research of face-to-face discussions suggests that some group processes (e.g., new ideas, disagreements, correct evaluations, questions, and justifications) in recent messages might increase the likelihood of a current message's CNI (e.g., Chiu, 2008a; Goldbeck, 1998; King, 1990). In this study, we examine whether these links also occur in online mathematics discussions. Furthermore, we consider whether an online author's (*e-author*) individual characteristics might be linked to his or her CNI creation.

2.1. Knowledge content

In contrast to face-to-face discussions, online discussions' structure and e-author diversity might yield more useful knowledge content, specifically new mathematics ideas and justifications such as proofs (e.g., Chen, 2004; Heckman & Annabi, 2005; Kim, Anderson, Nguyen-Jahiel, & Archodidou, 2007; Tallent-Runnels et al., 2006). In face-to-face discussions (or online chats), people are responding in real time and are less likely to edit their responses. In contrast, posting asynchronous, online discussion messages has no such time constraints, so e-authors can gather more mathematics information from other sources and spend more time contemplating their relationships and evaluating competing claims and justifications (De Wever, Schellens, Valcke, & Van Keer, 2006; Harasim, 1993).

As e-authors are often geographically and culturally diverse, they are more likely than face-to-face discussants to have diverse views and sources of knowledge (McLeod, Lobel, & Cox, 1996; Swann, Kwan, Polzer, & Milton, 2003). Capitalizing on this diversity, heterogeneous participants can both generate diverse ideas and build on one another's CNIs through processes such as sparked ideas and jigsaw pieces (Paulus & Brown, 2003). A CNI by one person (e.g., a key word) might spark another person to activate related concepts in his or her semantic network and propose another CNI (Nijstad, Diehl, & Stroebe, 2003). For example, in responding to a CNI, "$7 \times 9 = 7 \times (10 - 1)$", a participant might continue the thread and add another CNI: "$7 \times (10 - 1) = 7 \times 10 - 7 \times 1 = 70 - 7 = 63$." Like fitting jigsaw pieces together, participants also can put together CNIs to create a CNI (Milliken, Bartel, & Kurtzberg, 2003). Hence, recent CNIs can raise the likelihood of a subsequent CNI.

A justification can support an idea's validity by linking it to data, using a warrant, or supporting a warrant with backing (Toulmin, 2003). Furthermore, e-authors justify new ideas and give proofs in written form during online mathematics discussions, so they are likely to see errors more clearly and specify relationships among ideas more precisely than during face-to-face discussions (Jonassen & Kwon, 2001). Hence, justifications can support the validity component of new ideas, identify errors, and clarify relationships to help create CNIs.

2.2. Social metacognition

Through social metacognition, group members monitor and control one another's actions (Chiu & Kuo, 2009). By monitoring one another's actions, they can identify correct ideas and flawed components (*evaluations*) to create shared correct understandings on which to build new ideas (Chiu, 2008b). Hence, evaluations not only monitor group members' actions but also inform their interactions and serve as a basis to influence their subsequent actions (Chiu & Khoo, 2003). Then, group members can influence one another's subsequent thinking with various *invitational forms* (statements, questions, and commands; Chiu, 2000a). While commands demand a specific type of thinking or action from the audience, questions can invite the same behavior more politely, and statements place the smallest demands on the audience (at least in form, Chiu, 2000a).

Agreements, disagreements, and correct evaluations assess the validity of the previous message and try to influence the direction of the subsequent mathematics discussion. An agreement supports a previous action and reinforces the current direction of the discussion (Sacks, 1987). By agreeing with the previous idea ("yeah, you're right"), a responder can emphasize his or her shared information with the proposer and enhance their social relationship, especially if the group members are personally invested in their ideas (Chiu & Khoo, 2003), without creating a CNI. Or, a responder might build on the previous idea to create a CNI. A priori, it is not clear whether agreement increases or decreases the likelihood of a CNI in either face-to-face or online mathematics discussions.

Unlike agreements, a disagreement tries to alter the discussion trajectory by identifying obstacles/flaws of the previous action or by developing alternatives. A responder who recognizes a flaw in or has a conflicting view of the previous message's understanding of terms, concepts, or schemas (Gunawardena, Lowe, & Anderson, 1997) is likely to disagree with the previous message (e.g., "No, you are wrong, 7×9 is not 64"). To support his or her disagreement, the responder might provide an accompanying new idea (e.g., "No, you are wrong, 7×9 is not 64, *it should equal 63*"). Or, other participants might address the disagreement in subsequent actions, according to *socio-cognitive conflict theory* (e.g., "I agree with you, 7×9 is not 64, *it's 63*"; Buchs, Butera, Mugny, & Darnon, 2004; Piaget, 1985). In both cases, disagreements can aid creation of CNIs, either immediately or in subsequent actions in both face-to-face and online mathematics discussions.

When possessing both supportive and conflicting information regarding a previous message or conversation turn idea, online discussants tend to be more likely than face-to-face participants to disagree. During a face-to-face discussion, participants often seek to enhance their relationship with other group members by agreeing and withholding the conflicting information (Chiu & Khoo,