Group Micro-creativity in Online Discussions: Effects of New Ideas and Social Metacognition

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Abstract: This study examines how group members' new ideas and social metacognition in recent messages (micro-time context) affected a current message's micro-creativity (correct, new idea) during online discussions. Dynamic multi-level analysis was used to model statistically 894 messages by 183 participants on 60 high school mathematics topics from one of the world's largest mathematics problem solving website (www.artofproblemsolving.com). Results showed that new ideas (correct, new ideas and justifications) and social metacognition (correct evaluations and questions) in recent messages increased the likelihood of a current message's micro-creativity. Applied to practice, these results suggest that teachers might increase students' micro-creativity by encouraging them to post more correct, new ideas, justify their own ideas, evaluate others' ideas carefully, and ask more questions during online discussions.

Introduction

Students are increasingly using online asynchronous discussions for learning (Tallent-Runnels, Thomas, Lan, Cooper, Ahern, & Shaw, 2006), in part because online discussions are more accessible and more equal compared to traditional face-to-face (FTF) discussions (Harasim, 1993). Also, online discussions allow more time for students to prepare, do higher order and critical thinking, and search for extra information before posting a message in the discussion (Pena-Shaff & Nicholls, 2004). By understanding how online discussions evolve message by message, educators can improve their quality and facilitate students' online learning.

Past studies of face-to-face (FTF) discussions have shown that recent group processes (micro-time context) can affect the likelihood of a current speaker's creation of correct, new ideas (*micro-creativity*). In this paper, creativity refers to the "small c" creativity of ordinary people in daily life, not the "big C" creativity of new knowledge or products that substantially affect society (Gruber & Wallace, 1999). Hence, micro-creativity is defined as an expressed *correct, new idea* relative to the group members' experiences during a discussion.

Chiu (2008) showed that recent speakers' justifications and correct evaluations of one another's ideas aided a current speaker's micro-creativity. This raises the issue of how recent phases and messages (local message context) affect a current message's micro-creativity during online discussions. As micro-creativity is central to correct solutions and problem solving success, understanding the group processes that affect micro-creativity can help educators improve students' online discussions.

Most previous studies of online discussions examined the *individual* properties of each discussion message from course related forums (e.g., Hara, Bonk, & Angeli, 2000). Their results showed that many students processed course information at high cognitive levels during online discussions, supporting the claim that online discussion can promote students' micro-creativity. However, researchers have not systematically examined the *relationships* among messages to characterize online moment-to-moment creative processes.

In this study, a step is taken in this direction by examining how new ideas, justifications, social metacognition, and individual characteristics in recent messages facilitate or hinder a current message's micro-creativity during online mathematics problem discussions. This study contributes to the research literature in three ways. First, we introduced hypotheses regarding how new ideas, social metacognition, and individual characteristics help create a local message context that might influence micro-creativity during online discussions. Second, we explicated a new statistical discourse analysis method to model multi-topics of online conversations (Chiu & Khoo, 2005). Lastly, we applied this new method to analyze 60 high school-level mathematics topics from a non-course related forum in one of the world's largest mathematics problem solving website (AoPS, www.artofproblemsolving.com). By understanding the group processes that affect micro-creativity, group members can work together more creatively during online discussions.

Theoretical Perspective

In this study, several hypotheses are introduced regarding how local message context might influence micro-creativity, which in turn might affect problem solving success during online discussions (see Figure 1). In this paper, "E-poster" is defined as the author of an online discussion message.

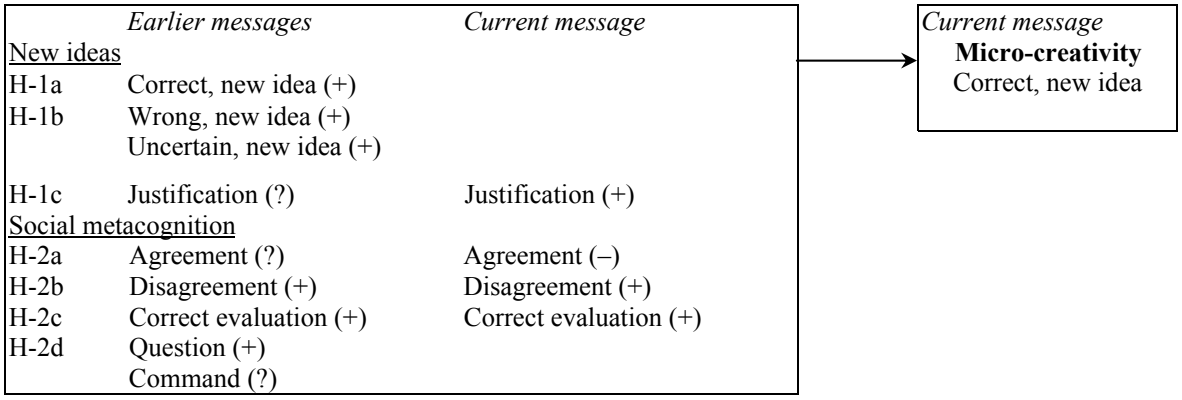

Figure 1. Model of recent messages' effects on the outcome variable micro-creativity in a current message. (Symbols in parentheses indicate the expected direction of the relationship with the outcome variable: positive [+], negative [–], or unknown [?]). H = hypothesis.

New Ideas

In FTF or online discussions, group members often have diverse perspectives and sources of knowledge (Swann, Kwan, Polzer, & Milton, 2003). Capitalizing on this diversity, heterogeneous group members often contribute new ideas that have not been mentioned earlier in the discussion. Like FTF discussants, e-posters' new ideas can be correct, wrong, or uncertain in many contexts (e.g., high school mathematics). Suppose a group is working on a mathematical problem (e.g., "What is 7 times 9?"). An e-poster's new idea can be correct if it does not violate any mathematics or problem constraints ("7 times 9 is 63"), wrong if it violates at least one mathematics or problem constraint ("7 times 9 is 64"), or uncertain if its validity cannot be determined by considering mathematics or problem constraints ("I'm not sure, but this link might help, [hyperlink]").

Ideally, e-posters build micro-creativity directly on previous micro-creativity. For example, in responding to a micro-creativity message, "7×9 = 7×[10-1]", an e-poster might continue the thread and build new micro-creativity: "7×[10-1] = 7×10-7×1 = 70-7 = 63." Or, e-posters might not be able to build micro-creativity directly based on previous micro-creativity. Instead, they might test the previous micro-creativity against their established facts, existing cognitive schema, or personal experience, especially in online discussions fostering critical thinking (Gunawardena, Lowe, & Anderson, 1997). By testing the micro-creativity, group members are likely to identify the obstacle(s) in it. Then, they can either use questions (e.g., "Could you explain the steps further?") or disagreements (e.g., "I don't think your steps are complete") to express the obstacle and invite further elaborations or justifications (Perturbations; Piaget, 1985). Then, in responding to the questions or disagreements, group members are likely address the obstacle and make micro-creativity (e.g., "Here are the full steps, 7×[10-1] = 7×10-7×1 = 70-7 = 63"). Hence, micro-creativity might spark micro-creativity in subsequent messages.

E-posters might also post wrong, new ideas during online discussions. A group of e-posters' diversity and increased critical thinking might help them detect flaws, modify these wrong ideas, and make micro-creativity (De Lisi & Goldbeck, 1999). However, wrong, new ideas might also lead a group astray, so the effect of them on micro-creativity is unclear.

Lastly, as online discussants are often from different cities or countries, they are likely to have diverse views and sources of knowledge, thereby increasing the likelihood of presenting uncertain, new ideas, which can be uncertain resources ("I'm not sure, but this link might help, [hyperlink]"), tentative suggestions ("There might be a general way to solve such problems"), and personal preference ("I think this method is easier to understand"). The useful part in these uncertain, new ideas might help elicit micro-creativity. However, like wrong, new ideas, these uncertain, new ideas might also lead a group astray. So the effect of them on micro-creativity is unclear as well.

E-posters' ideas might or might not be justified. A justified idea demonstrates that the proposer has tried to justify his or her claim (e.g., "7×9 is 63") by linking it to data/warrants (e.g., showing reasoning/evidence, "because 7×9 =7×[10-1] = 7×10-7×1 = 70-7 = 63"), backings (e.g., "we can solve it by converting multiplication to addition"), or a combination of them (Guiller, Durndell, & Ross, 2008; Toulmin, 2003). A justification argues that an idea is reasonable and can often improve the validity of it (Lindow, Wilkinson, & Peterson, 1985). Furthermore, justifying an idea in written form might help identify errors and provide clearer and more precise steps. Hence, justifications support the validity of an idea and can increase micro-creativity.

H-1a. Earlier correct, new ideas facilitate micro-creativity.
H-1b. Earlier wrong, new ideas and uncertain, new ideas facilitate micro-creativity.

H-1c. Justification in a message facilitates its micro-creativity.

Social Metacognition

Successful group problem solving often involves social metacognition in the problem content space (Roschelle, 1992). Whereas individual metacognition is monitoring and controlling one's own knowledge, emotions, and actions, social metacognition is group members' monitoring and control of one another's knowledge, emotions, and actions (Chiu & Kuo, 2009). Group members use social metacognitive strategies to evaluate one another's ideas (agreement, disagreement, or neutral), recognize problems, and invite audience participations (question, command, or statement).

In responding to a previous message, a responder might have supportive information, conflicting information, or both supportive and conflicting information. With supportive information, the responder is likely to agree with the proposer's idea and post a supportive message (e.g., "Yes, you are right, I got the same answer"). In such cases, a new idea, which might conflict with the old one, is less likely to be voiced. Hence, an agreement is less likely to aid micro-creativity.

Or, a responder might have conflicting information, which often indicates an inconsistency in understanding of terms, concepts, or schemas (Carson, Butcher, & Coleman, 1988). Then, the responder is likely to disagree with the proposer's idea and respond with a conflicting message (e.g., "No, you are wrong, 7×9 is not 64") to identify the inconsistency. According to *socio-cognitive conflict theory* (Piaget, 1985), the disagreements might aid micro-creativity, either immediately or in subsequent messages.

Lastly, an e-poster might have both supportive and conflicting information toward a previous idea. In online discussion reduces face concerns and allows delayed responses, which likely free an e-poster to provide the conflicting information as well. In such cases, the responder is more likely to disagree with the proposer's idea on at least one point (e.g., "Yes, your answer is correct, *but the method is too complex*"). Again, according to socio-cognitive conflict theory, the disagreement is likely to aid group members' micro-creativity.

Group members' evaluations of one another's ideas can be correct or wrong. Correct evaluations support previous correct ideas by providing supportive information ("Yes, 63 is right") or identify flaws in previous wrong ideas by providing conflicting information ("No, 7×9 is not 64"). In contrast, biased evaluations reject correct ideas ("Nope, 7×9 is not 63") or accept flawed ones ("I agree, 7×9 is 64"), embedding flaws in their partially shared understandings. Group members using these wrong, shared understandings might carry these flaws into their new ideas, resulting in more wrong ideas and fewer correct ones (Chiu, 2008).

H-2a. Agreement in a message hinders its micro-creativity.
H-2b. Disagreements in the current and earlier messages facilitate micro-creativity.
H-2c. Correct evaluations in the current and earlier messages facilitate micro-creativity.

Online discussions can promote e-posters' thoughtful questions and micro-creative answers through its asynchronous discussion mode and increased critical thinking (Gunawardena et al., 1997). The question-answer interactions, when enhanced by critical thinking, are more likely to generate thoughtful questions and micro-creativity. Unlike questions, commands stop or demand stop or demand audience participation and typically begin with verbs. Compared to FTF commands, online commands' effect on group members' micro-creativity is likely smaller. The anonymous nature of online discussions helps reduce a command's face threat. As a result, the target e-poster is less likely to retaliate emotionally and more likely to respond rationally to the command (e.g., "Explain your steps!") and create a new idea (e.g., "Here are my steps…"). Thus, commands might or might not reduce micro-creativity in online discussions.

H-2d. Earlier questions facilitate micro-creativity.

Other factors such as individual characteristics (online displayed gender, past posts, initiator of topic), message # (greater # indicates later posting) and message length (the number of words per message) were entered as control variables.

Method

Participants

In this study, 183 e-posters discussed 60 mathematics problems in the High School Basics (HSB) forum. About 80% e-posters were 13- to 18-year-old high school students in grades 9-11 from all around the US (calculated approximately from the participants' displayed personal information). The other 20% e-posters were from countries worldwide. The HSB forum is a free, non-course-related forum from the *Art of Problem Solving* website, which is among the world's largest mathematics problem solving websites.

Data

Sixty problems were randomly selected from the HSB forum of AoPS, excluding problems with less than 4 reply messages. The 60 problems covered the subjects of algebra, geometry, number theory, and counting. Every problem had definite, correct solution(s). The number of responses to the 60 problems ranged from 6 to 26 and the discussion durations of them ranged from 4 to 285 hours.

Each problem and its reply messages were linked to one another by multiple threads, single connections, and quotes of previous messages. See Figure 2 for example relationships between a problem and its 12 responses. The left side outlines the positions of the problem and its 12 responses on the web page. The right side shows their relationships. The number "0" denotes the initial problem; "1" through "12" indicates 12 reply messages in the order of time, where "1" means the earliest reply, "12" the latest.

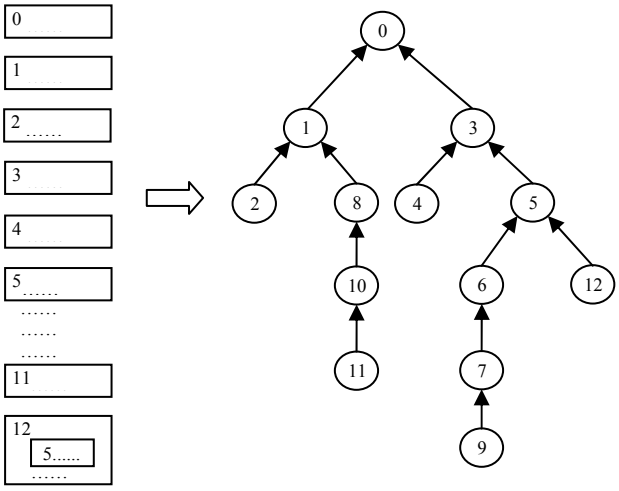

Figure 2. The relationships between a problem and its reply messages.

Multiple threads. The problem and 12 reply messages occurred along five discussion threads: (a) 0→ 1 → 2, (b) 0 → 1 → 8 → 10 → 11, (c) 0 → 3 → 4, (d) 0 → 3 → 5 → 6 → 7 → 9, and (e) 0 → 3 → 5 → 12. Messages in each thread were ordered by time, but they were not necessarily consecutive. In thread (d) for example, message #9 followed message #7 (not #8) and message #5 followed message #3 (not #4).

Single connections. All reply messages were linked together by single connections. The forum's interface design constrained each message to respond to only one previous message, which helped form clear multiple discussion threads and avoid ambiguous relationships among messages. For example, message #9 only responded to message #7.

Quote of previous messages. For two messages that were not consecutive along each single connected thread, the reply message automatically quoted the message to which it responded. By doing so, both messages can be read at the same place. As illustrated in Figure 2, message #12 quoted message #5, with the latter enclosed in the indented rectangle. For two consecutive messages that can be read at same computer window, the reply message did not necessarily quote the previous one.

Variables

Variables for a single message included the e-poster's past posts, message #, message length, and the following binary variables: micro-creativity (correct, new idea), wrong & new idea, uncertain & idea, justification, repetition, agreement, disagreement, correct evaluation, question, command, masculine, feminine, and initiator of the discussion topic. The analyses use two sets of variables: *current variables* measuring properties of the current message (0) and *lag variables* measuring properties of earlier messages in the same thread (-n, where n = 1, 2, 3, 4, …).

Coding

Two students coded each message separately. Then, they settled all coding disagreements by consensus. All 894 messages in the transcript were included and coded. Krippendorff'sα (2004) was used to compute the inter-rater reliability. Unlike other inter-rater reliability measures, Krippendorff'sα applies to any number of coders, any number of categories or scale values, any level of measurement, any sample size, and incomplete data. Its values range from -1 (maximum disagreement) to 1 (perfect agreement). A value near 0 indicates chance agreement among the coders, and a value of 0.7 or higher indicates satisfactory agreement.

The web server automatically recorded each e-poster's number of past posts and each message's # and length. Other variables were coded as binary variables. A message's variable (-n) was coded as the values of the

variable of the message n connections prior. For example, in Figure 2, the value of wrong & new idea (-1) for message #9 was the same value of wrong & new idea (0) for message #7, since #7 was #9's previous message.

Analyses

Dynamic multi-level models (Chiu & Khoo, 2005) separate unexplained error into message (level one) and topic (level two) components, thereby removing the correlation among error terms resulting from messages nested within topics. For the outcome variable micro-creativity, we first added *s* topic level variables as control variables: algebra topic, geometry topic, and number theory or counting topic (**S**). We then added *t* current message variables (0) as control variables: masculine, feminine, past posts, initiator, message # and message length (**T**). As the likelihood ratio test for significance of additional explanatory variables was not reliable for this estimation method, Wald tests were used. Non-significant variables and interactions were removed.

We then added *u* current message variables (0): justification, agreement, disagreement, and correct evaluation (**U**). Likewise, we repeated the procedure for **T** on **U**. Then, we tested for interaction effects among pairs of significant variables in **U**. Non-significant variables and interactions were removed from the specification. Next, we tested if the *u* regression coefficients (($\beta_{uj} = \beta_{u0} + f_{uj}$) differed significantly at the topic level ($f_{uj} \neq 0$?). If yes, we kept these additional parameters in the model. Otherwise, we removed them.

Next, we tested the hypotheses by entering lag variables measuring the property of earlier messages (-n), first lag variables (-1), then lag variables (-2), lag variables (-3), and lastly, lag variables (-4). First, we added lag variables (-1) at the message level: message length (-1), masculine (-1), feminine (-1), past posts (-1), initiator (-1), correct, new idea (-1), wrong & new idea (-1), uncertain & new idea (-1), justification (-1), repetition (-1), agreement (-1), disagreement (-1), correct evaluation (-1), question (-1), and command (-1) (**V**). Likewise, we applied the procedure for **U** on **V**. Then, we repeated the procedure for lags -2, -3, and -4 of the variables in **V**.

We used an alpha level of .05 for all statistical tests. Benjamini, Krieger, and Yekutieli's (2006) two-stage linear step-up procedure was used to control for the false discovery rate. We used Higgins and Thompson's (2002) I^2 index, which assesses both the statistical significance and the extent of heterogeneity simultaneously, for testing serial correlation in the residuals of the regressions for all topics.

Based on the multi-level analysis results, the path analysis estimated the direct and indirect effects of the significant explanatory variables separately to compute their total effects (Kennedy, 2003). To facilitate the interpretation of these results, we converted the total effects of each predictor to odds ratios, indicated by the percentage increase or decrease (+ X% or – X%) in the likelihood of an outcome variable (Judge, Griffiths, Hill, Lutkepohl, & Lee, 1985).

Results

Coding of each dimension showed high inter-rater reliability. The inter-rater reliabilities as measured by Krippendorff's α for knowledge content, evaluation, and invitational form were 0.85, 0.89, and 0.92 respectively (corresponding percentages of agreement were 90%, 94%, and 97%). The multi-level variance components analysis showed that e-posters' micro-creativity did not differ significantly across topics, so single-level analyses at the message level were adequate. No interaction effects were detected in the analyses.

As variables measuring earlier messages required data from preceding turns, some messages could not be used, leaving fewer messages available for analyses. As a variable measuring messages up to two turn prior was significant (i.e., correct, new idea [-2]), 501 messages by 137 e-posters were included in the final analyses.

Correct, new idea in the previous message (-1) reduced the likelihood of micro-creativity (–5%: 9% → 4%; when a previous correct, new idea did not occur, micro-creativity occurred 9% of the time; when a previous correct, new idea occurred, micro-creativity occurred 4% of the time; see Table 1 and Figure 3), whereas correct, new idea two messages prior (-2) increased it (+11%: 9% → 20%), supporting H-1a. Justifications aided micro-creativity (+48%: 9% → 57%), showing that a justified, new idea was more likely to be correct, supporting H-1c.

Table 1: Total effects of each explanatory variable on micro-creativity and explanatory variables.

Explanatory variable (E)		Target (T)	P(T|E) (%)[a]	P(T|~E) (%)[b]	Effect (%)
(1)	Past posts (0)	Micro-creativity	11	9	+2[c]
(2)	Initiator (0)	Micro-creativity	4	9	–5
(3)	Justification (0)	Micro-creativity	57	9	+48
(4)	Correct evaluation (0)	Micro-creativity	30	9	+21
(5)	Question (-1)	Micro-creativity	21	9	+12
(6)	Correct, new idea (-1)	Micro-creativity	4	9	–5
(7)	Correct, new idea (-2)	Micro-creativity	20	9	+11
(8)	Question (-1)	Justification (0)	43	22	+21

(9)	Question (-1)	Correct evaluation (0)	15	36	–21
(10)	Correct, new idea (-2)	Question (-1)	55	25	+30
(11)	Correct, new idea (-2)	Correct, new idea (-1)	19	39	–20

[a] Probability that the target occurs, given that the explanatory variable does occur.
[b] Probability that the target occurs, given that the explanatory variable does *not* occur.
[c] The +2% effect is explained by a 100% increase above the mean of e-posters' past posts.

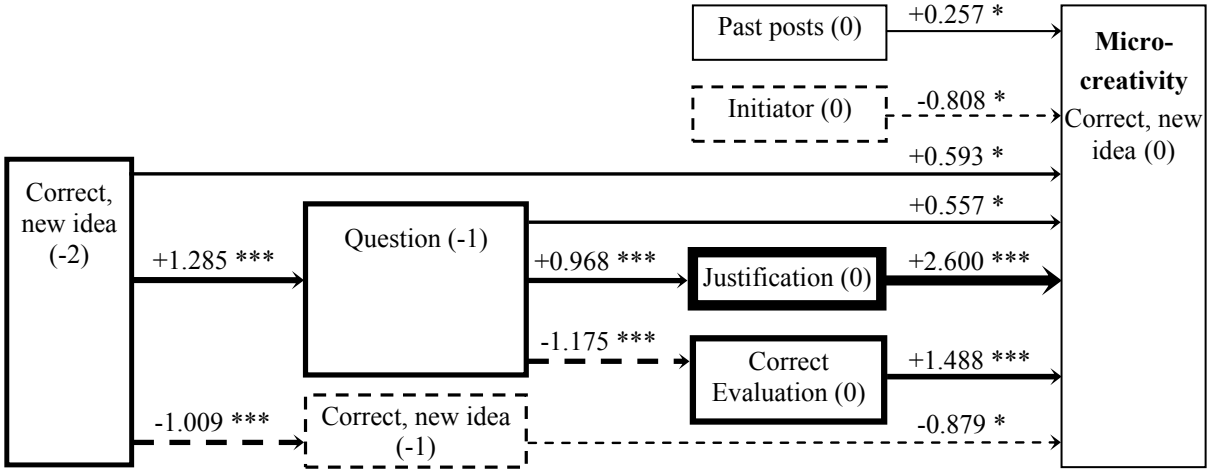

Figure 3. Path analysis of significant explanatory variables of micro-creativity using two-level Logit. Values are standardized parameter coefficients. Explanatory variables inside solid boxes indicate positive overall effects, while those inside dashed boxes indicate negative overall effects. Solid arrows (→) indicate positive direct effects, while dashed arrows (---→) indicate negative direct effects. Line widths indicate effect sizes according to the percentage changes in Table 1.

Correct evaluation (0), i.e., a correct evaluation in the current message, increased micro-creativity (+21%: 9% → 30%), supporting the first half of H-2c. If evaluating a previous idea correctly, either agreeing with a correct idea or disagreeing with a wrong idea, an e-poster was 21% more likely to show micro-creativity.

A question in the previous message (-1) increased micro-creativity (+12%: 9% → 21%), supporting H-2d. Commands in the earlier messages did not affect micro-creativity. As the data had only two commands (out of 501 messages), the statistical power was too low to test their effects.

This Logit model had an 82% accuracy rate for predicting micro-creativity in any given message (y_{ij}* vs. y_{ij}). The corresponding Probit model produced consistent parameter estimates. Furthermore, the final model' Q statistics and I^2 index showed no significant serial correlation of residuals for the 60 topics up to lag 3 (df = 60, 116, 170, respectively; Q = 46.062, 89.786, 106.139, respectively; p>.05 for all; I^2 index = 0 for all). So, the time-series model was likely appropriate.

Discussion

Of all 501 messages, 64% had new ideas, including 31% micro-creativity, 7% wrong, new ideas, and 26% uncertain, new ideas. The high proportion of new ideas is consistent with Heckman and Annabi's (2005) study where 83% online discussion messages and 30% FTF utterances contained new ideas (e.g., analysis, integration). Also, micro-creativity occurred more often than wrong, new ideas or uncertain, new ideas in this study, consistent with Chiu's (2008) study of FTF discussions showing that correct ideas occurred 20% of the time while wrong ideas occurred 10% of the time.

Correct, New Ideas Increases Subsequent Micro-creativity

Correct, new ideas in earlier messages aided a current message's micro-creativity. Specifically, Correct, new ideas in the previous message reduced the likelihood of a current message's micro-creativity, whereas correct, new ideas two messages prior increased it. Overall, correct, new ideas in earlier messages increased the likelihood of a current message's micro-creativity.

These results suggest that, in responding to correct, new ideas, e-posters were less likely to build micro-creativity directly. Instead, they tended to ask questions (or perhaps use other perturbations) as the path analysis showed that correct, new ideas predicted questions in this study. Then, in responding to these questions, they were likely to address the obstacle(s) in the earlier correct, new ideas and make new micro-creativity. Hence, correct, new ideas helped elicit more micro-creativity in subsequent messages, showing that the chain

reactions of micro-creativity might occur in online discussions, thereby supporting the claim that online discussions can promote students' micro-creativity.

The effects of wrong, new ideas and uncertain, new ideas on micro-creativity remained unclear. The useful parts in wrong or uncertain messages might have aided e-posters' micro-creativity (Nijstad, Diehl, & Stroebe, 2003). However, the wrong or uncertain information in these messages might also lead e-posters astray, thereby lowering the efficiency in eliciting micro-creativity.

Together, these results suggest that micro-creativity were more important than wrong or uncertain, new ideas for eliciting micro-creativity in this study, unlike Chiu's (2008) study of FTF discussion showing that wrong, new ideas were more important than micro-creativity for eliciting micro-creativity.

Justifications Increase Immediate Micro-creativity

Justifications aided immediate micro-creativity, consistent with the studies of FTF discussions (e.g., Chiu, 2008; Goldbeck, 1998; Lindow et al., 1985). Furthermore, justifications had the strongest effect on micro-creativity (+48%), larger than the combined effects of all other predictors. This result highlights the importance of justifications in aiding micro-creativity during online discussions. The process of justifying a new idea might help identify flaws in each step, obtain precise reasoning steps, and lead to micro-creativity. Hence, e-posters can capitalize on the time flexibility of online discussions to think and search for evidence to justify their new ideas, thereby aiding micro-creativity.

Correct evaluations Increase Immediate Micro-creativity

Like justifications, correct evaluations also aided immediate micro-creativity. If evaluating a previous idea correctly, the e-poster was likely to show micro-creativity. Controlling for correct evaluations, agreements or disagreements alone did not affect e-posters' micro-creativity. These results show that the accuracy of e-posters' evaluations was more important than the type of evaluations for facilitating micro-creativity in this study. Recognizing the previous ideas as correct or wrong helps e-posters build on them to make micro-creativity (Barron, 2003). Hence, e-posters can take time to evaluate one another's ideas carefully, thereby increasing the likelihood of presenting correct evaluations that aid immediate micro-creativity.

During the online discussions in this study, agreements did not reduce the likelihood of micro-creativity, nor did disagreements increase it, possibly because e-posters used fewer simple agreements and more simple disagreements. Unlike FTF discussions, online discussions do not expect any participant to respond soon or respond at all. Hence, simple confirmations or false agreements without micro-creativity (e.g., the "Uh-huh" or "Yeah" in FTF discussions) are less likely to occur in online discussions. Instead, the reduced face concern and increased psychological distance of e-posters might incline them to disagree more often with others' ideas, even without sufficient evidence for the opposition (e.g., "You're wrong", "I disagree"; Reinig & Mejias, 2004). Hence, simple disagreements without micro-creativity are more likely in online discussions. As a result, the expected negative effect of agreements and positive effect of disagreements on micro-creativity are likely to be mitigated.

Questions Increase Subsequent Micro-creativity

Questions yielded greater micro-creativity, showing that questions often received satisfactory responses. Questions also increased the likelihood of micro-creativity through inviting justifications (see Figure 3). These results show that e-posters were likely to ask questions that invite explanations or justifications, supporting the view that online discussions can promote e-posters' higher order thinking (Schrire, 2004).

Questions often occurred after micro-creativity and helped elicit more micro-creativity. After micro-creativity, the responders often asked questions inviting further explanations or justifications, which in turn yielded micro-creativity. The "micro-creativity (-2) → question (-1) → micro-creativity" and "micro-creativity (-2) → question (-1) → justification (0) → micro-creativity" effects suggest that e-posters are likely to identify the obstacles in micro-creativity, express them by questions, and use micro-creativity to address the questions. Meanwhile, these effects highlighted the importance of questions in facilitating micro-creativity during online discussions.

Implications for Teachers and Students

This study highlights the importance of micro-creativity, justifications, correct evaluations, and questions in facilitating micro-creativity during online discussions. To aid students' online micro-creativity and problem solving, teachers can encourage them to post more micro-creativity, justify their own ideas, evaluate one another's ideas carefully, and ask more questions during online discussions.

First, teachers can encourage students to post more micro-creativity during online discussions, which is not necessarily the ultimate solution to the problem. As micro-creativity fostered subsequent micro-creativity, even minor micro-creativity might serve as bases for creating more comprehensive micro-creativity. Second, teachers can encourage students to justify their own ideas and evaluate others' ideas carefully. Supported by a

justification, a new idea is more likely to be reasonable and micro-creative. Meanwhile, by evaluating a previous idea carefully, a student is more likely to evaluate it accurately and correctly, and thereby build micro-creativity on it. Third, teachers can encourage students to ask more questions during online discussions. By asking questions that invite explanations or justifications, students can stimulate one another's higher order thinking and micro-creativity. Lastly, teachers can intervene to ask leading questions to inspire students' micro-creativity.

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