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## Investigating the depth of problem-solving prompts in collaborative argumentation

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### ABSTRACT

To date, little is known regarding how to best design instruction/guidance prompts that support learners' participation in collaborative argumentation (CA). To address this gap, this study compared the influence of two instruction/guidance prompts prior to learners' CA: problem representation (executive summary of the problem) and full problem-solving (problem representation, alternatives, justification, evaluation). Discussions were analysed using Phases 1–5 of the interaction analysis model (IAM) to determine the degree to which learners engaged in CA. Those in the full problem-solving condition were more likely to challenge the assertions of their peers. However, participants in the problem representation condition were more likely to integrate feedback as interaction progressed. This research describes how the design of instruction/guidance prompts affects the degree to which concepts and solutions are fixed as learners encounter differing perspectives from their peers during collaborative argumentation.

### KEYWORDS

problem-solving;  
collaborative argumentation;  
computer-supported  
collaborative learning;  
scaffolding; inquiry-based  
learning

### Literature review

To support the development of higher-order learning, educators often pose cases to learners that are representative of domain-specific problems (Lazonder & Harmsen, 2016; Loyens & Rikers, 2011). Throughout this process, learners develop questions about the problem space, evaluate evidence over time, and share responsibility in the learning process. Moreover, learners work with peers to collaboratively construct argumentations as they identify misconceptions, refine knowledge, and expand perspectives (Chen et al., 2018; Wecker & Fischer, 2014). In doing so, collaborative argumentation requires learners to not only elicit their initial understanding, but also elaborate and justify their responses in light of counterclaims from their peers (Radkowsch et al., 2020; Vogel et al., 2017). Through sharing ideas during collaborative argumentation, learners can enhance personal understanding by interacting with others – receiving feedback on shared ideas and reconciling differences among the group (Ge et al., 2010; Tawfik et al., 2018).

To understand and support collaborative argumentation activities in online learning contexts, 'one should not only rely on students' argumentation knowledge, but also their behaviour during actual discourse' (Valero Haro et al., 2019, p. 330). In online collaborative argumentation activities, learners are expected to post their ideas, offer feedback to peers, and interact with instructors—helping to determine the direction of the course through interactions (Hew et al., 2010; Ringler et al., 2015; Ge & Land, 2004). To date, various theories and models explicate the collaborative argumentation process in online learning. For example, Oh and Jonassen (2007) aligned their model with elements of both problem-solving (problem identification, hypothesis development, solution generation) and argumentation actions (verification, rebuttal, evidence, elaboration). Alternatively, Weinberger and Fischer (2006) include a comprehensive model that describes both cognitive and collaborative modes: participation, epistemic, argumentative, and social. While these theories and models outline key aspects of collaborative argumentation, the interaction analysis model (IAM) especially highlights the phases by which learners progressively identify and reconcile differences across distinct phases (Gunawardena et al., 1997), including analogical reasoning and metacognition. Specifically, the IAM outlines the following five phases: (a) Phase 1- sharing information (sharing ideas and disagreements), (b) Phase 2- discovery of dissonance (articulating argumentation related to conflicting perspectives, weighing of evidence, or identifying inconsistencies between ideas), (c) Phase 3- negotiation of meaning (establishing a shared understanding; co-construction), (d) Phase 4- testing new knowledge (application of new knowledge towards the problem), and (e) Phase 5- collective agreement statements (metacognition). In doing so, the phases in this model depict advancement from 'lower to higher mental functions' as learners share ideas and justify solutions to complex problems in online learning (Lucas et al., 2014, p. 415). Studies using the IAM in online collaborative argumentation suggests that students often share an array of different ideas (Phase 1), but rarely achieve advanced phases when their interaction is not supported (Lin & Chan, 2018; Lucas et al., 2014). When left to navigate problem-solving and argumentation without support, research also suggests novice problem solvers struggle to develop a clear representation of the problem, consider key issues at a surface level, focus on proposing solutions without an understanding of problems, spend limited time engaged in reflective thinking, and fail to sustain meaningful interactions (Ertmer & Koehler, 2015; Ng & Tan, 2006).

To overcome these challenge in online spaces, prompts are designed scaffolds embedded in the learning environment that 'direct student attention to important aspects of problem-solving and guide the peer problem-solving process', during collaborative argumentation (Ge & Land, 2004, p. 6). Indeed, studies show improved domain-specific knowledge (Radkowsitch et al., 2020; Vogel et al., 2017) and interaction (Wecker & Fischer, 2014) during collaborative argumentation when different types of prompts are implemented. In terms of timing, learners may be given strategic prompts prior to working with peers (Felton et al., 2015b; Tsovaltzi et al., 2017) or at specific intervals during argumentation activities (Noroozi et al., 2017). Prompts in online environments can also be in the form of teacher facilitation, peer feedback, role and assignment, and instruction/guidance (Chen et al., 2018). Instruction/guidance prompts specifically outline defined structures when formulating their argumentation and responding to peers (Cho & Jonassen, 2002). In a recent meta-analysis, Chen et al. (2018) found differential effects on prompt types in online learning, with instruction/guidance prompts to be especially

effective on individual knowledge achievement and skill acquisition, as well as social interaction measures. These findings underscore how the type of instruction/guidance prompts support the entire interactive process during collaborative argumentation (Wecker & Fischer, 2014).

## Research questions

Although prompts have successfully supported elements of problem-solving, studies show that scaffolding collaborative argumentation still remains a challenging aspect in online settings (Baker et al., 2019; Wecker & Fischer, 2014). While studies highlight the effectiveness of instruction/guidance prompts, less is known about how differing designs of these prompts impact subsequent interaction (Felton et al., 2015b; H.-C. Wang et al., 2011; Tsovaltzi et al., 2015). Because collaborative argumentation consists of complex interactions among peers (e.g. share ideas, reconcile differences, evaluate evidence), research is needed about the specific design features of instruction/guidance prompts that engender productive forms of problem-solving among peers. Based on this gap, we proffer the following research question:

To what degree does collaborative argumentation in a problem-solving task differ when (a) not prompted, (b) given instruction/guidance prompts designed for initial problem representation, or (c) given instruction/guidance prompts designed to reflect on the entire problem-solving process?

## Methodology

### Participants

Participants (N = 121) were students enrolled in an online undergraduate course in the college of business at an American Midwestern university. The course was an upper-level sales management course, which consisted of junior- and senior-level students. Via email and a learning management system post, a research team member informed participants that this research was an adaptation of an existing assignment, while also giving them the option to opt-out if they did not want their data analysed.

### Procedure

The two-week activity was offered as part of an eight-week, three credit summer course. Participants were randomly assigned to peer groups and then each group was randomly assigned to one of three conditions: (a) not prompted for reflection prior to problem-solving (control group; N = 42 participants; 15 groups), (b) given instruction/guidance prompts designed for initial problem representation reflection prior to problem-solving (N = 37 participants; 13 groups), or (c) given instruction/guidance prompts designed to reflect on the entire problem-solving process (e.g. problem representation, alternatives, justification, evaluation) (42 participants; 14 groups). Each group was assigned a separate discussion forum to consider the given problem with their group members.

Instructions and the main problem to solve (i.e. 'Nick's Dilemma') were made available via the learning management system in the same way across the three conditions, with the only difference being the prompts (see Materials section). To begin the collaborative argumentation activity and promote reflection, participants were provided two days to read Nick's Dilemma so the participants would have adequate time to review the materials. Then, participants engaged in a collaborative argumentation activity for the next 12 days (see Table 1 Supplementary material).

Upon completion of the assignment, discussion board posts were downloaded from the learning management system and broken down into individual idea units. Finally, each idea unit was coded using the IAM (see Analysis section and Table 2).

## Materials

**Main Problem.** Instructional materials for this study were adapted from a problem-based learning module, entitled 'Nick's Dilemma,' developed and used in prior studies (Tawfik et al., 2018) and shared via a hyperlinked web page on the discussion board. Nick's Dilemma includes an ill-structured decision-making problem about maintaining a sales unit and requires learners to justify a hiring decision given training costs, employee morale, job competencies, and other variables.

## Instruction/guidance prompts

Individuals randomly assigned to the *control condition* were not provided any instruction/guidance prompts guiding peer collaboration. Alternatively, those in the *problem representation condition* were asked to (a) reflect prior to the activity and (b) share an executive summary of all the concepts they felt were relevant to the problem. In the final condition (*problem-solving condition*), participants were prompted through Ge and Land (2003) problem-solving process prior to participating in the discussion (see Table 1). Ge and Land (2003) instruction/guidance prompts were chosen because other studies underscore its effectiveness in scaffolding problem-solving and argumentation (Ge et al., 2010; Tawfik et al., 2018). Specifically, they offer a way to comprehensively scaffold multiple phases of the problem-solving process (e.g. including problem representation and solution generation) and key elements of argumentation, including asking students to articulate their solution, justification, and potential challenges to their approach.

**Analysis** The discussion board interactions were transformed into 1,877 unique idea units. As noted by others (Weinberger & Fischer, 2006), idea units are often defined based on the context and research questions. Because a single discussion post was lengthy and often entailed multiple elements (e.g. acknowledging the prior comment, sharing new evidence to counter the prior perspective), a single post could be broken down into multiple idea units. The current study focused on collaborative argumentation as outlined by the IAM, so idea units were predominantly demarcated based on elements of argumentation, including sharing of ideas, questions, areas of agreement, testing of ideas, and metacognition (Lucas et al., 2014).

Two research assistants were trained and guided on the IAM coding scheme (Gunawardena et al., 1997), as well as given coding examples of idea units (see Table 2 supplementary material). The analysis included the entire online problem-solving activity,

with all five phases of the IAM considered. The two research assistants coded the idea units separately, and data were then compared for areas of disagreement. To ensure reliability, the research assistants began by coding a subset of the data and later met to discuss potential discrepancies as they applied the IAM coding scheme. Furthermore, the team (two research assistants, lead researcher) evaluated the interaction and later developed a codebook, which consisted of exemplars for each code of the IAM. After three rounds of coding, a final agreement of 100% was achieved.

## Results

To answer the research questions, a Chi-squared analysis was completed for the 1,877 idea units. Chi-squared analysis was employed given the categorical nature of the participant groups (control, problem representation, problem-solving process), and phases (Phase 1–5) (Shan & Gerstenberger, 2017). The discussion posts were broken down as follows: Phase 1 = 762; Phase 2 = 178; Phase 3 = 649; Phase 4 = 213; and Phase 5 = 64 (see Figure 1). The distribution of posts across phase categories was uneven at a statistically significant level  $\chi^2(28.763; df = 8; p < .001)$ ; that is, statistically significant differences were found among the categorical variables. Cramer's V was 0.88, which indicates a relatively low level of association (Shan & Gerstenberger, 2017).

### Argumentation as IAM Phases Across Conditions

To further identify which cells were statistically significant, the study explored the standardised residuals. A standard residual can be interpreted as similar to a Z score; therefore, a standard residual of  $\pm 1.96$  is  $p < .05$  and  $\pm 2.58$  is  $p < .001$  (Field, 2017). Multiple associations were found between the cells at a statistically significant level. For Phase 1

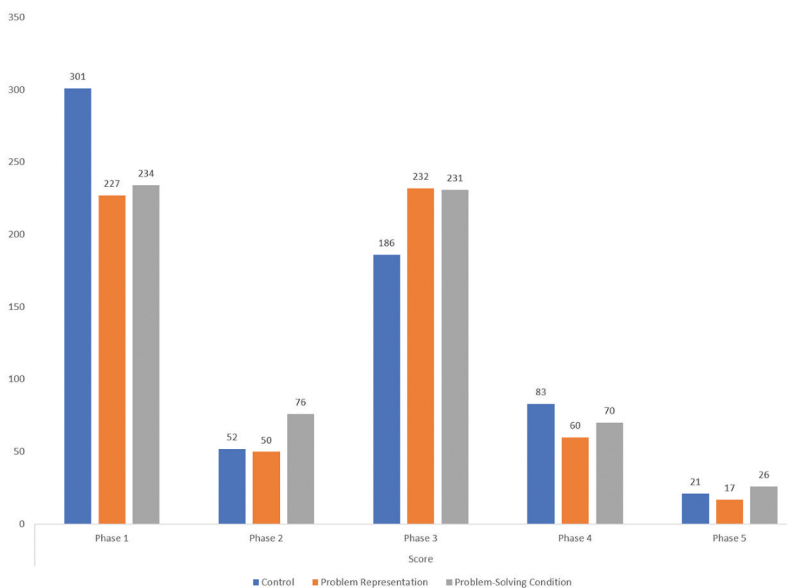


Figure 1.

(sharing/comparing ideas), those in the *control condition* were found to be statistically significant at the  $p < .05$  level ( $z = 2.4$ ). Hence, learners in the control group were more likely to externalise and share ideas when compared with the scaffolded conditions.

For Phase 2 (asking questions), statistically significant differences were found in participants in the *problem-solving process condition* at the  $p < .05$  level ( $z = 2.0$ ). That is, compared to the other groups, those in the *problem-solving process condition* were more likely to challenge their peers as they identified dissonance among the group members.

For Phase 3 (co-construction of knowledge), those in the *control condition* ( $z = 2.5$ ) and *problem representation condition* ( $z = 2.0$ ) were found to have statistically significant differences among their cells. As such, we can surmise that these two conditions were more likely to engage in co-construction of knowledge compared to the learners in the *problem-solving process condition*.

There were no statistically significant differences among the groups for testing of newly constructed knowledge (Phase 4) and metacognition (Phase 5).

## Discussion

Studies show that collaborative argumentation is challenging in online learning environments because technology changes the dynamicity of the interaction (i.e. timing of response); however, strategically designing interaction in meaningful ways may overcome some of the aforementioned struggles. To that end, the findings from this study build on prior research that explores how the design of instruction/guidance prompts impact collaborative argumentation (Avci, 2020; Chen et al., 2018; Noroozi et al., 2017; Wecker & Fischer, 2014). The results found that when sharing information (Phase 1), those in the control condition without the designed prompts shared more ideas; however, differences emerged across other phases as the argumentation process progressed. In the challenging phase of argumentation (Phase 2), those in the *problem-solving process* (problem, select a solution, justify, evaluate) condition were more likely to question the assertion of their peers. As the learners moved towards more co-construction to reconcile differences (Phase 3), those in the *problem representation condition* and *control* groups outperformed the *problem-solving process condition*.

Multiple interpretations for these findings exist. For Phase 1, the *control condition* – those without any designed instruction/guidance prompts – engaged in more sharing of initial ideas. On the surface, this may appear as a positive finding; however, a large number of initial ideas may not be a positive outcome if learners struggle to reconcile their ideas during the later stages of collaborative argumentation. This finding coincides with other research showing that learners initially share a variety of ideas when not scaffolded and often struggle to sustain that interaction throughout the problem-solving process (Avci, 2020; Lobczowski, 2020; Lucas et al., 2014). Additionally, when compared to the other conditions, one might conclude that learners in the *control condition* were quick to share incomplete ideas. In contrast, learners in the scaffolded conditions may have taken time to reflect and develop an initial schema, allowing them to share ideas that were better vetted.

Other differences emerged as learners moved from sharing ideas (Phase 1) to challenging the differing perspectives (Phase 2) during collaborative argumentation. Those in the full *problem-solving process condition* (problem, solution, justify, evaluate) were more likely to engage in this type of collaborative argumentation than learners in the other conditions, but not for co-construction (Phase 3), testing of the proposed solution (Phase 4), or metacognition (Phase 5). One might assume prompting learners to consider the entire problem-solving process would promote other interactions (Phases 3–5) that are important to the collaborative argumentation process. Possibly, the structure of this instruction/guidance prompt resulted in a more fully-formed mental model, allowing learners to more readily challenge the assertion of their peers when confronted with an equally developed alternative perspective. Therefore, the design and ensuing effect may be a different form of argumentation akin to ‘my-side bias’ than if the learner was contemplating the idea for the first time (Wolfe & Britt, 2008). In a study considering online argumentation comparing persuasion versus consensus building in online argumentation, Felton and colleagues (2015a) concluded that ‘responses [for the arguing to persuade condition] may have been provoked by the experience of arguing against someone who was more committed to maintaining their position than to critically examining other-side claim’ (p. 327). In line with other studies (H.-C. Wang et al., 2011; Tsovaltzi et al., 2015), Tsovaltzi et al. (2017) focused on the impact of individual interaction time and what they described as ‘premature knowledge consolidation’ on collaborative argumentation. Their interpretation of findings suggested that increased individual preparation had a negative impact on collaboration because it inhibited subsequent knowledge co-construction and knowledge convergence. In the context of the current study, this could explain why differences in the more robust *problem-solving process condition* emerged when learners challenged their peers (Phase 2), but did not result in discourse that required them to adopt additional perspectives and work with their peers as the argumentation process progressed. That is, the prompt encouraged them to develop a more fully formed mental model, so they were more focused on defending advised positions as opposed to the more collaborative aspects requiring them to adopt the perspective of others (Phase 3), test their positions (Phase 5), and engage in collective metacognition (Phase 5) during argumentation.

Additional differences emerged as learners shifted towards the reconciliation process and co-construction of meaning phase (Phase 3). An interesting finding is that those in the *problem representation condition* were more likely to engage in this collaborative argumentation action. In this condition, the design asked them to reflect in a general way using an executive summary and less structured format. These differences could be explained by students’ abilities to socially manage their learning, which ‘occurs when groups regulate together as a collective’ (Häkkinen et al., 2017, p. 30). In the more extensive *problem-solving condition*, students were given instruction/guidance prompts that considered the full problem-solving process prior to collaborative argumentation, which may have overscripted (Dillenbourg, 2002; Tsovaltzi et al., 2010) the interaction and caused students to be less open to new ideas. Compared to additional scaffolded strategy, those in the *problem-representation condition* prompt were less fixed and thus open to conceptual change as they engaged in argumentation with their peers. Although additional scaffolds may be needed for advanced tasks such as testing of argumentation (Phase 4) and

group metacognition (Phase 5), the *problem-representation condition* approach potentially included the right balance of focused interaction, but also left the process open to future ideas shared by their peers (Phase 3). This may also support the assertion that: 'learners of immature epistemic beliefs may seek information and resources to support their planned solution, while not willing to seek or to ignore the information that may challenge their original solution plan' (Law et al., 2020, p. 327).

### Future studies and limitations

While this research adds to the empirical literature of collaborative argumentation, multiple studies could build upon the research. As shown by our results, the design of instruction/guidance prompts impacted the degree to which learners engaged in their collaborative argumentation; it thus follows that future studies could explore how other scaffold formats impact the learning outcomes. Indeed, a variety of studies of computer-supported collaborative learning (Vogel et al., 2017) and argumentation (Wecker & Fischer, 2014) show that scaffolds play a vital role in learners' problem-solving. While the instruction/guidance prompts used in this case were focused on problem-solving, future experiments could consider epistemic prompts (Lin & Chan, 2018), social support (Weinberger et al., 2005), peer feedback (Noroozi & Hatami, 2019) and consider the relationship among these various support strategies. As opposed to instructional/guidance prompts that focused on the more cognitive function and internalise understanding, it is possible these prompts might better accentuate the collaborative aspect and thus achieve the higher phases of the IAM, such as testing against other scenarios (Phase 4) and group metacognition (Phase 5).

Additionally, future research could explore how the results are influenced by domain and problem type. In the context of this study, participants were given a decision-making problem within business education. As collaborative argumentation is key in solving ill-structured problems in other domains, future research is needed to understand contextual differences. For example, medical students often use argumentation as they discuss the best way to treat a patient during a diagnosis-solution problem (Ju & Choi, 2017). Alternatively, collaborative argumentation is a key aspect in how engineers engage in design problems that are often inherent within that domain. Future studies focused on different disciplines would provide valuable insight into complex problem-solving and collaborative argumentation for ill-structured problems found within diverse learning settings.

### Conclusion

The results of this research highlight the complexity involved with designing scaffolds for problem-centred and collaborative argumentation. Specifically, the results from this study suggest that the timing and structure of instruction/guidance prompts led to different interactions among peer groups. When compared to the other two groups, learners in the *control condition* spent most of their effort in sharing and comparing ideas (Phase 1), and like the *problem-representation condition*, were more likely to engage in co-construction of knowledge (Phase 3), as compared to the *problem-solving process condition*. However, learners in the *problem-solving*

*process condition* spent more effort asking questions (Phase 2), as compared to the other two groups. Efforts to engage in testing new knowledge (Phase 4) and constructing collective metacognition (Phase 5) decreased sharply across all groups, resulting in no significant differences across groups' performance.

The aforementioned findings are interesting in light of other recommendations from theorists: 'when learners find themselves in discord with other group members in data collecting or discourse, learners resort to negotiation and coordination in order to reach a consensus' (M. Wang et al., 2013, p. 78). To overcome this challenge, the results from this research suggest that eliciting collaborative argumentation may be a function of the scaffold design. Perhaps, students in the more extensive *problem-solving condition* had already executed some of the testing and modification of their solutions individually, committing to a specific solution and thus making social consensus more difficult. In contrast, individuals in the more general *problem representation condition* were more open to other options.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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