Coercing Shared Knowledge in Collaborative Learning Environments

Paul A. Kirschner(1), Open Universiteit Nederland, PO Box 2960, 6401 DL Heerlen, The Netherlands, paul.kirschner@ou.nl
Pieter Jelle Beers, Delft University of Technology, Jaffalaan 5, 2628 BX Delft, The Netherlands, p.j.beers@tbm.tudelft.nl
Henny P.A. Boshuizen, Open Universiteit Nederland, PO Box 2960, 6401 DL Heerlen, The Netherlands, els.boshuizen@ou.nl
Wim Gijselaers, Maastricht University, PO Box 616, 6200 MD, Maastricht, The Netherlands, w.gijselaers@educ.unimaas.nl

Abstract: Multidisciplinary teams are used in industry, government and education for solving complex problems because their use allows for different perspectives to be brought to bear on a problem. This, in turn, is expected to allow for rich problem analyses and solutions. On the other hand, these same differences can cause discussions in multidisciplinary teams to become veritable towers of Babel. This is because team members assume that what they say is properly understood (actually interpreted) by other team members and vice versa. Unfortunately, these differences in domain specific knowledge, background, opinions, et cetera stand in the way of this mutual understanding. Both meaning and position need to be understood and accepted before team members achieve the common ground necessary. The research reported on here shows how a negotiation formalism that was implemented in and ICT-tool coerced team members to negotiate both the meaning of each others contributions to the solution of a complex problem and their positions with respect to each others contributions so as to achieve more common ground. The results show that this coercion had positive effects on common ground without negatively affecting interaction within the teams.

Coercion and Negotiation

Rothkopf (1970), paraphrasing a well known saying, stated that you can lead a horse to water, but only the water that gets into its stomach is what it drinks. What Rothkopf meant is that learning depends less on what teachers or instructional designers plan or want to have happen in learning situations than on what the learners themselves actually do. Central to this idea is that what occurs is "a matter of choice on the part of the student …students choose whether they will pay attention in lectures, read assignments, or review what has previously been read" (Rhodes, 1993, p. 6). So is it also with collaborative learning environments. Experience and research has shown that learners don't work or learn well in collaborative learning environments we design and develop 'for them'. To remedy this, teachers and instructional designers often use of a number of stopgap measures to get the students to work and learn together such as requiring a certain number of emails or contributions to discussions or heavily moderating discussions.

But why? These same students who do not, or will not, collaborate in the CSCL-environments spend a great deal of their waking hours when not at school emailing, chatting or Skyping® each other! Often the task, the social conditions or the tool is at fault. With respect to *tasks*, it is often the case that the chosen learning tasks are not suited to collaboration. Tasks are often too closed, too easy, or too controlled. As for *social conditions*, it is too often the case that they are not present. In other words, the environment has neither the necessary pedagogical affordances (i.e., too much concentration on 'on-task' behavior) and/or technological affordances (i.e., lack of tools that present opportunities to create a sound social space through awareness) to allow and/or stimulate the social conditions necessary for good collaboration. Finally, and related to the previous problem, that environments themselves are not *technologically* suited to collaborative working and learning. In other words, the tools have an *ontology* that does not match the problem or task at hand, and/or those to *coerce* the needed activities.

Coercion

Merriam-Webster Online® defines *coerce* as "to compel to an act or choice", in other words to require or constrain certain acts or choices so as to shape or compel certain actions. Many researchers have used information and communication technology tools in their attempts to stimulate and sustain working in teams. These tools use *formalisms*; constraints that, for example, structure conversation and discourse among collaborators so as to guide the exchange of knowledge and information. They are sets of moves or actions that users are allowed make within a specific environment or situation. Specific formalisms have been tailored to influence specific aspects of problem solving, and a few ICT-tools have been developed to coerce (Dillenbourg, 2002) people to follow the rules of such formalisms. Coercion here refers to the degree of freedom participants are allowed in following a specific formalism. Coercion and formalism together constitute a *collaboration script*. The higher the script's coerciveness, the more participants are required to adhere to its formalism. Scripting requires "subjects…to make a particular type of speech act in a specific context." (Baker & Lund, 1997, p. 176).

Explicit Knowledge is not the same as Shared Knowledge

Bromme (2000) theorizes on the causes of misunderstanding of multiple representations, noting that people communicate on the basis of their assumptions about the others' perspectives. Thus, one's perspective of the other affects one's own externalization of knowledge, and one's own understanding of others' contributions. Unfortunately, assumptions of others' perspectives have been shown to be inaccurate (Bromme, Rambow, & Nückles, 2001), which explains misunderstandings found by Boshuizen and Tabachnek-Schijf. To this end, Bromme introduces the concept of negotiation of *common ground*, iteratively making one's private understanding of the other explicit and providing feedback so as to reach common ground; a common cognitive frame of reference. Common ground, once achieved, can act as a shared interface between multiple representations. Within this framework Beers, Boshuizen, Kirschner, and Gijselaers (2005) hypothesized that unshared knowledge in one participant's head becomes newly constructed team knowledge via three intermediate forms and four processes.

In this process, negotiation of both meaning and position are essential to achieve common ground (Alpay, Giboin, & Dieng, 1998; Baker, Hansen, Joiner, & Traum, 1999). *Negotiation of meaning* concerns making a private *understanding* of a contribution public, verifying whether and to what extent one's own understanding differs from what others intend, receiving feedback on this, re-verifying, etc. *Negotiation of position* concerns people doing the same about their private *opinions*.

Supporting Negotiation for Complex Problem Solving

Negotiation of common ground is intrinsic to solving complex problems because common ground is needed to afford sharing knowledge and the subsequent constructing of a shared problem representation in multidisciplinary teams. To do so, problem solvers need to explicitly verify their understanding of each other's contributions to the discussion and explicitly articulate their positions on those contributions.

To support this, five support principles that mimic the process of negotiation were developed by the authors. These support principles require participants to follow certain rules when solving complex problems. Learning occurs when grounding forces co-learners to elaborate explanations (Webb, 1991) and negotiate decision-making or meaning (Baker et al., 1999). Beers et al. developed a set of rules (i.e., a formalism) that serves as a model for conversation for both contiguous and distributed groups to negotiate meaning and position to ultimately increase common ground. New conversation topics are introduced using a *contribution* message, and verified and clarified using *verification* and *clarification* messages. Furthermore, participants use *agree*- and *disagree*-messages to make their position known to their team mates, and they can post *rejections* to messages that are unintelligible or objectively incorrect in their eyes. That formalism, aimed at making individual perspectives explicit to other team members, was developed, tested, and implemented in an ICT negotiation tool (NTool).

Three Studies

Research Questions

Different people attach different meanings to a word, often because they come from different content areas or have different perspectives and thus different norms. A word with a specific meaning in one domain may have a different meaning in another. What a designer understands to be 'elegant' is not the same as what a computer programmer understands. And even when those involved agree on the meaning of a term, their perspectives might differ. What an employee of an oil company sees as an acceptable environmental risk is rarely the same as what a member of Greenpeace sees as acceptable. Three related studies were carried out to determine whether it was possible to design and develop a tool to help learners in collaborative-learning environments negotiate meaning while solving a complex problem. The research centered on answering the following research questions:

- Can learners in collaborative environments use and profit from coercion, and if so, can a tool be designed that can effectively coerce them?
- How does coercion affect (negotiation of) common ground?
- How does the degree of coercion affect negotiation and common ground?
- Does the degree of coercion disrupt discussions?

For a full discussion of these studies as well as the methodological problems encountered and their solutions, the reader is referred to Beers (2005) and Beers et al. (2005).

Scripting and Coercion

As stated, coercion entails using specific constraints on communication; the amount of freedom participants are allowed in following a formalism. Coercion and formalism constitute a *collaboration script*. The more coercive the script, the more participants are required to adhere to its formalism. A script that uses very little coercion leaves participants much freedom whereby usage of the formalism attains a high degree of idiosyncrasy. A script with a high level of coercion constrains the number of options participants have, thus guiding them along the lines of the formalism. In the research reported here, three types/levels of scripting were used.

The first type was i*diosyncratic*, and used a low level of coercion. Participants are supplied with a formalism with specific message types (i.e., contribution, verification, clarification, agree, disagree, reject, accept), but without restrictions as to their use. In other words, they can use (or not use) the different message types as they see fit and in the order that they choose.

The second type was *scripted* and used a medium level of coercion. Participants are supplied with a formalism with the same specific message types, but are restricted in their use of it. Thus, certain (combinations of) moves or acts are permissible, but others are not. Participants are, for example, required to negotiate meaning of all contributions first and then to negotiate position.

The final type was *stringent* and used a high level of coercion. Participants used the same formalism, but were 'forced' to follow it. For example, they had to verify – one contribution at a time - each contribution through a series of clarification-verification moves before accepting or rejecting the contribution (i.e., negotiating the meaning of a specific contribution) and then agreeing or disagreeing with it (i.e., negotiating position on the contribution).

Variables and Data

Common variables were used and comparable data were collected in all studies (two (1 and 3) were face-to-face, while two others were in a CSCL-environment. Regardless of setting, the same or similar variables were involved and data were collected.

Negotiation

The analysis goal was identifying aspects of communication that deal with negotiation of common ground. To that end the same theoretical framework used for the formalism was used to characterize and measure negotiation. These were:

- *Contribution*: Introduction of a new topic of conversation.
- *Verification*: Information is requested about the contribution's intended meaning.
- *Clarification*: Elucidation is requested as a reaction to verification.
- *Acceptance*: A contribution is judged intelligible and/or correct.
- *Rejection*: A contribution is judged unintelligible and/or incorrect.
- *Agreement*: The sender voices his/her agreement with the contribution.
- *Disagreement*: The sender voices his/her disagreement with the contribution.

As a result of the coding that actually took place, two extra categories were added.

- *Elaboration*: When people built upon each other's statements without negotiating common ground.
- *Task Regulation*: Conversation dealing with regulating what participants were doing (monitoring the problem solving-process and regulating the conversation.

Common ground

Common ground was operationalized as the extent that the content of individual representations was present in other individual representations. The content of all individual representations, both initial (pre-test), subsequent to collaboration (post-test), and the group representation was characterized and compared such that the mean number of times that a contribution was present in pre-tests and post-tests could be computed for each group. This mean number of post-tests per contribution was used as a measure of common ground.

Cognitive load

Cognitive load was measured through self-report of invested mental effort on a scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort) (Paas, Tuovinen, Tabbers, & van Gerven, 2003). *Mental* *effort* refers to the cognitive capacity that is actually allocated to solve the problem and can be considered to reflect the actual cognitive load (Sweller, van Merriënboer, & Paas, 1998).

Qualitative data

In two of the studies, qualitative data was also obtained to get in-depth, background information on what the participants were doing and why. Due to lack of space only one study is discussed here.

Study 1: Face-to-face With and Without Coercion

A pen-and-paper version of the formalism in a face-to-face setting tested both the formalism and the analysis methods to determine (1) whether the formalism influences negotiation of common ground; (2) how participants experience negotiation and achieving common ground; and (3) how participants used the formalism. Six multidisciplinary groups (triads) of senior college students from different majors in a business degree program were required to make an investment decision for a company. Participants were provided with a computer simulation and a large amount of data relating to the company and its past decisions, competing companies, within-market developments, and overall macro-economic indicators. Half of the groups were used the formalism when working with a whiteboard and flip-over (formalism condition); the other groups could use these materials any way they wanted to (the idiosyncratic condition). All participants were interviewed after the session.

Participants were given 45 minutes to explore the simulation and browse the data after which they started working. To promote construction of individual perspectives, and to allow the researchers to determine individual representations, participants first wrote down their solutions individually (pre-test). Next, they carried out the task in triads in each of the two conditions; this collaboration process was videotaped. After the collaboration, participants were again asked to individually carry out the task (post-test). Interviews were conducted within 24 hours. The video recordings of the process were used during the interview to stimulate the recall of thoughts during collaboration.

Results

Formalism groups worked longer, discussed more contributions, and negotiated them more thoroughly (see the amount of negotiation of meaning per contribution), than idiosyncratic groups. In general, the number of verifications and clarifications was higher in the formalism groups. A Mann-Whitney test showed that the difference in number of clarifications was marginally significant, $U(N = 6) = .500$, $p = .072$. Furthermore, in the formalism groups the mean number of participants per conversation-episode was significantly higher than in the idiosyncratic groups, $X^2(2,\ N = 150) = 8.77$, $p < .05$. No other differences were statistically significant, although all of the observed differences were sizeable and in the expected direction. On the whole, the data suggest that the formalism groups negotiated more, and more thoroughly, than the idiosyncratic groups.

Participants in the formalism groups discussed more topics than those in the idiosyncratic groups and mentioned more different discussion topics in their individual problem representations after the problem-solving task. The idiosyncratic groups captured more discussion topics than the formalism groups on their group external-representation ($M = 13.0$ vs. $M = 10.7$). Also, the number of discussion topics mentioned in the post-tests (overlap after collaboration) by all members was the same for both conditions ($M = 2.0$, number of discussion topics in three individual representations), which means that no difference in common ground was found. Adding pre-tests to the measurement of common ground (measuring change in overlap) suggests a bit more common ground in the idiosyncratic groups.

With respect to overlap between post-tests and external representations, idiosyncratic groups captured more topics in their external representation, but did not subsequently show more overlap between individual post-tests.

Study 2: CSCL with three levels of coercion

Study 2 tested the development of NTool based upon the formalism and the results of Study 1. Three versions of NTool with matching performance constraints (i.e., idiosyncratic, scripted, stringent) were developed, implemented, and tested (see Figure 1). The performance constraints were based on the hypothesis that the fewer degrees of freedom when using NTool (i.e., the stronger the performance constraint), the stronger the effects of NTool will be. The study was carried out in a laboratory setting where 17, 3-person multidisciplinary teams ($N = 51$) of university seniors in Cultural Sciences, Economics, and Business Administration attempted to solve the complex problem of high school drop-out (cf. Kirschner, Van Bruggen, & Duffy, 2003). Before starting on the task, participants received instructions about how to use NTool, about the formalism, and about the specific performance constraints during problem solving.

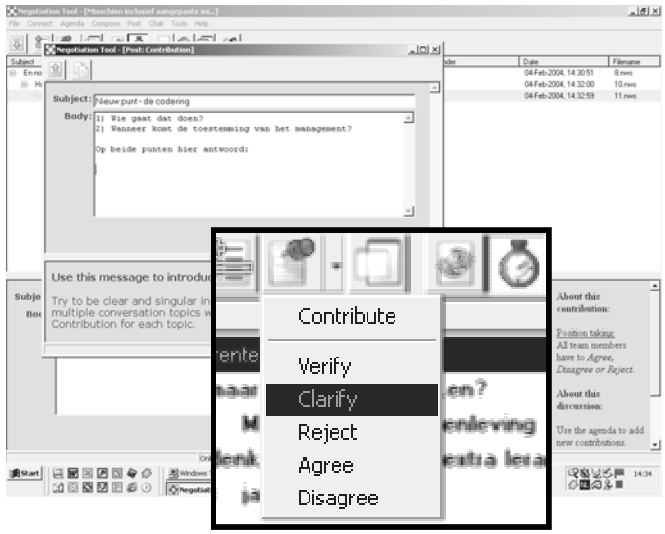

Figure 1. NTool

Results

NTool was shown to be increasingly effective with increasing stringency with a significant correlation between coercion and negotiation of common ground, $r_s(N = 17) = 0.51$, $p < .05$; the fewer degrees of freedom that the participants were allowed (more constraint) the higher the effects on the negotiation of common ground. However, the results also showed that the medium coercion groups required significantly more regulation than the other groups, $U(N = 17) = 4.00$, $p < .01$.

A Kruskal-Wallis comparison of the conditions on type of communication revealed significant differences between conditions for number of contributions, $X^2(2, N = 17) = 8.85$, $p < .05$, verifications, $X^2(2, N = 17) = 7.08$, $p < .05$, clarifications, $X^2(2, N = 17) = 7.33$, $p < .05$, acceptance messages, $X^2(2, N = 17) = 10.58$, $p < .01$ and regulation messages, $X^2(2, N = 17) = 8.03$, $p < .05$. Post hoc contrasting of Idiosyncratic groups with Scripted and Stringent groups revealed significantly more contributions in the Idiosyncratic groups, $U(N = 17) = 4.00$, $p < .005$. Finally, contrasting Scripted groups with Idiosyncratic and Stringent groups revealed significantly more acceptance $U(N = 17) < .001$, $p < .005$ and regulation messages $U(N = 17) = 4.00$, $p < .01$ in the Scripted groups.

Kruskal-Wallis tests showed that the amount of meaning negotiation per contribution differed significantly between the different versions of NTool, $X^2(2, N = 17) = 11.17$, $p < .005$. Coercion was significantly correlated with negotiation per contribution, $r_s(N = 17) = .83$, $p < .0005$. These results indicate that contributions were most heavily negotiated in the Stringent groups and least heavily in the Idiosyncratic groups.

No differences were found for common ground with regard to pre-tests, $X^2(2, N = 17) = 1.78$, $p = .41$. The distribution of contributions across post-tests was significantly different between conditions, $X^2(2, N = 17) = 6.14$, $p < .05$. Subsequent Spearman correlation testing showed that the distribution of contributions across post-tests was significantly correlated with coercion, $r_s(N = 17) = .57$, $p < .05$; the higher the coercion, the higher the number of post-tests a contribution would end up in.

Study 3: Face-to-face measuring cognitive load

Study 3 (a pen-and-paper experiment) was carried out to isolate and explain the results of Study 2. Participants worked in triadic multidisciplinary teams solving the high school drop-out problem. The same procedure as in Study 2 was used, but with additional measures for cognitive load. Participants were 12 university seniors from Psychology, Economics, and Cultural Sciences. Four multidisciplinary teams were formed by assigning one student from each discipline to a triad. The pen-and-paper version of the NTool support principle was used with a whiteboard and four colored markers during collaboration. Two teams - Scripted - received specific instruction for using the whiteboard and the markers. Two other teams – Idiosyncratic - could use their whiteboard and markers any way they wanted. The instruction required participants to write new contributions on the whiteboard (i.e., externalization of concepts), and react on others' new contributions by giving their own perspective on them. Participants were assigned personal colored markers to allow easy recognition of contributors.

Each team was given 30 minutes to collaboratively analyze the drop-out problem so as to come up with a solution. The team collaborations were videotaped. Participants were required to write down their individual perception of the problem and their solution(s) both prior to (pre-test) and after (post-test) the team collaboration.

Cognitive load was measured three times (after the pre-test, after the team collaboration, and after the post-test). Within two hours after the post-test, open and stimulated recall interviews were carried out in which participants were asked to recall their thoughts during collaboration.

Results

No differences in cognitive load were found after either the pre-tests or after group collaboration. However, after the post-tests, participants in the Scripted groups reported significantly more cognitive load, $U(N = 12) = 7.00$, $p < .05$, one-tailed, suggesting that scripted collaboration required more processing in the post-test idiosyncratic. Also, no significant differences were found for negotiation and common ground. Contributions were most heavily negotiated in the Idiosyncratic groups; Scripted groups made more contributions.

The Idiosyncratic groups achieved the most common ground after collaboration - content overlap in post-tests - but they also started with some unexpected overlap in pre-tests, which the Scripted groups did not have. Differences in common ground were not statistically significant.

Interviews were analyzed to gain insight in the participants' actual thought processes and focused on participants' thoughts about grounding processes, knowledge construction, the instruction, and the interaction (see Beers (2005) for a more thorough discussion of the qualitative results). Participants are aware of instances of agreement and disagreement, and of mutual understanding and misunderstanding. Participants also report thoughts about the background of the contributors to the discussion, including educational and philosophical backgrounds. In other words, they appear to actively attribute contributions to the contributor's background. Further, several qualitatively different reactions to differences in understanding and position became apparent, ranging from neglect of mutual misunderstanding to accepting something on the basis of another's expertise showing that possible misunderstandings are sometimes detected, but not actively addressed. Also, participants stated that they sometimes consciously wait for the contributor's clarification to see whether their primary (negative) reaction towards a contribution is justified. It seems that withholding one's reaction for a short time may allow for understanding that otherwise would not have emerged. Finally, the interview data show that participants actively build on each other's knowledge, and are capable of revising their own and each other's ideas.

Conclusions

What can be concluded from these studies? Study 1 showed that the formalism affects negotiation of common ground in the expected way; instructing participants to explicitly verify and clarify contributions increases negotiation of common ground. Also, it appeared from interview data that participants with the instruction were more committed to the negotiation of common ground. Study 2 - with an electronic NTool - showed that coercion is positively related to both the negotiation of and the amount of common ground. However, it also appeared that the specific way that the medium coercion condition was designed had unexpected disruptive effects on communication, as the users of this version used more regulation activities than users of the high and low coercion versions. Study 3, again a face-to-face study, showed that scripting alone probably had germane effects on common ground' The interview data suggested that the scripting did this by keeping participants from immediately voicing their opinions, who devoted some time to consider their fellows' contributions instead. The interview data supported the hypothesis that encouraging people to make their individual perspectives tangible to their fellow team members facilitates the negotiation of common ground.

In other words, coercion increases negotiation, but differentially affects common ground. At the level of the students used in these studies, university level, coercion did not appear to disrupt collaboration. Coercion does tax the cognitive resources of the students (high CL), but this is primarily germane (beneficial for learning) – something that education strives towards. Finally, the use of the formalism may have a longer lasting effect than an effect on the specific situation. That students using the formalism chose to wait for a clarification shows that getting might be getting used to presenting and requesting clarification.

The experiments also showed that the formalism affected negotiation activity, and that negotiation increased with coercion, confirming the hypothesis. NTool and its accompanying formalism affects negotiation; the more coercively the formalism is applied, the more negotiation of common ground takes place. Furthermore, there is evidence that NTool can increase common ground, although this effect may be bound to specific user conditions, such as motivation and sophistication of prior knowledge.

A follow-up experiment is not presented due to lack of space. The results showed that NTool not only works in a laboratory setting, but that it can be adapted for use in the classroom.

Note

(1) Paul Kirschner is currently Professor of Educational Sciences at Utrecht University and head of the Research Centre Learning in Interaction.

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