

## Coercing Knowledge Construction in Collaborative Learning Environments

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**Abstract.** Multidisciplinary teams are often employed to solve complex problems, but research has shown that using such teams does not guarantee arriving at good solutions. Good team-solutions require team members possessing a good degree of common ground. In this contribution an ICT-tool based upon making individual perspectives explicit to other team members is studied. Two versions of the tool that differed in the extent to which users were coerced to adhere to embedded support principles were used, in both a laboratory and a secondary professional education setting. Coercion, as expected, increased negotiation of common ground in both settings. However, results were contradictory with regard the amount of common ground achieved. Overall, it can be concluded that NTool and its underlying framework affect negotiation of common ground, and that adding some coercion increases this effect. However, one should be careful with the specific task and audience before implementing NTool.

**Keywords:** Negotiation of meaning, common ground, ICT-tools, knowledge construction, coercion

### INTRODUCTION

Professional organisations expect multidisciplinary teams to achieve improved problem solving. Expectations are especially high in the case of solving complex problems, because multidisciplinary teams can employ multiple problem perspectives. Indeed, research has shown that engaging multiple perspectives may lead to richer solutions to complex problems (Lomi, Larsen, & Ginsberg, 1997), and that neglecting relevant perspectives can lead to solving the wrong problem, and in some cases even aggravate the problem (Hasan & Gould, 2001; Vennix, 1996). Research has also shown that individual team members have to engage each other's thinking in order for these expectations to hold (Barron, 2003). In other words, team members need to achieve a common cognitive frame of reference, or common ground (Bromme, 2000; Clark & Brennan, 1991) in order to reap the benefits of multiple problem perspectives. This contribution deals with the facilitation of grounding processes with an ICT-tool called NTool.

NTool is an online communication tool with embedded support of grounding processes. Like other ICT-tools, NTool uses specific communication rules (a formalism) and constraints (coercion) to attain this facilitation. These formalisms are tailored to facilitate specific aspects complex problem solving and coerce<sup>1</sup> (Dillenbourg, 2002) people to follow the formalism's rules. However, whereas other ICT-tools that aimed at facilitation of problem solving focussed mainly on structuring the problem or the argumentation (e.g., Buckingham Shum, MacLean, Bellotti, & Hammond, 1997; Eden & Ackermann, 2001; Van Bruggen, 2003),

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<sup>1</sup> Some dictionary definitions (Webster's student Dictionary, 1996) of coercion hold that to coerce involves 'to constrain or force to do something'. We wish to stress that this contribution uses it in the sense of constraint, not force.

NTool is the first to address the grounding process at a more basic level. It does so by making users explicate their private understanding of other's contributions.

Researchers in the past have chosen to implement ICT-tools that use formalisms or constraints to structure conversation and discourse among collaborators with the aim of guiding the exchange of knowledge and information. Such ICT-tools are being used in fields and topics as diverse as design activities (Buckingham Shum et al., 1997), scientific reasoning (Suthers, 2001), and argumentation (Van Bruggen, 2003). Such tools have attained good results on cognitive aspects of group learning by focusing on task aspects. However, they have not explicitly addressed the problem of *common ground*.

In this contribution we report on two experimental studies in which two versions of NTool with different levels of coercion were tested. Study I was a laboratory experiment with university students in their senior year, while Study II took place in a practical educational setting with second year students of secondary vocational education. In Study II the effects of NTool over time were also studied. The goal of this contribution is threefold, namely to report on the effects of NTool on negotiation of common ground, to verify the laboratory findings in an educational setting, and to explore differences between the laboratory and practical educational settings.

## A FRAMEWORK

Barron (2003) showed that team performance is related to team interaction, noting that willingness to construct shared problem spaces is essential for engaging multiple perspectives. In her study (2003), members of high performing teams engaged each other's thinking, while members of low performing teams typically ignored each other's proposals. Performance depended on the negotiation of a shared problem space as basis for construction of complex problem solutions. Teams in which the members critically explored each other's thinking and explicitly accepted, agreed, and subsequently documented contributions to the discussion, ultimately generated better problem solutions. According to Johnson and Johnson (1994), synthesis of multiple perspectives may result in better decisions and solutions to complex problems. Bromme (2000) argues that a team needs common ground - a shared cognitive frame of reference - before it can attempt to synthesise perspectives. In other words, members of multidisciplinary teams need some kind of commonality between their different perspectives in order to benefit from them.

In our framework, we address *knowledge construction* to reflect on how individual knowledge becomes part of a solution to a complex problem, and *group processes* to reflect on the team processes that take knowledge from being in the 'mind' of one learner to becoming a team's constructed knowledge. It is inspired by research and theory on social learning (e.g., Salomon & Perkins, 1998; Sullivan Palincsar, 1998), knowledge sharing (e.g., Boland & Tenkasi, 1995; Walsh, 1995), and grounding (e.g., Baker, Hansen, Joiner, & Traum, 1999; Bromme, 2000; Clark & Brennan, 1991). The route from unshared individual knowledge to team knowledge goes through three intermediate forms (external knowledge, shared knowledge, common ground) via four processes (externalisation, internalisation, negotiation and integration) (see Figure 1).

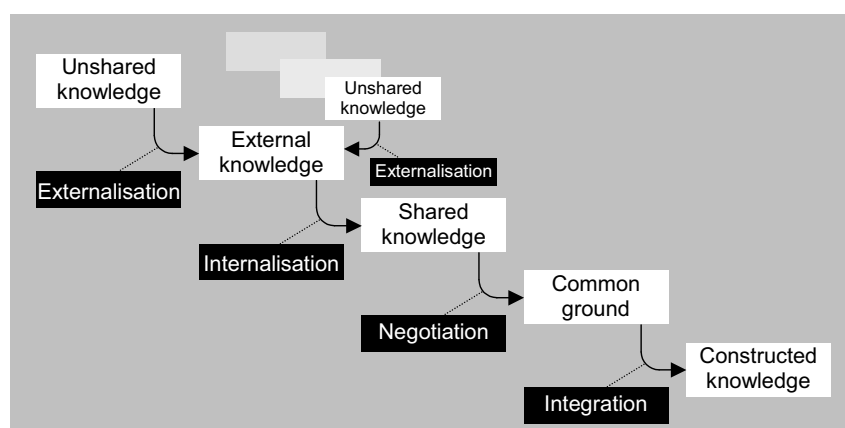


Figure 1. From unshared knowledge to constructed knowledge

Private knowledge is externalised when team members make their, as yet, unshared knowledge explicit or tangible to others (Leontjev, 1981), for example by contributing to a conversation. Once a team member has made such a contribution, the others can try to internalise it. While constructing their own individual

understanding, the other team members can consider knowledge of certain aspects such as the contributor's background, the current situation, and views held to better "understand" the contribution. Also, their own beliefs and assumptions play a role while trying to understand a contribution. A contribution is thus understood against the presumed perspective of the other, as well as against one's own perspective (Bromme, 2000). Having shared a contribution with a team does not mean that the team members all have arrived at the same understanding. Representational differences can result from interpreting a contribution in one's own perspective only (e.g., a graphical designer has a different understanding of the term "elegance" than a computer programmer) or from minimising or rejecting its validity or plausibility due to differences in conviction or opinion.

A shared contribution is the starting point for negotiation of common ground – the shared cognitive frame of reference (Bromme, 2000). It is through the process of internalising others' contributions, and subsequently providing feedback based on one's own perspective by word or action, that common ground can be negotiated (Alpay, Giboin, & Dieng, 1998; Baker et al., 1999). Common ground is never absolute or complete, but is continually accumulated and updated (Clark & Brennan, 1991).

Negotiation of common ground is conceived of as a dual concept in our framework. The first concept is negotiation of meaning which leads to an agreement regarding meaning and understanding of a contribution. This entails making private understanding of some *contribution* public to others, *verifying* whether and to what extent their own understanding of the contribution is different from what others intended, receiving feedback on this (*clarification*), re-verifying, and so on, until "the contributor and the partners mutually believe that the partners have understood what the contributor meant to a criterion sufficient for the current purpose" (Clark & Schaefer, 1989, p. 262, the grounding criterion). Negotiation of position, the second concept, concerns people making public to others their private *opinion* about a contribution, *checking* whether one's position is clear to others, and vice versa. Note that neither of these concepts implies the more common, generic use of the term negotiation, namely to discuss with an opposing or adversarial party until consensus or compromise is reached.

Starting from common ground, new knowledge can be built by adding new relations and concepts to common ground, via *integration*. Knowledge construction is based on the common ground the team has built, and will broaden and deepen the common ground because the common constructed knowledge becomes part of the common ground. With regard to problem solving, constructed knowledge represents the solution(s).

## A FORMALISM TO SUPPORT NEGOTIATION

The steps from unshared to constructed knowledge in the above framework serve as a basis for a *formalism* for the support of negotiation. The formalism consists of *primitives* of negotiation, and *rules* that prescribe the use of these primitives. Primitives are basic building blocks that model a specific type of dialogue (Dillenbourg, 2002). These primitives are coupled to a set of rules to mimic the negotiation process as explicitly as possible, which results in a formalism for negotiation. Note that this formalism models an ideal negotiation process; in regular communication, the status of people's statements in terms of negotiation primitives often remains implicit. The formalism must enable distinguishing between original contributions, clarifications, verifications, et cetera, making the steps explicit. By doing so, individual differences in understanding and opinion should more easily surface.

First, negotiation starts with a *contribution* (Primitive 1) such as a hypothesis or a position, which is assumed not to be part of a team's common ground (Rule 1). To detect differences between individual representations, team members must *verify* (Primitive 2) their understanding of the contribution (Rule 2) because people articulate and understand a contribution against their own background knowledge (Fischer, Nakakoji, & Ostwald, 1995). Third, a contribution needs to be *elucidated* (*clarification*, Primitive 3), using the ideas upon which it was based. For example, the educational background or the political orientation of the contributor may shed light on the meaning of a contribution. Clarification need not always be made by the original contributor, but may also be performed by another team member who feels knowledgeable. Rule 3 is that all verifications require a clarification. Together, Rules 2 and 3 can be iterated until common understanding of the contribution is reached. Note here that a correct clarification of a contribution of one team member can be seen as a successful verification by another.

The fourth primitive is *acceptance/rejection* of a contribution, whether one can judge a contribution as true (acceptance), based on the explanation given, or untrue, or unintelligible (rejection). For example, the statement  $1 + 1 = 10$ , is true only if we understand (through Rules 1 and 2) that the contributor is using the binary system. A contribution should be accepted as part of the common ground if it is true, or after it has been modified so that it has become true. Rule 4 is that every contribution needs to be accepted or rejected by the team members. Finally, Rule 5 is that people must explicitly state their own position (*position*, Primitive 5) on the contribution. In the case of irresolvable disagreement about previously accepted statements, Rule 5 may result in multiple scenarios, each based on another position (i.e., agree to disagree). This means that one may accept a certain contribution, but disagree all the same, for example when neither person can prove the other wrong. In such cases, people can agree to disagree, and alternate representations that are equally legitimate can ensue. Table 1 summarises these rules.

Table 1. Rules for a formalism for the facilitation of negotiation

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1.	Every new issue is termed a <i>contribution</i>
2.	Contributions require a <i>verification</i> by the other team members
3.	Each verification is responded to with <i>clarification</i> by the original contributor
4.	When all verifications are clarified, and no new verifications are performed, all team members state whether they <i>accept</i> or <i>reject</i> the statement
5.	All team members state their <i>position</i> about accepted statements

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## The Negotiation Tool

The formalism for supporting negotiation was implemented in an ICT-tool called the NegotiationTool (NTool). NTool is based on a newsgroup reader for asynchronous, distributed, text-based discussions. To optimise NTool for negotiation of multiple representations, the formalism was implemented to structure the negotiation process in two ways with different levels of coercion (cf. Dillenbourg, 2002).

Coercion, a form of scripting, is defined as the degree of freedom participants have in following a formalism. Coercion and formalism together constitute a collaboration script. The higher the coerciveness of a script, the more the participants are required to adhere to the formalism. Scripting requires “subjects on most or all occasions to make a particular type of speech act in a specific context.” (Baker & Lund, 1997, p. 176). For Dillenbourg (2002) a “script is a set of instructions regarding to how the group members should interact, how they should collaborate and how they should solve the problem.” (p. 64). This means that a script can be aimed at either the interaction and collaboration level, for example by offering sentence openers or prescribing communicative acts (e.g., Baker & Lund, 1997; Barros & Verdejo, 1999; Soller, 2002) and/or the problem solving process, for example in problem-based learning. In such cases, scripting results in the use of distinct phases for discussion, with distinct purposes with regard to problem solving (Barrows & Tamblyn, 1980; Dillenbourg, 2002; O'Donnell & Dansereau, 1992).

A script that uses very little coercion leaves participants many degrees of freedom such that 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 study reported here, two different ICT-implementations of the formalism were implemented (see Methods). One implementation had very little coercion and was called the *Idiosyncratic* version. This situation resembles giving a person a set of lines and symbols to be used in constructing a diagram, but leaving it up to her/him to decide which symbols and lines are used for what purpose. The other implementation used scripts aimed at interaction and collaboration (high coercion) and was called *Stringent*. In each implementation, coercion was aimed at the verification and clarification primitives, that is, the extent to which people were required to verify and clarify contributions in specific circumstances.

NTool was expected to increase negotiation of both meaning and position because it forced team members to make their private understandings and opinions public, making differences in understanding and opinion visible or salient (Bromme, 2000). We hypothesised that (1) the higher the level of coercion, the more negotiation would occur. We Likewise, we hypothesised that (2) common ground would be highest in the Stringent version and lowest in the Idiosyncratic version. Both hypotheses presume that more coercion will make participants follow more closely an ideal model of negotiation, as laid down in the formalism.

## METHOD

### Participants

Participants in Study I were senior students at Maastricht University from the departments of Cultural Sciences, Economics and Business Administration, and Psychology. Participants in Study II were second year secondary vocational education students from three different programmes, High-tech Metal-Electricity, Infrastructure, and Architecture. In both studies, participants were assigned to three-person multidisciplinary teams, which resulted in 12 teams in Study I, and 22 teams in Study II.

### Task

In Study I participants were required to solve a “school drop-out” case (Kirschner, Van Bruggen, & Duffy, 2003). They received the task description: “You have been asked by the government to advise the Minister of Education how to solve the high school drop-out problem. At the end of the session you are expected to come up with a viable solution that can be implemented as government policy.”

In Study II participants were assigned the task of making a functional design of floating housing as a remedy for sea-level rise. The task was designed in collaboration with teachers to ensure that the difficulty level was appropriate for the participants, and that the task was interesting to the different programmes. The task was split into two parts. In the first part ("Floating Houses") the participants designed a floating house. In the second part ("Amersfoort-by-the-Sea") additional information was given to keep the participants busy. Different though these tasks may seem, they both are complex problems (see Conklin & Weil, 1997), requiring multidisciplinary effort to solve them. In both cases the tasks were tailored to the various disciplines in the teams.

## Formalism

Each team was supplied with one version of NTool. Each version was used by the same number of teams.

*Idiosyncratic version.* This version used only the primitives. On-screen information was presented on every contribution, and whether it needed verification or a decision (agreeing or disagreeing). Furthermore, participants were informed when they had not verified all contributions, and when they had not decided on all contributions.

*Stringent version.* This version used the same primitives, but allowed negotiation of only one contribution at a time. Furthermore, participants were not allowed to compose reject-, agree-, and disagree-messages before the contribution had been verified. Participants were informed, via prompts, as to whether they had to verify or decide on a contribution.

## Procedure

Both experiments started with a practice phase. Study I had one experimental phase; Study II had two. The general procedure for these phases was the same for both studies, differences in timing are presented in Table 2.

*Practice phase.* Participants received a tutorial on the ICT-environment addressing the basics of NTool, and the formalism rules and how they constrained communication. To ensure that participants were proficient with NTool they received a practice case (about a problem of road traffic safety) to enable them to gain experience with NTool.

*Experimental phase.* After a 15-minute break, participants started working on the experimental cases. To promote the construction of an individual problem representation, as well as to allow the researchers to determine what this representation was, participants first had to carry out the task individually (pre-test). Participants could take notes while working individually. Next, they solved the problem collaboratively, and after that individually gave their solution (post-test). All resulting individual problem representations and solutions, as well as the group discussion were recorded. In their post-test, participants were also asked to state the points on which they felt that they had differences in opinion with their team members, to account for agreeing to disagree.

Study II had two experimental phases (a morning session and an afternoon session), with a 75-minute lunch-break between the sessions.

Table 2. Timing differences between Study I and Study II

	Study I	Study II
Practice phase	65 min	75 min
Tutorial	20 min	15 min
Practice	45 min	60 min
Experimental phase	130 min	90 min
Pre-test	20 min	15 min
Collaboration task	90 min	60 min
Post-test	20 min	15 min

## Variables and Analysis

Negotiation was measured by analysis of the collaboration. Common ground was measured by comparing individual representations before and after collaboration.

A coding scheme for coding function and content of messages during collaboration was developed (cf., e.g., Avouris, Dimitracopoulou, & Komis, 2003; Fischer, Bruhn, Gräsel, & Mandl, 2002; Mulder, Swaak, & Kessels, 2002; Thomas, Bull, & Roger, 1982). All messages were coded with regard to:

- Cognitive content - directly related to solving the problem.
- Regulative content - related to monitoring the problem solving process, regulating the collaboration process, which also entailed tool use.
- Other content - not in any other category or non-codeable.

Messages with cognitive content were specifically coded for function. The following subcategories were used:

- Contribution: A new topic of conversation that has not been discussed before is introduced.
- Verification: Information directly or indirectly requested about the intended meaning of a contribution.
- Clarification: A reaction to a verification or a perceived lack of understanding, where the intended meaning of a contribution or elaboration is elucidated.
- Acceptance: A reaction to a contribution in which the contribution is judged intelligible and/or correct.
- Rejection: A reaction to a contribution in which the contribution is judged unintelligible and/or incorrect.
- Agreement: A reaction to a contribution in which the sender voices his/her agreement with the contribution.
- Disagreement: A reaction to a contribution in which the sender voices his/her disagreement with the contribution.

In many cases, messages did not fit any of the above subcategories, for example if people built on each other's communications, without explicitly negotiating meaning of, or position on a contribution. Such messages were coded *Elaboration*: A contribution is elaborated upon by adding information or summarising. *Verification and clarification*, in contrast to elaboration, were considered indicative of explicit negotiation activities. The total number of contributions discussed was used as an indicator for the range of topics discussed.

Research-assistants were trained to use the coding scheme using data from the practice phase. Each assistant coded the data from one study. Comparing one randomly selected experimental session coded by the first author and a research-assistant resulted in substantial (Landis & Koch, 1977) inter-rater reliability (Cohen's kappa) for both studies, .70 ( $SE = .034$ ) in Study I, and .73 ( $SE = .024$ ) in Study II.

*Common ground.* Common ground was operationalised as the extent to which the content of individual representations was present in individual representations. The contributions identified in the coding procedure were used to characterise the content of the individual representations.

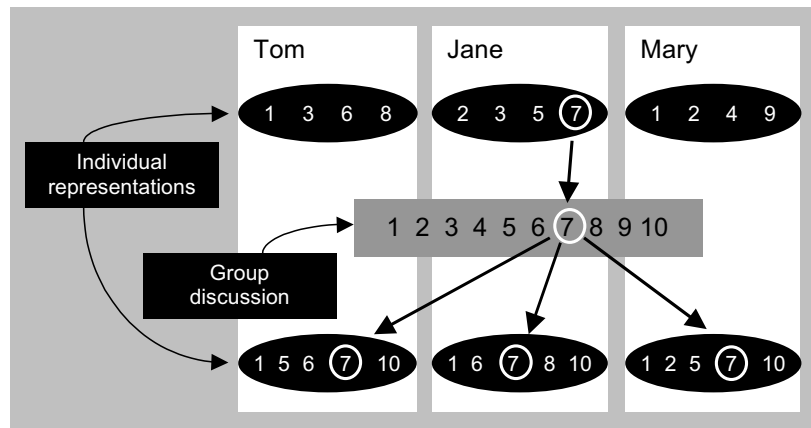


Figure 2. Analysis of common ground; numbers indicate contributions

Each contribution was first numbered and summarised. The next step involved characterising the content of all individual representations, both initial (pre-test) and subsequent to collaboration (post-test), and the group representation. The summaries were used to identify the content within individual the representations. For every individual representation the topics that were and were not represented were assessed. For example, in Figure 2 episode number 7 is present in Jane's initial individual representation, in the group discussion, and in all post-tests. By repeating this procedure for each of the contributions in the discussion, the origin of each topic, whether it was present in the group representation, and whether participants used it in their post-tests was determined. Using these data we computed, for each group, the mean number of pre-tests and post-tests that a contribution would end up in. This mean number of post-tests per contribution was used as a measure of common ground.

### Statistical analyses

Statistical testing was done using various ANOVA techniques. Negotiation was analysed using ANOVA, and common ground using ANCOVA, with the number of pre-tests per contribution (i.e., common ground prior to collaboration) as a covariate. In Study II, these analyses were done using a repeated measures statistical model to account for the two-session format. All analyses were performed with SPSS version 11. Due to no-show after the first experimental phase in Study II, the number of groups used in the statistical analyses was lower than 22. Data for 9 groups in the Idiosyncratic, and 5 in the Stringent conditions were eligible for statistical analysis. Because of the effects of such small sample sizes on statistical power we feel that reporting marginally significant effects ( $.05 < p < .10$ ) is justified. Significant effects of phase I on phase II (effects of time) were not considered relevant to our hypotheses, and are not discussed here.

## RESULTS

### Study I

ANOVA revealed significant differences between the conditions for the number of contributions,  $F(1, 10) = 12.27, p < .01$ , number of verifications,  $F(1, 10) = 13.72, p < .005$ , and number of clarifications,  $F(1, 10) = 7.25, p < .05$ . In other words the Idiosyncratic teams made significantly more contributions, whereas the Stringent teams verified and clarified more often (see Table 3). Common ground was highest in the Stringent groups  $F(1, 9) = 6.23, p < .05$  with common ground prior to collaboration as a covariate. Eliminating the non-significant ( $p = .56$ ) covariate from the model resulted in a significant main effect from condition  $F(1, 10) = 7.14, p < .05$ .

Table 3. Negotiation Primitives and Common Ground in Study I

	Condition			
	Idiosyncratic ( $n = 6$ )		Stringent ( $n = 6$ )	
	M	SD	M	SD
Contribution	8.0	1.27	5.0	1.67
Verification	8.8	4.36	16.7	2.81
Clarification	10.7	4.50	17.7	4.50
Elaboration	56.6	22.42	48.5	21.52
Acceptance	3.0	2.10	1.8	2.14
Rejection	1.2	.98	1.7	2.73
Agreement	8.7	2.66	11.7	7.74
Disagreement	1.3	1.21	2.0	1.41
Regulation	30.7	22.52	43.7	17.18
Other	8.0	8.92	5.0	4.47
Common Ground	1.97	1.90	2.39	.33

### Study II

Repeated measures ANOVA tests revealed a significant interaction between time and condition for the number of verifications,  $F(1, 12) = 8.28, p < .05$ . In both sessions, Stringent teams made more verifications than Idiosyncratic teams, but in the Stringent teams' afternoon sessions have less verifications than morning sessions, while in the Idiosyncratic teams it is the other way around. Noteworthy marginal interactions were the number of contributions,  $F(1, 12) = 4.37, p = .06$  and the number of elaborations,  $F(1, 12) = 4.38, p = .06$ . Both figures dropped quite markedly between sessions in the Stringent groups compared to the Idiosyncratic groups.

Noteworthy marginal main effects were revealed for the number of verifications,  $F(1, 12) = 4.35, p = .06$ , the number of clarifications,  $F(1, 12) = 4.56, p = .05$  the number of disagreements  $F(1, 12) = 3.75, p = .08$ , and the number of regulations,  $F(1, 12) = 3.86, p = .07$ . These figures were highest in Stringent groups (see Table 4). In other words, the marginal effects suggest a trend in the expected direction, that is, more verifications and clarifications in the Stringent teams. Unexpectedly, common ground was highest in the Idiosyncratic teams  $F(1, 11) = 7.83, p < .05$  with common ground prior to collaboration as a covariate. Eliminating the non-significant ( $p = .80$ ) covariate from the model resulted in a significant main effect from condition  $F(1, 12) = 8.46, p < .05$ .

Table 4. Negotiation Primitives and Common Ground in Study II

	Condition							
	Idiosyncratic ( <i>n</i> = 9)				Stringent ( <i>n</i> = 5)			
	Morning		Afternoon		Morning		Afternoon	
	M	SD	M	SD	M	SD	M	SD
Contribution	6.22	1.99	4.89	1.90	7.20	2.28	3.80	1.64
Verification	1.22	1.30	1.67	1.80	4.80	2.28	2.00	2.83
Clarification	1.89	1.97	.78	.67	3.60	1.67	2.40	3.21
Elaboration	27.44	16.36	27.11	14.43	46.00	23.05	20.40	18.15
Acceptance	1.56	1.13	1.33	1.32	2.00	1.58	2.60	2.41
Rejection	.44	1.01	.00	.00	.80	1.10	.20	.45
Agreement	3.33	2.78	4.44	2.96	3.80	3.27	2.80	2.39
Disagreement	.44	.73	.44	.73	1.40	.89	.80	.84
Regulation	27.22	20.57	25.00	20.54	48.20	18.87	43.80	15.37
Other	28.89	31.16	70.33	68.02	72.40	58.22	112.00	46.35
Common Ground	1.90	.65	2.02	.61	1.41	.39	1.55	.41

## CONCLUSIONS AND DISCUSSION

This research studied the relationship between negotiation, the negotiation formalism, and coercion, with the ultimate goal being to design an ICT environment that facilitates knowledge construction. The main approach was the design of a formalism for the facilitation of common ground, which appears to be a prerequisite for knowledge construction.

The results showed that the two versions of NTool differed with regard to negotiation and common ground. In both studies, coercion was shown to increase negotiation, as hypothesised. However, with regard to common ground the results are contradictory. Whereas high coercion was associated with high common ground in Study I, the idiosyncratic groups were shown to have the most common ground in Study II. Analyses showed that the Idiosyncratic groups made significantly more contributions than the other versions. This may mean that the range of topics was widest in the Idiosyncratic version, which could suggest a trade-off between topic range and common ground. However, it may also be the case that participants in the Stringent versions, knowing that they had less opportunity to post contributions, chose to word their contributions more broadly, in which case fewer contributions would still cover the same topic range. Further, more qualitative research may shed some light on these explanations.

Disruption of collaboration (Dillenbourg, 2002), which can be caused by over-scripting collaboration, may explain some of the results. The need for more regulation in the Scripted version (Study II) may have caused some disruption in task performance. In that respect, the marked drop in contributions and elaborations in the Stringent afternoon sessions and the lack thereof in the Idiosyncratic groups, may indicate a loss of attention to the task in the Stringent groups that may have not occurred in the Idiosyncratic groups. This might show that using NTool was quite taxing in Study II. In Study I, where participants were university students, no such differences were observed. In sum, NTool influences both negotiation of common ground and common ground itself, and does so increasingly as coercion increases. The Stringent version may have caused some disruption in Study II but not in Study I.

The results are promising with regard to the facilitation of the grounding process, but they also indicate some limitations in the applicability of such facilitation. In her study, Barron (2003) showed that interaction is important for problem solving, and that engaging in each other's thinking was related to better solutions. The present study has shown that ICT-tools can be used to facilitate such interactions, by using a formalism for negotiation, and coercing the user into following it. However, these results were more easily achieved in the laboratory than in a secondary vocational education institution. Whereas in Study I all expected effects occurred, in Study II some unexpected effects occurred as well. This shows that the ultimate implementation of a tool like NTool should be weighed against the expected benefits, and the capacities of the intended audience.

More research is required to test our ultimate aim of facilitating complex problem solving. The present study does argue a relation between common ground and the quality of problem solutions, but does not explicitly measure it. Overall, it can be concluded that NTool and its underlying framework affect negotiation of common ground, and that adding some coercion increases this effect. However, one should be careful with the specific task and audience before implementing NTool.



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