Paper 2: Matching Representational Tools' Ontology to Part-task Demands to Foster Problem-solving in Business Economics

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Background and Aim

Collaborative problem-solving is often regarded as an effective pedagogical method beneficial for both group and individual learning. The premise underlying this approach is that through a dynamic process of eliciting one's own knowledge, discussing this with peers, and establishing and refining the group's shared understanding of the knowledge domain, students acquire new knowledge and skills and process them more deeply (e.g., O'Donnell, Hmelo-Silver, & Erkens, 2006). However, due to its complexity (i.e., diversity in concepts, principles and procedures, see Miller & VanFossen, 2008) students in business economics encounter difficulties with acquiring a well-developed understanding of the knowledge domain (e.g., Marangos & Alleys, 2007). When solving problems, students, therefore, rely primarily on surface features such as using objects referred to in the problem instead of the underlying principles of the knowledge domain, and employ weak problem-solving strategies such as working via a means-ends strategy towards a solution (e.g., Jonassen & Ionas, 2008). This hinders students in effectively and efficiently coping with their problem-solving task because the ease with which a problem can be solved often depends on the quality of the available problem representations (e.g., Ploetzner, Fehse, Kneser, & Spada, 1999). To this end, it would be beneficial if students are supported in acquiring and applying suitable representations (e.g., Ainsworth, 2006). Research on concept mapping (Nesbit & Adesope, 2006; Roth & Roychoudhury, 1993) has shown that the collaborative construction of external representations (i.e., concept maps) can guide students' collaborative cognitive activities and beneficially affect learning. Due to its ontology (i.e., objects, relations, and rules for combining them, see Van Bruggen, Boshuizen, & Kirschner, 2003) a representational tool enables students to co-construct a domain-specific content scheme fostering students' understanding of the knowledge domain in question. Problem-solving tasks, however, are usually composed of fundamentally different part-tasks (i.e., problem orientation, problem solution, solution evaluation), that each requires a different perspective on the knowledge domain and, thus, another representational tool with a different ontology. To be supportive for problem-solving, the ontology provided in a representational tool must be matched to the part-task demands and activities of a specific problem phase. Otherwise, effective problem-solving may be hindered (e.g., Van Bruggen et al.).

The goal of the study presented in this paper is to determine whether an instructional design aimed at providing ontologically part-task congruent support in the representational tools leads to more successful problem-solving performance in the field of business economics.

Method

Participants and intervention: Students from six business-economics classes in from two secondary education schools in the Netherlands participated in this study. The total sample consisted of 93 students (60 male, 33 female). The mean age of the students was 16.74 years (*SD*=.77, Min=15, Max=18). Working in a Computer Supported Collaborative Leaning (CSCL) environment, all groups had to solve a case-based problem in business-economics in which they had to advise an entrepreneur about changing the business strategy to increase profits (i.e., company result). To come up with a suitable advice, students had to carry out three different part-tasks in a predefined order, namely (1) finding out the main factors that affects the company's results and relate them to the problem (problem orientation), (2) evaluate how certain interventions such as changing the business strategy affect company results (problem solution), and (3) calculate and compare the financial effects of these interventions and formulate a final advice based on this comparison (solution evaluation). To study the effects on problem-solving performance, the ontology in the representational tool was either matched or mismatched to the part-tasks (see Table 1). The students were randomly assigned to 31 triads divided between the four experimental conditions; seven triads in the match condition and eight triads in each of the mismatch conditions (i.e., conceptual, causal, and simulation condition).

Table 1: Overview of the Experimental Conditions

Condition	Part-tasks and provided ontology			Match / mismatch
	Problem orientation	Problem solution	Solution evaluation	
Conceptual	Conceptual	Conceptual	Conceptual	Match for the orientation phase
Causal	Causal	Causal	Causal	Match for the solution phase
Simulation	Simulation	Simulation	Simulation	Match for the evaluation phase
Match	Conceptual	Causal	Simulation	Complete match

Hypothesis: It was hypothesized an instruction design aimed at providing ontologically part-task congruent support in the representational tools leads to more successful problem-solving performance in the field of business economics than not receiving it.

Data gathering: All student groups spent six 45-minute lessons solving the problem during which each student worked on a separate computer connected by a network to enable synchronous communication (i.e., chat-tool and the sharing of the representational tool(s). Before the first lesson, students received an instruction about the CSCL-environment, the group composition, and the problem-solving task. Students worked on the problem in the computer classroom where all chat-discussions and answers to the part-tasks were logged.

Data analysis: To measure the effect of condition on problem-solving performance, an assessment rubric for all criteria of the problem-solving task was developed (see Table 2). The problem-solving task consisted of three part-tasks in which the groups each had to answer three questions. All nine answers were evaluated based on their *'suitability'*, *'elaboration', 'justification'*, and *'correctness'*, resulting in 36 items (9 answers * 4 criteria). It was also evaluated whether groups used answers from a subsequent phase and altered their way of reasoning when they had to answer the questions asked in a following phase (i.e., *'continuity'*). There were two phase transitions (i.e., transition from problem orientation to problem solution and transition from problem solution to solution evaluation) and therefore two items (2 items). Finally, the *'quality of the final advice'* was evaluated by three items; number of concepts incorporated in the advice, financial consequence of the advice, and whether the final answer was in line with the guidelines provided in the original task description. All 41 items were coded as 0, 1 or 2; a '2' was coded when the answer given was of high quality. Groups could, thus, achieve a maximum score of 82 points (41 * 2 points). One-way MANOVA with Bonferroni post hoc analyses was used to analyze the effect of condition. Since there were specific directions of the results expected (see hypothesis) all analyses are one sided.

Table 2: Items and reliability for problem-solving performance (N = 31).

Criteria	Description	Items	α
Suitability	Whether the groups' answers were suited to the different part-tasks.	9	.81
Elaboration	Number of different business-economics concepts or financial consequences incorporated in the answers to the different part-tasks.	9	.56
Justification	Whether the groups justified their answers to the different part-tasks.	9	.71
Correctness	Whether the groups used the business-economics concepts and their interrelationships correctly in their answers to the different part-tasks.	9	.68
Continuity	Whether the groups made proper use of the answers from a prior problem phase.	2	.67
Quality advice	Whether the groups gave a proper final advice. - Number of business-economics concepts incorporated in the advice. - Number of financial consequences incorporated in the advice. - Whether the final answer conformed to the guidelines provided.	3	.76
Total	Overall score on the collaborative problem performance.	41	.92

Results and Conclusions

One-way MANOVA on the total score of the problem solving performance showed a significant difference for condition (F(3,27)=4.38, p=.01). Bonferroni post hoc analyses revealed that groups in the match condition scored significantly higher than groups in both the conceptual (p=.01; d =1.46) and the simulation condition (p=.01; d=1.48). When the results for the dependent variables were considered separately, using one-way ANOVAs with Bonferroni post hoc analyses, condition effects were found for 'justification' (F(3,27)=4.85, p=.01) and 'correctness' (F(3,27)=3.97, p=.01). The mean scores indicate that there were two significant differences between conditions. First, groups in the match condition scored significantly higher on 'justification' than groups in both the conceptual condition (p=.01; d=1.56) and the simulation condition (p=.01; d=1.56). Second, groups in the match condition scored significantly higher on 'correctness' than groups in both the conceptual condition (p=.01; d=3.97) and the simulation condition (p=.03; d=2.52). Although expected, no significant differences were found between the match and the causal condition. Students in both conditions received the causal ontology (relevant concepts, solutions and their causal interrelationships), providing students the means to co-construct multiple qualitative perspectives on the knowledge domain. It seems, therefore, important to recognize that causal reasoning is beneficial for collaborative problem-solving (e.g., Jonassen & Ionas, 2008).

Collaborative problem-solving in business economics is facilitated by an instructional design aimed at making the different part-tasks explicit, sequencing them properly, and foreseeing them with ontologically part-task congruent support in the representational tools. The complementary function of those different perspectives can gradually increase students understanding and, therefore, support them in solving a complex problem (see Ainsworth, 2006). That is, groups receiving ontologically congruent support for each part-task (i.e., match condition) gave more correct and justified answers to the part-tasks and a came up with better final solutions to the problem than groups in the non-matched conditions. Future work is aimed at analyzing the chat-discussions and the constructed representations (i.e., concept maps) to gain more insight in the learning process itself and the lack of difference between the match condition and the causal condition. During the conference insight into students' discussions about the knowledge domain (i.e., concepts, principles, and procedures) will be presented.