Support for Collaborative Multimedia Learning: Considering the Individual and the Group

Daniel Bodemer, Alexander Scholvien
Applied Cognitive Psychology and Media Psychology, University of Tübingen, Germany
d.bodemer@iwm-kmrc.de

Abstract: Collaborative multimedia learning is a scenario that places various demands on the learners. On the one hand, individuals have to interrelate multiple external representations mentally, in order to understand the representations and the underlying concepts; on the other hand, learners acquire representational knowledge during collaboration and have to use multiple external representations to exchange conceptual knowledge. In this paper, the development and experimental evaluation of a tool is presented that is intended to simultaneously support both individual and collaborative learning processes during collaborative multimedia learning.

Keywords: multiple external representations, representational tool, representational guidance, group awareness

Introduction

Translating between multiple external representations and mentally integrating them is an important but difficult challenge for learners. While integrating multiple representations is, in the end, an individual process, the acquisition and exchange of knowledge about external representations often occurs during collaboration [1], which places additional demands on learners [2]. However, tools and instructional tasks that support learning with multiple representations usually focus on the individual. A main requirement in developing a tool that supports collaborative learning with multiple external representations is the simultaneous consideration of both individual and collaborative processes. In this paper the development and experimental evaluation of such a tool is presented.

1. Learning with multiple external representations

Multimedia learning materials commonly comprise differently coded external representations, such as texts, formulas, and diagrams, in order to encourage learning in various ways [3]. However, learners are frequently not able to detect relevant structures within representations and relate multiple external representations systematically to each other [1]. In addition, simultaneous processing of differently represented information can require a considerable part of a learner's working memory capacity [4]. As a consequence, learners often concentrate on surface characteristics instead of thematically relevant structures of the external representations and, therefore, do not recognize the strengths of particular representations, resulting in disjointed mental representations.

In order to enable learners to take advantage of the potential of differently represented information, several methods have been suggested that try to support translation processes between representations by reducing visual search processes, such as presenting text and pictures in a spatially integrated format [4], or linking multiple representations by various symbolic conventions, such as using the same color for corresponding entities in different representations [4; 5; 1]. While these instructional suggestions have the potential to reduce cognitive workload, they do not directly support learners in active and constructive integration processes. Therefore, Bodemer and colleagues tried to initiate meaningful mental activity by enabling learners to systematically and interactively integrate different representations in the external environment, which improved learning significantly [6; 7].

2. Collaborative multimedia learning

External representations are beneficial not only for individual learning. They can perform important functions during collaborative learning that exceed supporting individual knowledge acquisition. For example, research has shown that by means of external representations individual contributions can be illustrated and objectified [8], but also coordinated and interrelated [9]. Moreover, it has shown that the type of a shared external representation can influence the focus of the learning partners' activities [10].

Most CSCL tools use shared external representations in any way. However, there is only little research on collaborative learning with complex multimedia learning material. Most of the existing studies focus on collaborative learning with animations or simulations [11; 12; 8; 13; 14; 15]. Those studies that focus on the representational code of the learning material showed that learners can potentially interrelate their knowledge and construct shared meaning on the basis of multiple external representations [16; 17].

Moreover, studies on collaborative multimedia learning have concentrated on face-to-face scenarios and neglected net-based learning, although spatial distribution of learners is a main potential of CSCL. One reason for this might be the high complexity of such learning situations that combine the demands of multimedia learning and net-based knowledge communication. As previously mentioned, learning with multiple representations is demanding even in individual learning settings. During distributed knowledge communication learners encounter additional difficulties, such as (1) establishing references between external content and collaboration content [18], (2) constructing a mutual understanding and a common ground [19] and – associated therewith – constructing a representation of the learning partner's knowledge or beliefs [20], as well as (3) interacting with each other in a structured and goal-oriented way [21].

3. A collaborative integration tool for supporting collaborative learning with multiple external representations

In order to facilitate collaborative net-based multimedia learning, a tool has been developed that is intended to support learners in meeting the various demands. A main requirement in developing such type of tool is the simultaneous consideration of both collaborative and individual learning processes. We based this tool on the previously mentioned active integration task [6] that has repeatedly been shown to foster individual integration processes during multimedia learning. This task has several characteristics that enable it to be used in a collaborative scenario as well. Regarding the difficulties specified in this paper, (1) it constrains content information in a way that allows the interrelation of information gathered from the learning material and from the learning partner, (2) it provides information about a learner’s knowledge that can be easily compared to represented information about a learning partner’s knowledge, (3) it structures learning processes implicitly and adaptively by externally representing assigned and unassigned information.

Based on these assumptions, we developed a collaborative integration tool that enables two spatially distributed learning partners to simultaneously integrate components of multimedia learning material on computer screens. Learners are provided with a shared visualization that contains the current state of integration of both learning partners. While interactively integrating different sources of information is intended to support individual elaboration processes by means of external and mental structure mapping, there are other supporting functions that address the collaborative scenario.

As learners can assign multiple representations independently of each other, the collaborative integration tool visualizes information about each learner’s knowledge. However, as the tool displays corresponding assignments of both learners side-by-side, it additionally visualizes information about group knowledge [22], such as which part of the learning material is covered by at least one of the group members. Furthermore, the spatial contiguity of assignments allows the comparison between both learners for each subset of representations. With regard to this comparison, four cases of knowledge distribution can be distinguished that are visualized by the tool (cf. Fig. 1): None of the learning partners has assigned a subset of representations (OO), only one learner has assigned it (XO), both learners have performed the same assignment (XX), learners have performed different assignments (XY).

Figure 1: Collaborative integration of multiple external representations during learning statistics. Two learning partners simultaneously drag algebraic components onto drop areas adjacent to the visualization (learner A’s assignments on the left side of each drop area, learner B’s assignments on the right side). The four cases of knowledge distribution are highlighted.

The visualization of the learning partner’s knowledge in the collaborative integration tool has the potential to support collaborative learning in several ways. Basically, it may reduce grounding costs, as each learner is provided with information about the learning partner’s assumptions. More specifically, the learning discourse can be structured on the basis of the four cases of knowledge distribution. If learners have assigned a subset of representations identically, they can easily recognize that there is probably no need to deeply discuss the underlying concept. On the other hand, if a subset of representations could not be assigned by any of the learners individually, a joint problem-solving process might help to solve the integration task. If only one learner has assigned a specific subset of representations, it is apparent that the learner who is not knowledgeable with regard to this subset might benefit from explanations by the learning partner. In this case, the visualized awareness information can also help in the formulation of questions and answers that are adapted to the difference in knowledge between the learning partners. A very important case with regard to knowledge construction occurs if both learners have assigned different representation components. Such conflicting issues are supposed to be especially fruitful for the learning discourse [23]. It is assumed that learners benefit much more from discussing conflicting issues than from repeating issues they both agree on.

In order to evaluate the potential benefits of a collaborative integration tool, an experimental study has been conducted that compared this collaborative integration tool to the active integration task investigated by Bodemer and colleagues [6]. As we assume that a collaborative integration tool can facilitate individual as well as collaborative learning processes during collaborative multimedia learning, we anticipate both higher individual learning outcomes and more beneficial discussion processes if learners are supported with this type of tool.

4. Experimental study

In this experiment, dyads learned spatially separated in two consecutive learning phases. (1) In an *individual learning phase*, they were individually provided with paper-based learning material about various statistics concepts underlying the one-way analysis of variance. The learning material differed within the dyads in an interdependent way in order to prompt different perspectives on the learning subject that go along with the representational code the material focuses on. While one learner is provided with algebraic and rather quantitative information, the other learner is provided with visual and rather qualitative information. (2) In a *collaborative learning phase*, dyads were provided with a computer-based integration tool that comprised corresponding algebraic and visual information. In this phase learning partners were able to communicate by means of a chat tool.

4.1 Design

Two experimental groups were compared that differed with regard to the visualization of the learning partner’s knowledge. One experimental group was provided with an *individual integration tool* that enables learners to interactively integrate algebraic and visual components. The other experimental group was provided with a *collaborative integration tool* that additionally visualized the current state of integration of the learning partner.

4.2 Participants

Forty psychology students (33 females and 7 males) of the university of Tübingen, aged 20-29 years (M = 22.63, SD = 2.43), were randomly assigned to the two experimental groups. They were paid for their participation or given course credits. All students had attended courses in introductory statistics but were largely unfamiliar with the specific statistics concepts and visualizations addressed in this experiment.

4.3 Materials and Procedure

The study consisted of five phases: (1) *training phase* (2) *individual learning phase,* (3) *knowledge test 1,* (4) *collaborative learning phase,* and (5) *knowledge test 2.*

(1) At the beginning of the experiment, all participants were spatially separated and received a general introduction into the experimental environment on the computer where they could exercise dragging and dropping objects in a neutral domain.

(2) In the *individual learning phase* all participants were provided with the interdependent instructional material for 20 minutes in which they learned about the application domain. It consisted of various statistics concepts and principles underlying the one-way analysis of variance (ANOVA), such as the concepts of error and squared error, the principle of least squares, the method of partitioning the sums of squares, and the effect of outliers. The *learning material* differed within the dyads, giving one learner algebraic and rather quantitative information, while the other learner was provided with visual and rather qualitative information of the concepts.

(3) *Knowledge test 1* consisted of eight multiple choice questions, which can be classified into four different categories: (a) basic understanding questions, referring to the basic information given in both kinds of learning material, (b) visual understanding questions, which required the information of the visual learning material and thus the interpretation of the graphical elements, (c) algebraic understanding questions, which required the information of the algebraic learning material and hence the interpretation of the formula elements, and (d) transfer questions, which required the integration of both, visual and algebraic information leading to more interrelated concepts.

(4) In the *collaborative learning phase*, dyads were provided with a chat tool and an integration tool that comprised corresponding algebraic and visual information. Learners had 40 minutes to interactively integrate the information and to gain an understanding of the statistics concepts. In this phase, the two types of integration tools have been implemented. One group was provided with an *individual integration tool* that enables learners to interactively integrate algebraic and visual components. The other group was provided with a *collaborative integration tool* that additionally visualized the current state of integration of the learning partner.

(5) Finally, the participants took *knowledge test 2*, which consistent of 32 multiple choice questions. While the first test comprised two questions of each type, the second test comprised eight questions each.

4.4 Results

Learning outcome. With regard to knowledge test 1, a two-tailed t-test revealed a significant difference between the two experimental groups ($t(38) = 2.11$; $p < .05$). In the condition *individual integration* a higher level of previous knowledge was measured. This difference was unexpected, as no experimental variation had taken place before. However, further analyses showed no significant influence of this difference on any other dependent variable.

Regarding knowledge test 2 a one-tailed t-test exposed no significant effect ($t(38) = -.28$; $p = .389$): Learners performed nearly equal in knowledge test 2 no matter if they had an additional external representation of the partners actions and knowledge or not.

In order to take into account the unexpected (pre-) knowledge difference, another t-test regarding the learning gain (difference between the relative learning outcomes of both knowledge tests) has been conducted. It revealed a marginally significant effect ($t(38) = -1.32$; $p = .097$, one-tailed). As we assumed, the individual learning gain was, on average, higher with the *collaborative integration* tool than with individual tool-support only.

Further analyses regarding the types of questions demonstrated that the benefit of the *collaborative integration tool* especially appeared in the most demanding category of the knowledge test, that is transfer knowledge (*t*(38) = -1.89; *p* < .05, one-tailed). Table 1 presents the means and the standard deviations for performance in the knowledge tests and for learning gain transformed to relative frequencies.

Table 1. Means and standard deviations of knowledge test performance and learning gain

	Collaborative Integration		**Individual Integration**		**Overall**	
	M	SD	M	SD	M	SD
Knowledge test 1	.35	.12	.44	.16	.40	.15
Knowledge test 2	.61	.17	.61	.18	.61	.17
Learning gain (overall)	.27	.22	.17	.24	.21	.23
Learning gain (transfer questions)	.36	.42	.12	.42	.24	.44

Processes of collaboration. In order to gain first insights into the learners' collaboration processes, we initially analyzed the learners' manipulations within the integration tools conducted during the collaborative learning phase. We present the results of these analyses in the following. Presently, we additionally analyze the learners' discourse, but can only give a glimpse of the first impressions of this analysis in the discussion. As the log-file of one dyad has not been recorded (due to technical reasons) the sample is 19 dyads for the following analyses.

As previously mentioned the case of unequal assignments is particularly relevant for learning and can be differentiated into two sub cases: conflicting assignments (XY) and partial assignments (XO). Regarding the number of unequal assignments appearing during the collaborative learning phase, a two-tailed *t*-test showed no significant difference between the two experimental groups for neither the number of conflicting assignments (*t*(18) = .445 ; *p* = .331) nor the number of partial assignments (*t*(18) = -.284 ; *p* = .390). Hence, as we presumed, in both conditions nearly the same amount of unequal assignments appeared.

With regard to the final assignments at the end of the collaborative learning phase, a one-tailed *t*-test (*t*(18) = 2.21; *p* < .05) revealed more conflicting final assignments (XY) in the group using the *individual integration* tool than in the *collaborative integration* group. Regarding the frequency of partial assignments (XO) at the end of the collaborative learning phase there was a marginally significant effect (*t*(18) = 1.55 ; *p* = .068). Hence, although the average number of unequal (conflicting and partial) assignments was nearly equal in both conditions, learners in the *collaborative integration* condition rather agreed at the end of the collaboration phase. In general this supports our expectations of a beneficial effect of the *collaborative integration* tool on processes during collaboration that are relevant for learning.

This assumption is also supported by the results regarding the correctness of assignments at the end of the collaborative learning phase, revealing a marginally significant difference between the two groups (*t*(18) = -1.40; *p* = .089). Thus, learners provided with the *collaborative integration* tool made to some extent more correct final assignments than those using the *individual integration* tool. The means and standard deviations for all types of assignments are displayed in table 2.

Table 2 Means and standard deviations of the number of assignments

	Collaborative Integration		**Individual Integration**		**Overall**	
	M	SD	M	SD	M	SD
			during collaboration			
Conflicting assignments (XY)	3.40	2.99	4.00	2.87	3.68	2.87
Partial assignments (XO)	13.20	5.79	12.56	3.78	12.89	4.82
			after collaboration			
Conflicting final assignments (XY)	.20	.63	2.60	3.37	1.40	2.66
Partial final assignments (XO)	.20	.42	1.20	1.99	.70	1.49
Correct final assignments	11.05	2.49	8.75	4.55	10.22	3.59

5. Discussion

This paper reports on the development and experimental evaluation of a CSCL-tool that is intended to support multimedia learning. The tool is based on an external integration task that proved in earlier studies to facilitate the individual mental interrelation and integration of multiple representations. The newly-developed collaborative integration tool enhanced the original version by visualizing the learning partner's assignments as indicators for the partner's conceptual assumptions or knowledge.

An experimental study compared the collaborative integration tool to the individual version. We hypothesized that the collaborative integration tool supports both individual and collaborative learning processes to a greater extent during collaborative learning with multiple external representations. Thus, we expected higher individual learning outcomes as well as more beneficial collaborative learning processes.

While the results of a post knowledge test couldn't approve this assumption, the analysis of the learning gains – especially regarding to transfer knowledge – revealed better learning of the group provided with the collaborative integration tool. The benefits of the visualization of the partner's knowledge on the learning process were analyzed by the number of unequal assignments during and at the end of the collaborative learning phase. Different assignments by the learners, as well as assignments that had been performed by only one of the learning partners, have both been resolved to a much greater extent during the collaboration process if learners were aware of the inequality of assignments. Moreover, more correct final assignments occurred in the collaborative integration group.

With regard to our assumptions on the support of collaborative discussion processes, the analysis of unequal assignments as indicators for the emergence, discussion and resolving of conceptual conflicts can give some insight into the way a collaborative integration tool might structure a learning discourse. However, in order to gain a deeper understanding in the functionality of the tool the reported variables have to be completed by further quantitative and qualitative analyses. For example, it appeared that learners talked more about conflicting issues if they were supported by the collaborative integration tool, which would explain the better resolving of integration conflicts. Moreover, it seems that learners adapted their discussion behaviour to their awareness of knowledge constellations, which might emphasize the importance of visualizing cognitive conflicts.

Furthermore, a detailed analysis of the learning discourse and a follow-up study could disentangle the structuring mechanisms of the collaborative integration tool. Some representational guidance [10] might be given by the empty drop areas; further guidance might be initiated rather information-based [22] as a result of the visualized knowledge of both learners.

Both guiding principles that underlie the tool we introduced in this paper have the potential to implicitly structure computer-supported collaborative learning processes, thereby saving cognitive capacities for additional individual and collaborative tasks. This is especially important during collaborative learning of complex concepts with multimedia learning material, but can be also helpful in many other areas of CSCL.

References

[1] Kozma, R. B. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction*, *13*(2), 205-226.

[2] Dillenbourg, P., & Bétrancourt, M. (2006). Collaboration Load. In J. Elen & R. E. Clark (Eds.), *Handling Complexity in Learning Environments: Theory and Research* (pp. 142-163). Amsterdam: Elsevier.

[3] Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16*(3), 183-198.

[4] Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*(4), 293-332.

[5] Kalyuga, S. (2008). Relative effectiveness of animated and static diagrams: An effect of learner prior knowledge. *Computers in Human Behavior*, *24*(3), 852-861.

[6] Bodemer, D., Ploetzner, R., Feuerlein, I., & Spada, H. (2004). The active integration of information during learning with dynamic and interactive visualizations. *Learning and Instruction, 14*, 325-341.

[7] Bodemer, D., & Faust, U. (2006). External and mental referencing of multiple representations. *Computers in Human Behavior, 22*, 27-42.

[8] Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer Supported Collaborative Learning* (pp. 69-97). Berlin: Springer.

[9] Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences, 3*, 265-283.

[10] Suthers, D., & Hundhausen, C. (2003). An experimental study of the effects of representational guidance on collaborative learning processes. *Journal of the Learning Sciences, 12*(2), 183-219.

[11] Vahey, P., Enyedy, N., & Gifford, B. (2000). The Probability Inquiry Environment: Learning probability Through the use of a collaborative, inquiry-based simulation environment. *Journal of Interactive Learning Research, 11*, 51-84.

[12] Rebetez, C., Sangin, M., Bétrancourt, M., & Dillenbourg, P. (in press). Learning from animation enabled by collaboration. *Instructional Sciences*.

[13] Saab, N., van Joolingen, W. R., & van Hout-Wolters, B. H. A. M. (2005). Communication in collaborative discovery learning. *British Journal of Educational Psychology, 75*, 603-621.

[14] Sangin, M., Dillenbourg, P., Rebetez, C., Bétrancourt, M., & Molinari. M. (in press). The effects of animations on verbal interaction in computer supported collaborative learning. *Journal of Computer Assisted Learning*.

[15] Schnotz, W. (1999). Visual learning with new technologies: Introduction. *European Journal of Psychology of Education, 14*, 163-165.

[16] Kozma, R. B. (2000). The use of multiple representations and the social construction of understanding in chemistry. In M. Jacobson & R. B. Kozma (Eds.), *Innovations in science and mathematics education: Advanced designs for technologies of learning* (pp. 11-46). Mahwah, NJ: Erlbaum.

[17] Ploetzner, R., Fehse, E., Kneser, C., & Spada, H. (1999). Learning to relate qualitative and quantitative problem representations in a model-based setting for collaborative problem solving. *The Journal of the Learning Sciences, 8*, 177-214.

[18] Buder, J. (2007). Net-Based Knowledge Communication in Groups. *Zeitschrift für Psychologie/Journal of Psychology, 21*(4), 209-217.

[19] Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127-149). Washington: APA.

[20] Dillenbourg, P. (2006). The solo/duo gap. *Computers in Human Behavior, 22*, 155-159.

[21] Bromme, R., Hesse, F. W., & Spada, H. (2005). Barriers, biases and opportunities of communication and cooperation with computers: Introduction and overview. In R. Bromme, F. W. Hesse, & H. Spada (Eds.), *Barriers and biases in computer-mediated knowledge communication – and how they may be overcome* (pp. 1-14). New York: Springer.

[22] Buder, J., & Bodemer, D. (in press). Supporting controversial CSCL discussions with augmented group awareness tools. *International Journal of Computer-Supported Collaborative Learning*.

[23] Doise, W., & Mugny, G. (1978). Socio-cognitive conflict and structure of individual and collective performances. *European Journal of Social Psychology, 8*(2), 181-192.