Fostering hypermedia learning with different argumentation tools: The role of argument visualisation

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Abstract : In this study the effects of visualization tools were examined on argumentation skills, knowledge acquisition, and cognitive load during hypermedia learning. Participants in this experiment had to complete an argumentation task on issues of genetics and gene manipulation by using a hypermedia learning environment as a resource. In one condition, participants were provided with a graphical mind mapping tool in order to complete an argumentation task. In another mind mapping condition, participants were provided with images representing the content in the hypermedia information database expecting a dual-coding of information. In a third condition, a two-columned text editor was given. Results suggest that the text-based argumentation tool contributed most to produce more arguments with a higher degree of soundness. Nevertheless, all three conditions led to comparable results regarding knowledge acquisition and motivation.

1. Introduction

Fostering elaboration processes in media-represented information has a long tradition within educational and cognitive psychology research. Many approaches for triggering active learning instead of a passive reception of printed text have also been adapted to hypermedia learning (e.g. summarizing, organising or concept mapping; cf. Jonassen, 1996; Jonassen, Beissner & Yacci, 1993). Such external representations are assumed and proved to support memory as well as awareness processes. This paper examines how tools for external representations can contribute to foster informal reasoning and learning. In order to support informal reasoning and applied knowledge acquisition, one possible strategy is to provide argumentation tasks for enhancing and deepening learning (here with non-linear information media) and to enhance reflection processes and critical thinking (Ennis, 1987; Voss & Means, 1991). In combination, argumentation tasks and hyper-

media learning are potentially able to support multiple perspectives and, thus, to provide for cognitive flexibility.

Concept mapping approaches are very common in external visualisation of thoughts, ideas, structures, etc. Possible functions of such concept mapping tools may be to create overviews, to restructure or reorganize content, deepen or elaborate a subject's knowledge (for an overview see Jonassen et al., 1993). Such tools have some similarities (e.g., representing a 2 or 3-dimensional network structure by nodes and links) but also have differences (e.g., by providing specific ontologies, labelling of edges etc., cf. Gaines & Shaw, 1995; Jonassen et al., 1993; Tan, 2000).

2. Cognitive rationale for using concept mapping tools

Concept or Mind mapping approaches (these terms are used synonymously here) as *Cognitive Tools* are able to fulfill several functions and tasks (cf. Mandl & Fischer, 2000). In this study a cognitive and applied educational function is addressed by supporting the learning processes of a person by visualising knowledge or augmentation structures externally.

By externalizing and restructuring one’s knowledge, a deeper elaboration of the content that has to be learned could be fostered. According to the level-of-processing-approach (Craik & Lockhart, 1972) a deeper mental effort and, thus processing level could be initiated – especially when learning from text (cf. Schnotz, 1988). But does the more active involvement of learners justify the popularity of mind mapping or is it equivalent with other methods like summarizing, making notes or questioning in order to foster elaboration?

Another benefit of concept mapping approaches could be the semi-graphical representation of information as no advantage of common concept mapping could be expected from a dual-coding perspective (cf. Paivio, 1978). As typical concept mapping does not contain pictorial information that interacts with verbal information or could be represented either verbally or visually (cf. Mayer, 2005) any advantage over text-based approaches seems not justifiable. Despite these concerns, there is evidence that within computer-based learning environments and hypermedia learning the use of concept mapping seems to be beneficial for learning processes (e. g., Bruillard & Baron, 2000; Kommers & Lanzing, 1997, Tergan, 2006). Within controlled experiments comparing hypermedia learning with and without support by concept mapping tasks the advantageous use of the cognitive tool is shown (Tergan, 2006).

3. Open research questions and hypotheses

The use of mind mapping as a cognitive tool for enhancing learning seems to be evident. The question about the function of the semi-graphical structure remains unclear. It could be that the kind of representation in concept mapping approaches increase learners' cognitive load following Cognitive Load Theory (CLT; e.g., Sweller, 1999; Sweller, van Merriënboer & Paas, 1998). Especially in argumentation tasks that might enhance learners critical thinking skills, as well represent authentic learning activities, it could be beneficial to provide simpler – but nevertheless task adequate devices – in order to reduce learners' cognitive load. In order to fully exploit the benefits of concept mapping approaches, it might be beneficial to leave the semi-graphical representation level by inducing and combining textual representation with images. Thus, an advantage over mono-codal information processing could be aspired (according to theories of image/text processing; Schnotz, 2005; Mayer, 2005). Therefore, we examined in this study the influence of a common concept mapping task, a concept mapping task including pictorial and textual information and a text-based tool on learning outcomes as well as cognitive load. The learning task was to conduct an argumentation by using a hypermedia learning environment on issues of genetics and gene manipulation.

4. Method

A one factor design with three conditions of the independent variable was used. In one condition, participants were assigned to conduct an argumentation task during information retrieval within a hypermedia learning environment with a graphical mind mapping tool. A second condition was operationalized by using the same tool as in the first condition but enriched by pictures representing central concepts as provided within the hypermedia learning environment. In a third condition, participants had to conduct the same argumentation task within a two-columned text editor.

4.1 Participants

Forty-five university students (43 women and 17 men, mean age = 26.98 years, SD = 9.31) that were randomly assigned to one of the three treatment conditions volunteered to participate. Volunteers received a study related certificate.

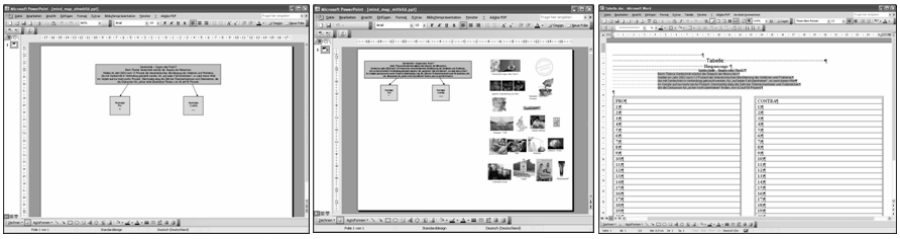
4.2 Material

The learning material for all participants was a hypermedia learning program on "Genetics and Gene Manipulation". At the beginning of each experiment, participants were introduced to the program, followed by a pre-test. In the pre-test, a knowledge test was conducted. The knowledge pre-test consisted of 20 multiple-choice questions covering the content of the hypermedia learning system and three open questions in order to assess transfer (also applied in the post-test).

The actual experimental task in all argumentation conditions was the argumentative analysis of the following statement: "Gene manipulation – chance or curse?" Subjects were asked to look for relevant information in the underlying hypermedia system and to use the given argumentation editors (and pictures that were presented in the concept mapping editor with images).

In the text-editor condition, a tool using an input formula with two columns, one for pro and one for contra arguments (see Figure 1, right) was given to the learners. The complementary graphic-based mind mapping tool was a pre-structured power-point page that allowed participants to draw notes and to connect them with arrows. Participants were required to mark cards with a "+" or a "-" in order to mark a pro or a contra statement (see figure 1, left screen below). The graphics-supported concept mapping task was similar, but included central images representing the content of the hypermedia system (see figure 1 center screen below).

Fig. 1. Different argumentation tools used in this study.



In all conditions, participants' statements were analyzed quantitatively (number of statements), but also regarding their quality, their content and their relationship to other arguments. For the analysis of arguments, categories developed in problem solving research considering informal reasoning by focusing on enthymemes were used (i.e., incomplete arguments; Voss, Blais, Means, Greene, & Ahwesh, 1989; Voss & Means, 1991). Each single statement was rated on one of the categories "Acceptability", "Relevance Emotionality" and "Distinctiveness" (from a minimum of 1 to a maximum of 5). The experiment ended with the post-test where the same instrument as in the pre-test was administered (a concept mapping task for assessing structural knowledge). In addition, the NASA-TLX assessing cognitive

load was applied in a slightly adapted version (cf. Hart & Staveland, 1988). Time on task was constant for all three conditions with about one hour.

5. Results

The analyses for dependant measures were conducted separately for each category of variables: knowledge acquisition, quality of argumentation, and motivation.

5.1 Knowledge

An ANOVA with repeated measurement between multiple choice pre and post-test revealed a significant main effect for the time of measurement ($F(1, 42) = 203.88.88$, $p < 0.001$), but no significant interaction between time of measurement and the independent variable ($F(1, 42) = 0.63$, $p = 0.54$). All three groups had a significant increase in test performance but did not differ significantly in the post-test. Nevertheless, the gain is highest in the condition with the text-based argumentation tool (see Figure 2). A similar result was provided by the analysis of the transfer questions with no significant differences between all three conditions but the highest difference between pre and post-test in the text-based argumentation condition.

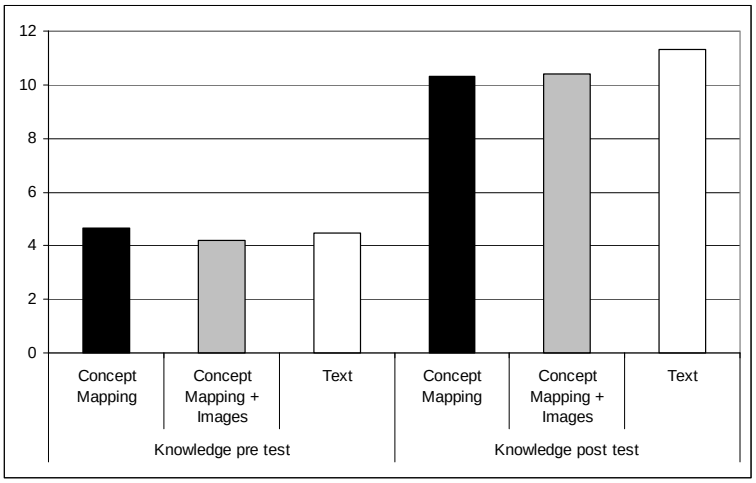
5.2 Quantity and quality of argumentation

A MANOVA was computed on the number of arguments, acceptability, relevance emotionality, distinctiveness as well the balance between pro and contra arguments (using the geometric mean value). There was a significant main effect ($F(12, 76) = 2.77$, $p = 0.04$; eta squared = 0.31). A test for between-subjects effects revealed significant differences in emotionality of arguments ($F(2, 42) = 5.61$, $p = 0.007$; eta squared = 0.21), where participants in the concept mapping condition with images had the highest and participants in the text-editor condition had the lowest score. There was also a significant difference in the overall number of arguments ($F(2, 42) = 4.42$, $p = 0.015$; eta squared = 0.18) where participants with the text editor had the highest number of single statements. There was no significant difference among groups in balance between pro and contra arguments ($F(2, 42) = 2.54$, $p = 0.08$).

5.3 Cognitive Load

An ANOVA regarding Cognitive Load using the overall mean value of the NASA-TLX revealed no significant difference between all three groups ($F(2, 42) = 0.58$, $p = 0.56$), although the highest score was found here in the concept mapping condition with images.

Fig. 2. Outcomes in knowledge tests.



5.4 Regression Analyses

A linear regression analysis regarding increase in performance from knowledge pre-test to post-test revealed as significant predictors the performance in the knowledge pre-test and subject matter interest. Explaining about 29% of variance, the model predicts that the lower prior knowledge and the higher interest, the more learners benefit from the treatment ($p<0.001$). Another regression analyses regarding quality of argumentation reveals, that only prior knowledge is here a significant predictor: the higher prior knowledge, the higher is the quality of argumentation.

6. Discussion

In this study three different tools for visualization of argumentation structures during hypertext-based learning on knowledge acquisition, motivation, and argumentation quality were analyzed. Two graphical mind mapping tools (one with and one without images) and a two-columned text-based argumentation tool have been provided. While mind mapping tools often are preferred due to their semi-graphical representation of information, this possible advantage is more than questionable from a cognitive science point of view. It was argued here, that it may rather increase cognitive load compared to the basic text-based argumentation tools although the graphical organization might support organization of one's argumentation structure. Nevertheless, we expected a combination of concept mapping with images, which represented central concepts of the area that had to be explored by argumentation, to be superior.

In this experiment, we found no single advantage or disadvantage of one tool compared to the other within effects on knowledge acquisition. In all three conditions, the argumentation task led to superior results from pre to post-test. Thus, the argumentation task seemed to be successful in fostering a deeper elaboration of the content provided by the hypermedia information system.

A comparison between the qualitative (acceptability, relevance, emotionality, distinctiveness) and quantitative (number of arguments) aspects of learners' argumentation revealed slight advantages of the text-based argumentation editor, where learners produced the highest number of arguments and kept their argumentation thread rather rational than emotional.

All in all the study suggests that the combination of argumentation tasks and learning with hypertext is an effective approach for knowledge acquisition. Nevertheless, there was no superior effect of the semi-graphical concept mapping tools with or without image support. It was rather the text-based argumentation tool that led to a sounder argumentation and to more single arguments. The use of graphic-based tools for external visualization purposes might provide one possibility out of many to foster an active learning, but in fact we could not find a surplus value in cognitive support compared to rather common approaches.

7. References

Bruillard, E. & Baron, G.-L. (2000). Computer-based concept mapping: A review of a cognitive tool for students. In D. Benzie & D. Passey (Eds.), *Proceedings of the conference on educational uses of information and communication technologies* (pp. 331-338). Beijing: PHEI.

Craik, F. I. & Lockhart, R. S. (1972). Levels of processing. A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671-684.

Ennis, R. H. (1987). A taxonomy of critical thinking dispositions and abilities. In J. B. Baron & R. J. Sternberg (Eds.), *Teaching thinking skills: Theory and practice* (pp. 9-26). New York, NY: Freeman.

Gaines, B.R. & Shaw, M.L.G. (1995) Concept maps as hypermedia components. *International Journal of Human-Computer Studies, 43*, 323-361.

Hart, S.G., & Staveland, L.E. (1988) Development of NASA-TLX (Task Load Index): Results of experimental and theoretical research. In P.A. Hancock, & N. Meshkati (Eds.), *Human Mental Workload* (pp. 139-183). Amsterdam: North Holland.

Jonassen, D. H. (1996). Computers in the Classroom: Mindtools for Critical Thinking. Columbus, OH: Prentice Hall.

Jonassen, D. H., Beissner, K., & Yacci, M. (1993). Structural knowledge: techniques for representing, conveying, and acquiring structural knowledge. Hillsdale, NJ: Erlbaum.

Kommers, P. A. & Lanzing, J. (1997). Students' concept mapping for hypermedia design. *Journal of Interactive Learning Research, 8*(3/4), 421-455.

Mandl, H. & Fischer, F. (2000). Mapping-Techniken und Begriffsnetze in Lern- und Kooperationsprozessen. In H. Mandl & F. Fischer (Eds.), *Wissen sichtbar machen* (pp. 3-14). Göttingen: Hogrefe.

Mayer, R. E. (2005). Cognitive Theory of Multimedia Learning. In R. E. Mayer (ed.), The Cambridge Handbook of Multimedia Learning (pp. 31-48). Cambridge: University Press.

Paivio, A. (1978). A dual coding approach to perception and cognition. In H. L. Pick & E Salzman (Eds.), *Modes of perceiving and processing information* (pp. 39-51). Hillsdale, NJ: Erlbaum.

Schnotz, W. (1988). Textverstehen als Aufbau mentaler Modelle. In H. Mandl & H. SPada (Eds.), Wissenspsychologie (pp. 299-332). Weinheim: PVU.

Schnotz, W. (2005). An integrated Model of text and picture comprehension. In R. E. Mayer (ed.), The Cambridge Handbook of Multimedia Learning (pp. 49-69). Cambridge: University Press.

Sweller, J. (1999). Instructional design in technical areas. Camberwell: ACER Press.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. W. C. (1998). Cognitive architecture and instructional design. Educational Psychology Review, 10, 251-296.

Tan, S.C. (2000) The Effects of Incorporating Concept Mapping into Computer Assisted Instruction. *Journal of Educational Computing Research, 23 (2),* 113-131.

Tergan, S.-O. (2006). Individuelles Wissens- und Informationsmanagement mit Concept Maps beim netzbasierten Lernen. In H. Mandl & H. F. Friedrich (Eds.), *Handbuch Lernstrategien* (pp. 307-324). Göttingen: Hogrefe.

Voss, J. F. & Means, M. L. (1991). Learning to reason via instruction in argumentation. *Learning and Instruction, 1,* 337-350.