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Scripting the Collaboration for Exploiting the Learning Affordances of a Modeling Environment

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Abstract

This paper describes two studies that explored how specific instructional measures enabled students to take advantage of the diagrammatic representations of a learning environment for conducting effective collaborative modeling. The two studies employed different instructional measures to support collaborative learning and employed two different research designs. One study was a case study with video analysis while the other compared achievement scores of two groups. Results from both studies complete each other and show the combined and integrated need for structuring the collaboration as well as for providing concrete visual anchors for collaboration. The studies show that the affordances of the learning environment get exploited by appropriate scripting.

Keywords: Collaboration, Scripting collaboration, Modeling, Collaborative modeling, Diagrammatic representations.

Introduction

Among studies on science education two approaches for enhancing learning are highly advocated: use of diagrammatic representations and collaboration. Studies show the importance of representational aids to individual learning and problem solving (Koedinger, 1991; Novak, 1990; Larkin and Simon 1987; Novick & Hmelo, 1994; Zhang, 1997). Diagrammatic representations can support the process of relating and comparing different information elements by making conceptual information more directly available for perception (Kulpa 1994). Good visualizations make structural aspects of knowledge explicit, which can facilitate internalization of complex concepts (Cheng et al. 2001). Thus external visual and diagrammatic representations are recommended for science education (E.g. Ainsworth, 1999, 2006; Bouwer and Bredeweg, 2010 ; Gilbert, 2005). Studies also show the potential benefits of collaborative learning (Lave &Wenger, 1991; Scardamalia & Bereiter, 1991; Webb & Palincsar,1996) and particularly for science education (Springer et al., 1999; Van Boxtel et al., 2000; Van Joolingen et al., 2005; Randinsky, 2008). Visual representations can support grounding processes for collaborative knowledge construction (Suthers, 2005), and several studies addressed the role of representational aids in supporting collaborative learning processes. Such studies emphasized both communication acts and topical representations (Baker et al., 2001; Or-Bach and Joolingen, 2004). Unfortunately learners generally do not interact in cognitively effective ways without some structured guidance and a number of methods have been developed for scaffolding collaboration. Zumbach et al. (2005) suggest a taxonomy where a general distinction is made between scaffolds that are (instructional) design-based (all decisions are made before the collaboration begins) and those that are management-based (the major decisions are made based on observations from learners' ongoing interaction, and decisions are made at "run time"). In the two studies presented here only design-based scaffolds were used, and we refer to this design as scripting. Although the term script originated in cognitive psychology (Schank and Abelson 1977), it is used in educational contexts to describe ways of structuring interaction and scaffolding collaborative learning through the use of roles, activities, and sequencing of activities (King, 2007). Scripts can be computer-based and relate to computer-based activities; and can also integrate a variety of mediated or face-to-face activities. Scripts can be of different granularity: Micro-scripts which are dialogue models, and Macro-scripts which are pedagogical models (Dillenbourg and Hong, 2008). We employed scripting elements for pedagogical guidance.

The word affordance was first coined by the perceptual psychologist James J. Gibson (1977) and was popularized (especially in the HCI community) through Donald Norman's book: The Psychology of Everyday Things (Norman, 1988). An affordance is the design aspect of an object which suggests how the object should be used (Norman, 1988). Independent of perception, affordances exist whether or not the actor cares about them, perceives them, or has perceptual information about them (Gaver, 1996). Kirschner (2002) further defined educational affordances as those characteristics of an artifact that determine if and how a particular learning behavior can possibly be enacted within a given context.

Affordances of a modeling environment for science education, as provided by diagrammatic representations and simulation facilities, might not be enough for effective learning and additional support might be required (de Jong, 2006; Or-Bach and Bredeweg, 2012a). Some scripting of the collaboration is required in order to exploit the affordances of the representational aids for effective collaborative learning.

In this paper we present two studies where the collaboration was guided by two different instructional scripts. In the first study the main scripting element was the collaboration protocol, while in the second study the main scripting element was a specially designed assignment. The two studies were conducted while evaluating the DynaLearn modeling environment (http://hcs.science.uva.nl/projects/DynaLearn/) for science education. In this paper we re-present and re-interpret part of the findings of these studies. We try to show how two general macro scripts supported collaborative learning by exploiting the benefits of the diagrammatic representations of the learning environment.

The following sections present the DynaLearn modeling environment with which the studies were conducted during a conceptual modeling course; the two studies with their relevant findings; and a discussion of the interpretation and implications of these findings.

The DynaLearn Modeling Environment and Introduction to the Studies

This section describes the DynaLearn modeling environment and especially the diagrammatic representation for constructing a model and for observing the model simulation results. This section includes also a description of the Conceptual Modeling course where the studies took place. DynaLearn is an intelligent learning environment with which learners can construct qualitative models of scientific knowledge by manipulating icons, and their inter-relationships using a diagrammatic representation (Bredeweg et al., 2010). The diagrams represent models that can be simulated and thus confront learners with the logical consequences of the knowledge they expressed. The underlying mechanism that enables the simulation of a model is built on the Qualitative Reasoning (QR) approach (Bredeweg and Struss 2003). More specifically, the DynaLearn modeling environment provides diagrammatic tools for constructing models, an underlying mechanism that enables the simulation of a model, and several viewpoints for observing the simulation results by a diagrammatic representation. The icon-based modeling primitives include entities, quantities, and causal dependencies, which are combined into a model. Figure 1 presents a model with indications of the various primitives of the modeling environment.

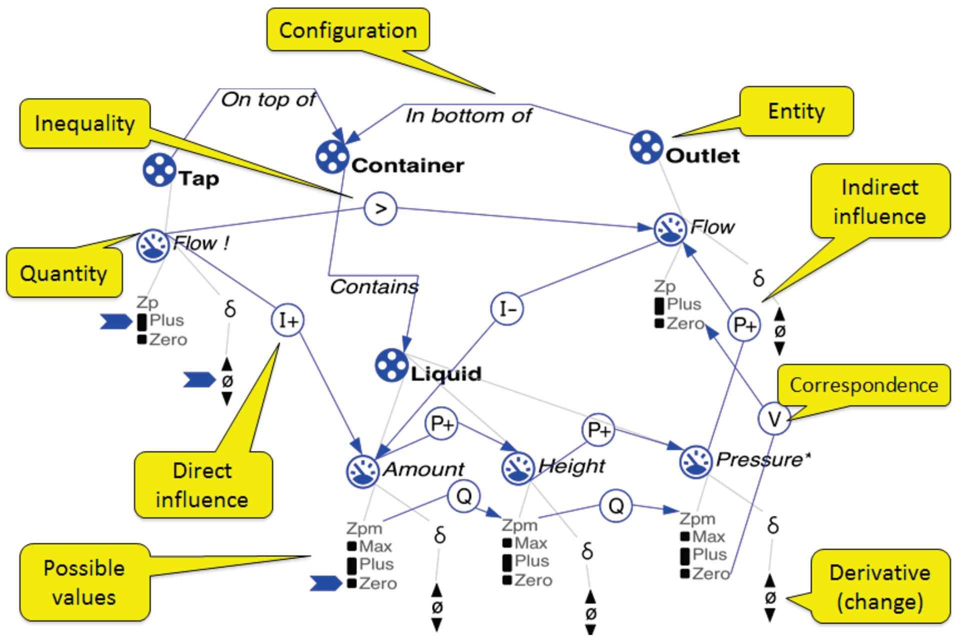

Figure 1: The diagrammatic modeling primitives as employed for constructing a specific model

The qualitative simulation engine generates predictions in the form of state-transition graph (Bredeweg et al. 2009). The viewpoints users can employ for observing the simulation results include state diagram, value history for different quantities and different paths, and equation history (Bouwer and Bredeweg, 2010). These viewpoints are presented in Figure 2 for the model of figure 1. Users can choose a viewpoint and specific elements within a viewpoint in order to inspect the behavior of the model. For example, the value history for each quantity can be referenced and discussed separately, and with relation to other quantities, while switching back and forth between the model and simulation results. The diagramatic representation of the various specific elements (e.g. the value and the direction of change for a specific quantity in a specific state) enables easy reference for productive collaboration.

The two studies were conducted during an undergraduate mandatory course on Conceptual Modeling, which is part of an interdisciplinary program on environmental science. The course is concerned with the use of computer models and simulations as a means for describing, analyzing, and explaining systems and their behavior, with an emphasis on non-numerical modeling methods. During the course students are expected to develop interdisciplinary thinking and to see and make use of analogies between systems from different disciplines. The course ran for 8 weeks, and each week the theoretical lesson was accompanied by a 3 hours practical class, in a computer laboratory using the Dynalearn software. During these hours students were required to work on a set of DynaLearn modeling assignments related to the theoretical material of that week. Students were required to submit these assignments that were graded as part of the course final grade. For the laboratory session the students were divided into two groups in order to enable proper help for the students. During the first five weeks, students were required to work individually on the laboratory assignments and during the rest of the sessions they were required to work collaboratively. Several students did not pass the original course because of various reasons and a re-sit course was suggested to them. The second study was conducted with two of these re-sit students.

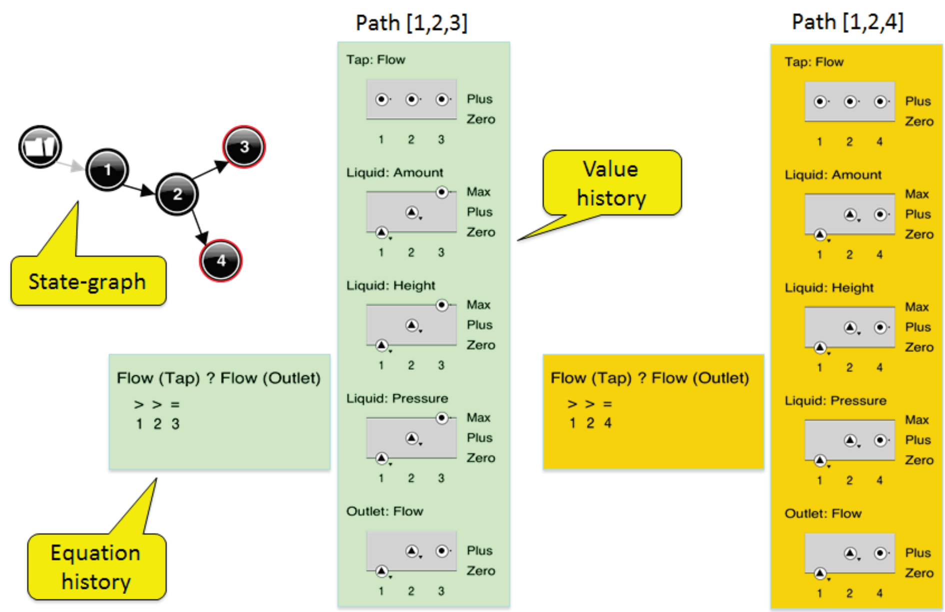

Figure 2: Different diagrammatic viewpoints of the simulation results of the model in Figure 1.

Study 1: Scripting the Collaboration by a Collaboration Protocol

Research Goals, Design and Tools

The Pair Modeling (PM) technique, which we introduced in this study for the collaboration protocol, is an adaptation of the pair programming technique (Beck, 2000) that is employed in software development projects in the industry as well as in introductory Computer Science courses in higher education. Williams et al. (2002), defined pair programming as a practice in which two programmers are sitting side-by-side using only one computer to work collaboratively on the design, algorithm, code or test. The pair consists of two developers who change their role alternately as “driver” and as “navigator”. The idea being captured by these metaphors and adapted for PM is that the driver is using the facilities (keyboard, mouse) focusing on performing the task, while the navigator is less occupied with the immediacy of code/model production and can concentrate on the overall direction of the development of the program/model. In the adaptation we emphasized the importance of scheduled alternations between the roles and emphasized the need for continuous communication between the “driver” and the “navigator”.

The study involved 56 students taking the Conceptual Modeling course. The PM technique was employed during two of the laboratory sessions of the course (in consecutive weeks). In order to study the effect of the PM technique one of the groups employed PM for the first week and the other during the second week, enabling the existence of a control group during the first week with exactly the same assignment, exactly the same course materials and exactly the same previous assignments. Students in the control group worked also in pairs but with no predefined structure for the collaboration. During the 3 hours of the laboratory session each student had a chance to perform the same role twice. Students were reminded each time a switch of roles was required. The experimental group and the control group consisted each of 14 pairs (28 students). At the end of the session the pairs had to submit the 5 exercises of the assignment for that session and the exercises were scored. The scores were used to investigate the actual effect of employing the PM technique on students' achievements. A questionnaire was administered to the students of both groups after both groups had a chance to experience PM. The two groups were also observed during these two weeks with more attention to the group using the PM technique that week. The observations were of an exploratory nature, not a structured observation; and focused on the students' roles and students'communication processes.

Findings

The maximum total score for all the 5 modeling exercises of this assignment was 5. The average score for the experimental group was 3.18 (standard deviation 0.9) with 4 pairs having a score higher than 3.5 and one pair of them had a score of 4.5. In the control group the average score was 2.57 (standard deviation 0.6) with no score higher than 3.5. The difference between the averages of the groups is statistically significant (T-test resulting in p=0.023). The fact that the average for the experimental group was 24% higher than the average of the control group required additional checking whether the experimental group consisted by some chance of better students with regard to DynaLearn modeling. So we compared the average score of the same groups of students for the two previous assignments of the course. These scores were on individual modeling exercises with DynaLearn. The comparison showed a very slight difference, 4% and 2% respectively, in favor of the control group. From these results it seems that the students in both groups were on about the same level and the differences in achievements that were found during the experiment may be attributed to the use of the PM technique.

The Observations focused on the communication dynamics, not on the content. The general impression was that the group employing PM was working more seriously, concentrating more on the task on hand. It was interesting to see how the students talked and used the pointing devices: the driver with the mouse and the navigator with a finger or a pen. In most pairs there was a lot of communication between the driver and the navigator as expected with this technique.

More details about this study can be found in a previous paper (Or-Bach and Bredeweg, 2011).

Study 2: Scripting the Collaboration by the Task Design

Research Goals, Design and Tools

A special task was designed to promote reflection on the modeling activities that the students carried in both the original and the re-sit course. The task required re-visiting and re-interpreting the models that the students constructed for the various course assignments. The task consisted of several parts. The students were required to describe eight of the models they constructed for their course assignments according to a set of given descriptors (meta-data). Criteria for choosing the descriptors were: fundamental concepts for expressing understanding of the behavior of phenomena, fundamental elements for interpreting the simulation results; and issues where misconceptions or alternative conceptions were expected and thus might trigger a discussion between the students. After the required individual reflection was submitted the students were asked to collaborate in pairs and submit the same reflection task. The students were expected to compare their individual submissions, discuss arising issues, and together compile one agreed-upon set of files.

The collaborative session of one pair was recorded and analyzed using Transana (http://www.transana.org/). Keywords mapping served as the main research tool. A categorization scheme for the keywords' groups was designed before the video analysis, but was finely tuned during the analysis. The list of keywords within a group emerged during the video analysis and thus forced an iterative analysis process. Each clip appearing in the map relates to a discussion regarding a specific descriptor as manifested in a specific model. A semi-structured interview was conducted with each of the students immediately after the collaborative reflection session.

Findings

Figure 3 presents the keyword map (created with Transana) according to the keywords that were assigned to the various clips of this collaboration session. The division of the time line into clips describes topic-based units rather than time-based units. It means that the clips are not of the same time length. The list on the left side is the list of keywords (each preceded by the respective group name). For each keyword the respective line (and a respective color for readability) shows the density of appearance through the clips of the sessions.

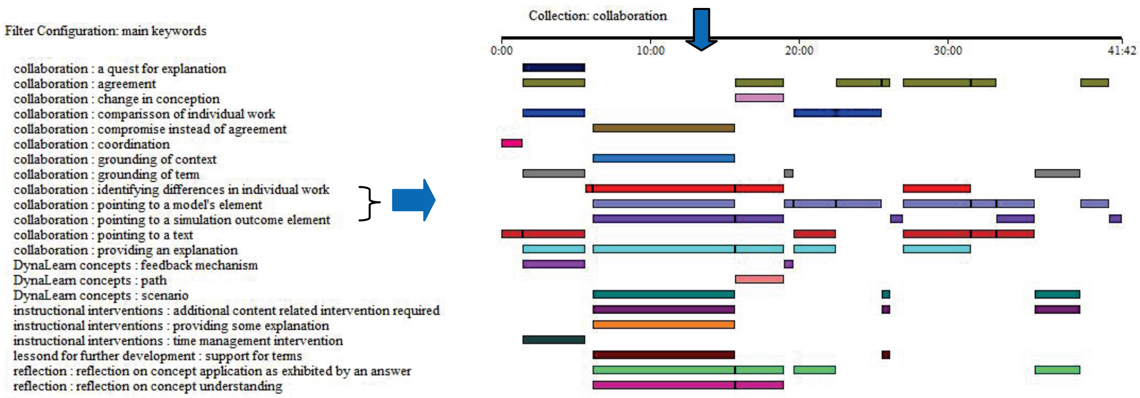

Figure 3. Transana keyword map for the video clips during the collaborative models' description.

The map shows some evidence of a variety of collaboration acts. Three keywords (the added arrow in figure 3) relate to students' deictic gestures for grounding the communication (pointing to a model's element, pointing to a simulation outcome element, and pointing to a text in the assignment). It can be seen that the students pointed often to the visual artifacts of the learning environment during the discussions. The map shows also that the keyword "identifying differences in individual work" is always accompanied by pointing gestures. Even though this map provides a view of the collaboration, the role of the task design to script the collaboration is not evident enough from this map. A finer description is required in order to show the role of the task and how the diagramatic representations are employed for the respective collaboration. We discuss here one clip (referenced by the added upper arrow of figure 3). In this clip the students discussed the model dealing with liquid in a flexible container according to the specific given descriptor "The most meaningful path(s) to look at in the simulation is:". The discussion was triggered by the difference between the students' individual submissions. Each of the students explained his answer by referring (pointing) to the simulation results. While talking and pointing to the state diagram it turned out that S1 did not know the exact definition and manifestation of a path in the software but still had the correct idea of a timeline description of what was happening. The explanation that S2 provided, pointing at the respective manifestation in the state diagram, filled this gap; and from that point they both were using the same interpretation of path for completing the task. Further reflection and learning activities by the students were evident when both students returned to the individual submissions and S1 re-explained his input in accordance with the correct path definition. This revised explanation brought S2 to realize that actually S1 initial input was a better answer (suggesting a more meaningful path).

One of the students addressed explicitly in the interview the important role of the initial individual work as prescribed by the instructional script "....When you do it separately you make decisions and then later you can compare your decisions…. When you have it already than you can see mistakes".

More details about this study can be found in Or-Bach and Bredeweg (2012 b).

Summary and Discussion

In the literature about scripting collaboration one can find suggestions for various scripts (King, 2007; Dillenbourg, 2008). In our studies we employed scripting elements that seemed most appropriate for exploiting the special affordances of the modeling environment for effective collaborative learning. The scripts were intentionally not strictly defined nor reified in the learning environment in order to avoid over-scripting (Dillenbourg, 2002). The two studies complete each other by both the scripting elements and the research tools. In the first study the main scripting element was the collaboration protocol, and the research focused on the collaboration outcomes employing both quantitative and qualitative methods. In the second study the main scripting element was the specially designed reflection task; and the research focused on the collaboration process employing qualitative methods. Findings from the first study showed that scripting the collaboration by the PM technique (size of group, roles, alternation between roles) brought better results than the unstructured collaboration. The video clip analysis of the second study showed the role of scripting the collaboration by the task design, scripting for encouraging the identification of conflicts and thus encouraging reflection. We saw the contribution of the initial individual work for triggering reflective collaboration and especially for providing each of the students with a context to re-examine and restructure his/her own understanding. King (2007), in a chapter presenting a cognitive perspective about scripting collaborative learning processes, brings up the effective learning activity of reconciling cognitive discrepancies to be fostered in scripted collaboration. Reconciling cognitive discrepancies can give rise to a number of other cognitive, metacognitive, and socio-cognitive processes (King, 2007). In a modeling environment where diagrammatic representations are used for expressing students' conceptions and for representing its simulation outcome(s); scripting for encouraging the identification of conflicts might support learning (Or-Bach and Van Joolingen, 2001).

The visual artifacts of the DynaLearn modeling environment were shown to be instrumental in both studies. This was evident during the observations in both studies and can be seen also in figure 3. Shared representations play several roles specific to group use, including prompting participants' negotiations, supporting reference to prior ideas through gestural deixis, and providing a foundation for shared awareness (Suthers et al., 2003). In the first study we observed students' frequent use of gestural deixis that the visual representations of the modeling environment enabled. With the PM technique, when the pointing device was used by the 'driver', the 'navigator' used a finger or a pen for pointing to a visual artifact and thus focusing the conversation. The frequent pointing while moving between modes (modeling, simulation results and the different perspectives to view the simulation results) was observed also in the second study showing the power of the visual representations for grounding students' communication. Gergle et al. (2004) investigated how action replaces explicit verbal instruction in a shared visual workspace. A detailed sequential analysis of the communicative content revealed that pairs with a shared workspace were less likely to explicitly verify their actions with speech. Rather, they relied on visual information to provide the necessary communicative and coordinative cues. These processes can explain how the diagrammatic representations of the DynaLearn modeling environment reduced the collaboration load (Dillenbourg and Betrancourt, 2006). But our first study that compared scripted collaboration with unstructured collaboration in a shared visual space showed that the scripting had an additional effect. Further reduce of the collaboration load was probably achieved by the responsibility division between cognitive and metacognitive layers of the task (the "driver" and "navigator" respectively). In addition, the re-switch of roles may have reduced the cost of "mutual modeling". Collaboration requires some type of mutual modeling, ways to understand the collaborator (his knowledge, role, communication etc.). The fact that students had the opportunity in our study to play the same role again after performing the other role helped them understand the collaborator better.

We believe that adequate scripting, as was employed in this study, can further enhance and exploit the affordances of the learning environment. In the above studies the special affordances of the modeling environment, namely the diagrammatic representations for constructing a model and for investigating the results of the model simulation, were exploited by the special scripting elements we employed for the collaboration.

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