Communication through the Artefact by Means of Synchronous Co-construction

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Abstract: This paper examines the collaborative features of a tool environment called Cool Modes. Cool Modes provides different modelling environments allowing learners to co-construct representations of domain-specific models. These systems range from curriculum topics such as stochastic to subjects with a non-standard character such as astronomy. In the current study we focus upon the Stochastic palette and the Moon palette, which both provide visual languages to support modelling activities specifically in the subject matter area of mathematics. These visual languages are embedded in the Cool Modes Framework providing tools for annotating and enriching the co-constructive modelling process. Both palettes have been tested and adapted for learning scenarios taking place in formal and informal learning environments. In this paper we report the findings from observational material collected from 3 classes in Germany using Cool Modes. The observation concentrates upon assessing the effectiveness of supporting co-constructive modelling activities in a synchronous learning setting.

Introduction

According to the socio-cognitive perspective learners construct knowledge by actively engaging in collaborative activities such as formulating arguments and sharing ideas. We aim to support the socio-cognitive argument/hypothesis that learning is grounded in participating in an activity. The social aspects that enable students to create knowledge are triggered through using computational artefacts to stimulate collaborative knowledge exchange by communication through the artefact (Dix, Finaly, Abowd & Beale, 1997). In order to support students to not only participate, but actively engage in the knowledge construction process, we develop learning environments that allow collaborative manipulation of scientific artefacts. In face-to-face settings, allowing learners to frame the learning activity using "computational objects to think with" can facilitate this collaborative knowledge construction process (Hoppe, 2004). Inspired by Jonassen's (2000) notion of mindtools we develop learning scenarios to establish a reciprocal environment that engages students to co-construct representational objects.

Collaboration

Communication through an artefact is characteristic of co-construction in shared workspace environments, in which the artefact-based communication complements natural language-based exchange (Hoppe, 2005). From a design point of view, the emphasis is on increasing awareness of collaborators' actions, whereby the artefact is treated as the mediation device. A peer-to-peer group can manipulate representational objects establishing control and feedback and thus communicate through the learning object. Both can observe each other's actions. This communication is necessary to improve and re-adjust the decision making process that is represented by the artefact. While this feedthrough communication is important for both asynchronous and synchronous learning settings, it is also the direct communication within and across groups that can be facilitated when co-constructing models. Observing the direct communication in synchronous classroom and informal lab settings is critical when evaluating the learning process. Different dynamics of communication can be noticed during a modelling session: Question asking (often to the instructor), peer-to-peer discussions and knowledge exchange on a group level (across peer groups). The communications differ in content depending on the problems that occur. In a computer-supported environment the communication that concerns the functionality of the learning environment is a thread that can be observed, in addition to task-related and further non-task-specific communication. This tool-related information is necessary. Conversely this can take up limited cognitive recourses that could be otherwise used for the task when constructing a scientific model.

During the scenarios that have been analysed here, students conducted scientific experiments by constructing models using an inquiry approach (de Jong & Joolingen, 1998). During this study we focus on the direct communication within and across groups using observation as an instrument of assessment. The feedthrough communications were assessed using log files containing time stamps indicating the evolvement of models created by students. The learning objects are stored and retrieved in a Learning Object Repository called LOR (Pinkwart, 2005). This software logging method was used as a complementary evaluation method for observation.

Learning Environment

The learning environment CoolModes (Pinkwart, 2003) is a framework for various visual languages with domain specific semantics that support modelling activities. Representations with different semantics (e.g. Petri Nets, System Dynamics, Concept Maps) can serve as either operational or conceptual models, which can be enhanced through annotating these models using visual languages to support argumentations and scientific inquiry. The Cool Modes framework allows the learner to mix different modelling languages including annotation tools in the same workspace. Discrete palettes indicate the domain to what the modelling activities are related to.

The Stochastic palette (Kuhn, Hoppe, Lingnau & Wichmann, 2005) for example is related to probabilistic experimentation activities. It is an open modelling environment where students are required to solve the task of probabilistic problems such as the "Birthday Problem". The task is not only to adjust parameters, but also in constructing a model to select and combine elements of the visual language "stochastic experiments" in collaboration with peers, to represent as well as run and analyse an experiment within the field of stochastics (see Figure 1).

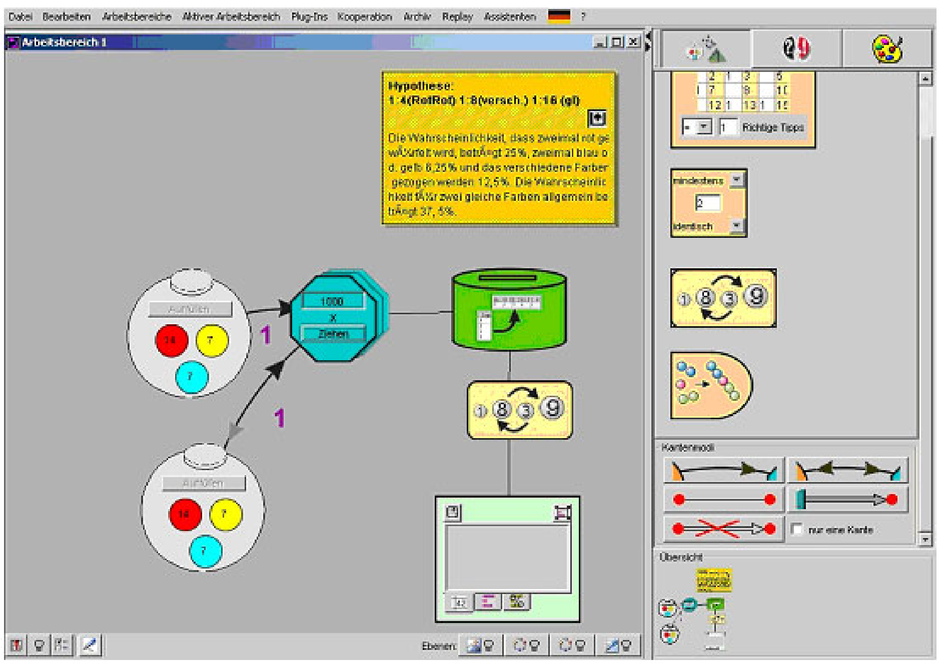

Figure 1. Model of a stochastic experiment with hypothesis note

The Modelling activities in Cool Modes are the results of selecting and linking elements of a visual language that includes random generators, simulation controller and displays. Every element has its own meaning and semantics, which are represented by its visual appearance. Appropriate elements can be linked according to the dataflow. These elements are generated as a subset from the model of a probabilistic experiment. The control element repeats the simulated experiment. A "collector" allows storing the experiment results, displayed as either a list or diagram. Another palette, the Moon palette (Hoeksema, Jansen & Hoppe, 2004) allows learners to load and measure distances on the moon using modelling and calculation tools. Students can make astronomical observations by taking photos using small telescopes or utilizing available pictures that can be displayed in the Cool Modes workspace (see Figure 2). Students calculate the height of lunar craters by determining the radius of the crater and calculating the shadow length using the intercept theorems.

To be able to measure lunar heights learners can model calculation trees to visualize mathematical operations. Collaborative features such as a voting activity and visualization of arguments accompany the modelling activities. These framing activities can be attached in the same workspace as the modelling activities taking place using either the voting palette or the discussion palette. Even though the extra-curricular character of Astronomy has a non-standard aspect to it, the modelling activity itself requires students to work with standard mathematical topics; namely Sentence of Three, and Theorems of Similar Triangles.

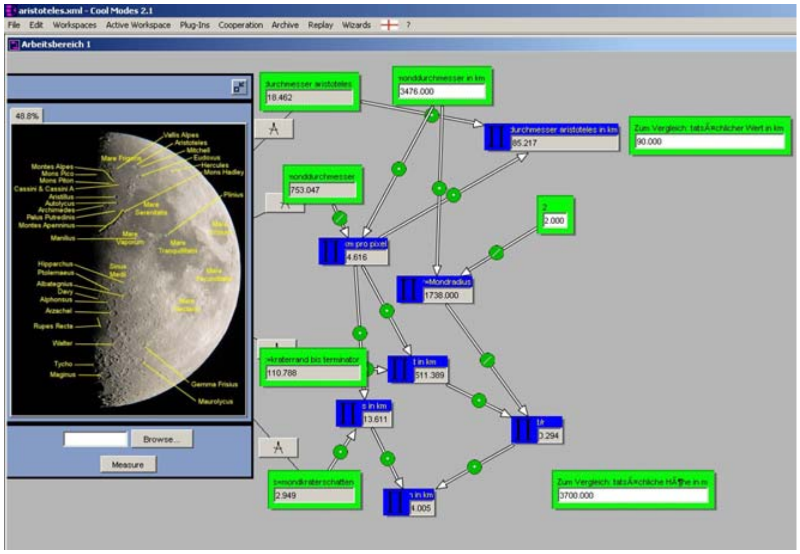

Figure 2. Calculating lunar heights with the Cool Modes Moon palette

The feature in both palettes described above uses multi-modal representations. Self-generated hypotheses are to be represented within the capabilities of the Cool Modes environment. The students have a set of model representations available that can help to make useful decisions within the choice of collaboratively constructing an appropriate model that leads to solving a problem. During the Cool Modes modelling activities a feature for collaboration support is available through a communication server called “MatchMaker”. Through MatchMaker learners can share objects in a joint real-time session. Shared representations can be individually annotated by coupling workspaces.

Besides the synchronous object sharing capabilities, Cool Modes comes with an interface to a Learning Object Repository (LOR) that allows for the index, storage and retrieval of specific learning objects for immediate or later re-use. The uploading mechanism includes semantic indexing that autonomously stores contextual information of the artefacts to facilitate the students’ active learning, rather than spending time on indexing artefacts themselves.

Focus of Study

The study was carried out as part of the final evaluation of the EU funded project COLDEX (IST-2001-32327). The activities were integrated in the rich context of remote and face-to-face scenarios developed to support scientific experimentation activities in formal as well as informal learning settings. The face-to-face settings for this study allowed us to intensively observe the collaborative behaviour of students engaging in scientific activities such as constructing models, measuring distances and interpreting simulation data. The focus of the study was on the technological development whereby the basis was in assessing to what extent students were really supported by the environment to engage in effective collaboration. Based on the work by Grudin (1988) we decided to conduct field evaluation to be able to assess social-psychological and anthropological effects of the environment appropriately. More specifically we were interested in the effectiveness of the learning scenarios adapted to run in both formal and informal learning settings. The focus of observation was the level of interaction that took place during the scenario. One goal of the COLDEX scenarios was to allow technology immersion by supporting scientific practice (Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001) through co-constructing knowledge using features of the tool environment CoolModes.

Method

Study Setting

The evaluation study with 3 classes took place in two computer labs and one outside of the formal school environment. The participants consisted of complete school classes, while the teachers were responsible for delivering both the theory and the student activities. Two researchers assisted with the technology. Only one palette of CoolModes was assessed at a time. The palette “Stochastic” was tested with two classes. The palette “Moon” was used by one class. All three classes were participating for the duration of 1 day in a computer lab at university. In all cases the teacher introduced the students to the topic of Stochastic in previous lessons.

Participants

The students were 9th grade and from German high schools. All three classes had no prior experience of using the Cool Modes environment. Scientific Inquiry skills such as hypothesis building and collecting data were introduced as elementary methods in science classes. Autonomous student activities as well as teacher-centred instruction were part of all lessons. The theoretical introductions to subject matter and the short introduction to Cool Modes tended to be more teacher-centred. During the Cool Modes activities students were working on one table of 4-8 people to allow different modes of collaboration (e.g. peer-to-peer, small group, whole group). Two students shared a single computer.

Data Source

Participant observation techniques were chosen to observe the students’ mode of interaction. A category system was developed to specifically capture interaction patterns in connection toward whether the type of instruction encouraged using the learning technology or not. The assessment of teaching / instruction styles in conjunction with technology integration seems necessary because in synchronous learning settings the teaching methods can affect the level of technology integration (Painter, 2001). The category system developed for that observation was translated into a rating scale that identified four discrete levels (1 = low, 4 = high) of interaction. The focus of observation was the students’ interactions and teaching styles. The categories regarding students’ interactions (see Table 1) aims at helping to assess the level and type of collaboration (e.g. peer-to-peer collaboration vs. collaboration across groups vs. knowledge sharing), support of arguments (visualising arguments, using discussion threads etc.) and type of communicated content. To further analyse the quality of communicated content, we distinguished between tool-related communication and task-related communication. Tool-related communication included content that was related to the functionality of the Cool Modes software. Task-related content refers to communication regarding the task itself, e.g. constructing a model in Cool Modes. The coded instructional styles concentrate upon the overall teaching method (learner-centred vs. teacher-centred) and level of teacher involvement in student activities. During the course of observation a list of program related bugs and interface problems that students encountered were generated. Additional material to observation: Additionally to the interaction and annotations, student artefacts were used for convergent validation and pictures were taken throughout the instructional learning unit.

Table 1: Excerpt of 4 (out of 12) Interaction Patterns for Coding

1) *Types of Collaboration*	No **one-to-one** peer collaboration	Little **one-to-one** peer collaboration
2) *Types of Collaboration*	No Collaboration **within** one group	Little collaboration **within** one group
3) *Types of Collaboration*	No collaboration **among** groups	Little collaboration **among** groups
4) *Types of argumentation*	**Requests** no information from other groups or only when prompted	**Requests** little information from other groups

Every Observer was briefed about the observation material and methodology to attain the highest level of standardization across each test. The observational material that consisted of rating scales was explained beforehand

and the appropriate method of recording observations was introduced. Since the rating scales that were developed for this observation are considered complex, a legend (including schemes) was attached to the rating scales and openly discussed with each observer. Every item of the scale was explained, and its specific meaning agreed upon in order to achieve a high comparability of the observed data. Observation of *all* students who are involved in an activity was considered to be too resource intensive, therefore we decided upon an appropriate sampling method. According to Baber (2005) taking the sociological approach by seeking to collect data from a smaller sample group, but over a comparatively longer duration of time, can control extraneous variables and better reflect real practice in real environments. Four experienced evaluators were selected as observers, choosing one or two peer-to-peer groups to observe them throughout one learning unit. In total 11 groups were observed. The students were informed beforehand that an observation would take place. Permission was gained from the students via the appropriate method of informed consent. The samples for observation were selected depending on their activeness in the activity. This decision of disregarding generalisability was made in favour of capturing rich descriptive results.

Analysis and Results

After the observation took place, the observers shared and discussed their observational material. This consisted of the annotated scales as well as rich descriptions of content and activity that the students were working with during the observation. The different material was discussed to ensure equality of initial conditions and context of activities. The reviewed results of the scales were aggregated. This was done for every unit. The aggregated results of every unit were then compared with other units.

In summary, three units were observed. The unit Stochastic took place twice, with different classes and teachers; the unit Moon took place once. Categories were determined depending on type of instruction and content. We compared the level of collaboration and interaction within the following sessions that are applicable throughout the classes: Introduction to the theory/ task, Introduction to the environment Cool Modes, Cool Modes Practice Session I, II and III, and LOR (Learning Object Repository) session. During the LOR session, students uploaded and retrieved their artefacts to the LOR via an interface in Cool Modes.

A comparison between theory-related instruction and Cool Modes related instruction mode showed expected differences in the level of student interaction. We observed that theory-related session engaged students to a smaller extent in collaborative activities across groups than within peer groups. It was observed that little communication took place during theory-related instruction. During the Cool Modes session, more communication took place. Here, students actively exchanged information. Furthermore, it was observed that learners shared ideas across group members and requested information related to the tool as well as task-related question. Besides comparing different modes of instruction, we compared the change of collaborative behaviour during one mode of instruction over a period of time. It could be observed that quality and intensity of collaboration changed during one Cool Modes session. In Cool Modes Session I, students collaborated only in small group settings (peer-to-peer) within peer settings. Little or no collaboration was observed across groups and therefore little knowledge exchange took place in the whole class. In Cool Modes Session II, and III group structures softened and students exchanged information across peer-groups. In particular the quality of information exchange increased and the learning objects built included more annotations such as formulating hypotheses etc. First, we observed more one-directional communication in the sense that students requested small pieces of information. After working with the Cool Modes environment for a while, sharing of ideas and small discussions could be observed. In Cool Modes Session III, students exchanged ideas freely across groups, exchanging problems about the functionality and sharing experiences of choosing appropriate objects to construct a model. While the collaboration across groups and level of knowledge exchange increased over the day when working with Cool Modes, the peer-to-peer group collaboration maintained a strong performance from the first until the third Cool Modes session.

Students discussed content-related issues (task-related) and issues regarding the functionality of Cool Modes (tool-related). Tool-related communication included for example how to resize tables in the Cool Modes workspace, how to save files, where to find other palettes, how to scale nodes and how to open a file. This type of communication was addressed using the term tool-related. Task-related content on the other hand, addressed communication about subject matter, such as discussions about a given task, problems with understanding instruction. Comparing the results of both, theory-related and Cool Modes-related, instruction mode, we observed more task-related discussions within the Cool Modes sequence than in the theory-related sequence. Tool-related content was only applicable in the Cool Modes Sequence and was therefore only observed there. In a second step, we analysed the change of communication during Cool Modes sequences over the course of the whole lesson. In the beginning of the Cool Modes session, we observed some task-related communication and much tool-related communication.

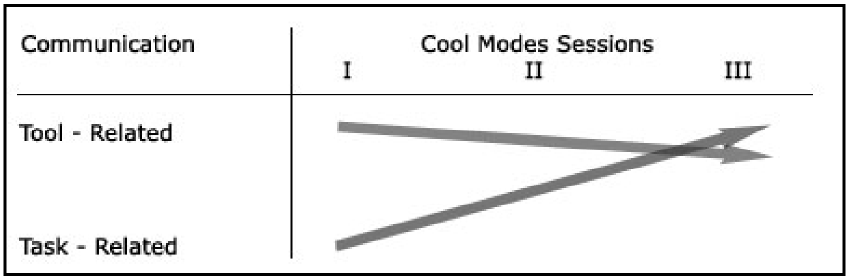

Figure 3. Change of communicated content over time during Cool Modes Session

Towards the end of the Cool Modes activities students discussed more task-related content, even though tool-related communication only slightly decreased (see Figure 3). Students created operational models in all three Cool Modes sessions. Only in the second Cool Modes session and especially in the last session students annotated these models by adding explanations and hypotheses. Also then students autonomously tried out other palettes and integrated them in the existing workspace. During the LOR session tool-related communication prevailed. The interface for uploading artefacts includes section where artefacts can be described by the authors. Especially then, students discussed in peer groups how to distinguish between the models that have been created. However most communication took place between the students and the teacher about how to use the LOR interface properly.

Conclusions

We conducted observations over two different scenarios of the EU project COLDEX to gain insights into the way the Cool Modes software supports interactive behaviour with an emphasis on observing collaboration between students within and across group behaviours. Our results indicate that both, the scenarios of Stochastics and Moon within the Cool Modes learning environment engaged students in rich collaborative behaviour. During theory-based discussions that took place without involving Cool Modes, students collaborated very little. This was expected due to the teacher-centred nature of instruction during the theory session. The Cool Modes sessions allowed for an enhanced opportunity to interact with peers and to discuss problems as and when they arose. It appeared that the more the students became familiarised with the software and the more they were able to open up to other groups in order to share ideas within the class community the more they engaged with the task itself.

When looking at the content that was communicated in discussions, it became apparent that the learners initial reactions to the Cool Modes software was that the students' primary focus was centred on the functionality rather than on the subject matter itself. Furthermore, it appeared that in the beginning, students expelled the majority of their cognitive resources to cope with the software. After getting accustomed to the software we observed a change of behaviour towards more task-related discussions, and thus the software tool became transparent, allowing for the learner to allocate a greater cognitive load to the actual subject matter. Students spent more time with for example discussing and rethinking hypotheses.

Collaboration has been assessed on a behavioural level using observational data. Log-data was used to support this observed data on a more formalised level. Results showed that the Cool Modes software enabled students to engage in different types of collaboration. Students worked on models and rule-sets within peer groups as well as across groups. Cool Modes seemed to support and enhance collaboration, especially after students overcame the basic task of familiarising with the software. We observed that in the initial phase of working with Cool Modes, students used their cognitive resources to collaboratively explore the tools while neglecting the task (e.g. building a model) itself. After this initial phase, students constructed models using the Cool Modes software while actively discussing and planning the learning process. Students did not only exchange ideas with their peer group but also with the whole class in its entirety, within both informal and formal settings.

Discussion

It is a commonly accepted and discussed phenomenon (Kalyuga, Chandler & Sweller, 1998) that when students perform a new complex task, more cognitive resources are needed and a higher cognitive load is associated with it.

The fact that we found that students allocated more cognitive effort towards the task at the end of the learning sequence could suggest that the students became more and more experts in using the software and therefore the cognitive load reduced. This is in line with Van Merriënboer et al. (Van Merriënboer, Kirschner & Kester, 2003) who describe that learners at a certain level of expertise can perform routines without investing extra mental effort. Future design efforts should have the goal to speed up this process of turning complex processes related to functionality into automated schemata and thus allowing the learner to concentrate on the task and the subject matter content related to it. Cognitive load theorists distinguish between extraneous cognitive load and intrinsic cognitive load. It is the extraneous cognitive load that we can affect by developing an environment that reduces unnecessary working load.

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