ABSTRACT

Collaborative modelling tools can support rich activities in the classroom, including both small group work and plenary activities. They can also support the processing and analyses of material gained from observations outside the classroom. This is demonstrated with an application in the area of astronomy, namely for "lunar cartography". The implementation is based on the collaborative modelling platform Cool Modes. A first trial in school is described.

KEYWORDS

Astronomy, moon, images, measurement, calculation, modelling

1. INTRODUCTION

Computing technology for group learning can be more than just an application of computer mediated communication in that it can allow for jointly creating and manipulating “computational objects to think with” in collaborative environments [4]. Research into these types of systems has been orientated towards facilitating structured scientific argumentation in learning groups [1], another line of research aims at supporting modelling processes using more or less standardized operational representations such as Petri Nets or System Dynamics [6,8]. Our Cool Modes system [7] belongs to this second category. Its specialty is that it provides a variety of different modelling languages and comes with a general programming interface for defining and plugging in new languages. Following the metaphor of a flexible paper-like notepad, different modelling languages can be mixed in the same workspace, and they can always be combined with typed or hand-written annotations. This supports smooth transitions between informal and formally structured operational representations.

The prototypical usage scenario for Cool Modes is a classroom setting in which the tool can be used by students working in small groups, e.g. on tablet computers, as well as by the teacher when exposing and demonstrating ideas on an interactive whiteboard. Here, the general possibility of sharing workspaces flexibly between different participants is not only used to support co-constructive model building but also to enable the flow of information, e.g. in the transition from group work to plenary demonstration and discussion. Here the notion of “educational workflow” or “learning flow” comes into play. It has the following functional facets: (1) allowing for a smooth transition of intermediate or final results in a group learning setting between different phases and scales of group work; and (2) the consistency and “connectivity” of different software tools (also representation languages) used in the learning process; the inclusion of materials, e.g. from lab phases or field trips.
Beyond interoperability in a technical sense, the notion of connectivity has a conceptual dimension: Represenational tools used in one area should be re-used and extended into other more specialized areas. It is particularly this point which is illustrated in the following in the area of learning astronomy. Our focus is on using the results of observations as material for modelling and scientific inquiry.

2. LEARNING CHARACTERISTICS OF THE ASTRONOMY DOMAIN

Astronomy is an exciting and fascinating learning domain, either as part of physics or as subject of its own value. Sky observations go back to ancient times and are connected to some of the deepest questions of mankind. The field of astronomy has a broad range of phenomena and can be subject on different levels through many school years from discovering the moon up to deep sky objects. To understand astronomical theories mathematical (incl. geometrical!) and physical knowledge needs to be integrated. Many schools can already provide access to smaller telescopes for hands on experience and the access to more professional equipment can be provided through the internet. In the European project COLDEX [9], astronomy is one domain of scientific experience and learning for which we try to adapt more general software technologies. In the sequel, three examples based on different astronomical sub domains with different demands on the students pre-knowledge are described.

A concrete phenomenon to start with astronomical observations is the moon. It can easily be seen and photographed with a digital camera. A small telescope allows us to examine different details like craters, walls, mares. Especially the diameters and heights of craters can be measured and calculated already in K8. The mathematical theory of plane geometry and of similar triangles is needed. The students need to process the taken images of the moon and measure important data out of the resulting image [3].

Another interesting project is the observation of sun spots [11]. It has the practical advantage that the observations are possible during the usual school hours. Many observations still can be done with a small telescope at school. Using a remotely controlled mid-range telescope positioned at a good observation site enables much better possibilities (e.g. examination of Pluto, Jupiter moons). Planet orbits can be modelled, therefore the theory of trigonometrical functions and the basic differential calculus within three dimensional space can be taught. The most challenging astronomical task is the observation of deep sky objects such as far distant galaxies, double-star-systems, globular clusters, several kinds of Nebulas and Supernovae. Advanced observation and image processing methods deliver impressive images. On a higher educational level (K12) the distances of galaxies (e.g. Andromeda) can be treated. More advanced astronomical approaches like the parallactic method or distance calculating by observing variation periods of cepheids can be followed [2]. These kinds of experiments require long term observations with big remotely controlled telescopes, advanced image processing possibilities and tools to measure the brightness of stars.

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Many international educational projects are related to the astronomical domain (e.g. Hands-On-Universe Project by the University of California, Berkeley, USA [14] or the Telescope in Education project TIE [13] by the Mount Wilson Institute California, USA). Often live access to telescopes is possible, sometimes e.g. image processing tools are provided for work in school. The Eudoxos project e.g. provides live and queue-based scheduled access to telescopes situated in Greece exclusive for educational use, combined with online theoretical and practical guidelines and suggested lesson plans [3].

The example domain of our environment is the astronomy or “geography” of the moon, particularly the calculation of lunar heights such as crater walls. The students often learn in school very early about the moon orbit around the earth and the earth orbit around the sun, why the moon looks different between new moon and full moon, why and within what period the shadow is changing all the time and that it is (normally) not the shadow of the earth which can be seen. Although the moon is physical “nearly” unreachable for humans, it is the most easy astronomical object to observe and has a big influence on our life on earth (e.g. tides). Images can already be taken with normal cameras or retrieved from public repositories accessible through the internet. For the following classroom scenario, we assume that prior knowledge about the moon has been built, observations have been made and resulting images are available.

To be able to overcome the challenge of calculating lunar heights several supporting tools are needed. The students should be able to use images taken by themselves and improve their quality with a simple image processing tool. Further they need a tool to measure several distances out of the moon image and need a possibility to calculate a crater height with this input. In our environment the students have to model the calculation network to calculate the crater heights out of the measured input by themselves.

3. COOL MODES EXTENSIONS

Our contribution described in this paper is not about new types of astronomical observations but it introduces a toolset which facilitates the embedment of study and learning activities into a richer context. It supports “connectivity” with mathematical tools and general discussion and annotation mechanisms, all combined in the Cool Modes framework. Additionally, the tools use the MatchMaker [5] communication mechanism which makes them collaborative in that they support synchronous group work during the modelling process. For example students can discuss their results, compare results with results of other groups synchronously or they can model e.g. the calculation networks in groups.

Extension 1: Image processing

The moon images can be taken local at the school site or can be retrieved from a repository for astronomical observations. Within the COLDEX project we have access to several different sized telescopes in Europe and America (Chile). All the telescopes are remotely controllable and accessible through web services. Thus, there is no need to change the client software when choosing another telescope. Image series can be used to improve image quality by applying overlay and filtering techniques. To support this, we have developed a plug-in for our Cool Modes environment. Figure 1 shows the processing of an image series using this plug-in.

![Figure 1 – image processing in Cool Modes](imageProcessing.png)
Extension 2: Calculation trees

To measure distances and heights on the moon with our Cool modes tool, the students need to be able to model calculation trees. Mathematical background are the sentence of three and the theorems of similar triangles. To model those calculations the students only need the basic arithmetic rules. In our visual language we provide three different kinds of nodes:

- **input nodes** with values either provided “manually” or imported from other sources,
- **accumulator nodes** which compute either products or sums of an arbitrary number of input nodes.

Additionally, we defined two types of edges to connect the input nodes with accumulators. The first edge is used for “normal” input (+ or *), the other for inverse input (- or /, respectively). Each “accumulator” (or result) node can itself act as a new input node so that complex calculations can be constructed. Figure 2 shows the model for the calculation of an average grade.

The idea to use calculation trees to visualize mathematical operations is quite old, e.g. the WATGRAF editor helps students from primary school level on to solve word problems by creating calculation trees [10,12]. Here, complicated formulae correspond to quite large and not easy to read calculation trees, so that the advantage of visualization is diminished. To minimize the number of nodes needed for a calculation network within the developed Cool Modes plug-in we relaxed the restrictions for possible operations by providing “accumulator nodes” with multiple (n-ary) input. Inverse operations can also be fed into the accumulators by using inverse connection links. This leads to much more compact calculation trees. This visual representation can be used in a way similar to a spreadsheet (re-use, value updates and changes), but additionally it allows for combinations with other visual elements in the 2D workspace of Cool Modes. In the astronomy domain, these are particularly so-called “image nodes” from which geometrical measurements can be taken and integrated into calculations.
Extension 3: Lunar cartography

The scenario in which the students should calculate lunar heights is implemented as a plugin for Cool Modes. This plugin provides a node that allows to measure the necessary distances the students need to calculate lunar heights. On the left side in figure 3 we see this node in action. One problem we encounter with this method of measuring is that the measured data for very small distances, like the shadow width of a crater wall, is relatively imprecise. To improve the measurement there is a zooming possibility integrated into the node. After zooming into the image as far as needed the students can take a measurement out of the image by button click. A new input node for a calculation tree is created, labelled, and the measured value is stored there. When clicking later on this input node the measured distance is shown within the image node as a red line. Re-measurements can be taken on demand, so the built calculation tree is easily reusable after built once. Other crater heights can be calculated only by making two re-measurements.

An example model of such a calculation is shown in Figure 3. Within this net, we can see the two parts of the graph that are needed to model the necessary calculations. The one is necessary to model the theorem of intersecting lines and the other is to model the sentence of three that is needed to transfer the measured distances from pixel to kilometers or miles.

4. EXPERIENCE FROM A FIRST IN-CLASSROOM TEST

The described tool has so far been tested in a lesson (90 minutes) with a group of ninth-graders, 12 boys and 12 girls, in a German high school (Gymnasium). The students had no preknowledge about astronomy and had not worked with Cool Modes before. Image 1 shows one group of students working on the calculation network needed to calculate the heights of the crater Eudoxos.
The lesson was structured as follows:
- introduction to the usage of Cool Modes
- group exercises with the calculation palette (1-3 students per group)
- problem specific introduction: geometrical background of moon crater height calculation
- group exercise: calculation of one or more crater heights from a given moon image.
  (1-3 students per group)

Figure 4 - Dynamic geometry model – three views with different crater heights / positions

Figure 2 shows a group work result (building the average out of a number of scores) of the first phase. The second group exercise, to calculate moon crater heights, needed a short theoretical introduction to develop the essential relationship between crater height H, crater shadow S, distance L to the terminator and moon radius R. This was enabled by a teacher-built dynamic geometry model which allowed to manipulate the crater height and position interactively on a whiteboard (see figure 4). The students could discover that the two triangles became nearly similar when the crater height was small enough (which is realistic). Because of time reasons the teacher assisted here, using the dynamic geometry model on their computers the students had been able to find the relationship by themselves. With this background they started working in groups (see figure 5). Nearly all groups managed to develop a model how to calculate a crater height and use this model to calculate the height of the crater Eudoxus (height: 3350m). Most of the results overestimated the height of Eudoxus within a +20% range. The difficulty appeared to be in the exact measurement of the distance between crater and terminator.

A questionnaire filled in by the students after the lesson confirmed our impression that the tool was considered both usable and useful by the students. More than 80% of students declared that they could handle the Cool Modes Environment at once. More than 75% of the students described the astronomical introduction as sufficient. More than 90% were able to calculate at least one moon crater height, some needed the help of other students therefore. The calculation of moon crater heights would be a bigger challenge when the students had to find out its theoretical essentials all by themselves using the dynamic geometry model.

Figure 5 - Group discussion about calculation strategy
5. COLLABORATIVE SCENARIOS

Several competitive or cooperative scenarios using the described environment are possible. An example for cooperative collaboration is the following: Within a school project “building a moon lexicon” one chapter could be about the biggest mares and highest or deepest craters. The student groups first have to decide which group is responsible for which part of the moon by loading a full moon image and drawing lines into it (this can be done within the Cool Modes environment). The groups have to decide from which minimum size they start to annotate. Two groups always work on one area. First they have to understand the simple mare measurement (sentence of three) and the slightly more complicated crater height calculation (more measurements and calculations needed, see figure 3). Then they have to decide which images they request from the telescope service and to determine on which date and time the images should (have) be(en) taken according to when the terminator is at the best position for working in their area. When the school owns a local telescope the images can be taken by the students themselves and loaded into the environment. The result of such a sub project could be a chapter in a moon lexicon with mare and crater data and a ranking of “highest craters and biggest mares of the moon”.

An example of a competitive scenario using the described environment could be the “moon measuring contest”: At the begin of the contest the students get access to the dynamic geometry model, to the telescope image repository and the names of the craters which are part of the contest. Within a predefined time limit they have understand the calculation principle and to measure the heights of the craters as exact as possible to them. Therefore they could e.g. use different images, process their images and build the averages out of their results. The effectiveness of such a group work will be related too how the students distribute the different parts of the work within their groups. This could be a focus on the following discussion.

When the students have several computers to work on within one group they can build the network to calculate the crater heights working synchronous in a shared workspace. After agreeing on the built calculation model is correct they could disconnect having all a copy of this model using it for working on different moon craters.

6. PERSPECTIVES

The field test reported in the previous section could not more than corroborate the general usability and effectiveness of the tool. The issue of “educational connectivity” requires larger studies involving different subjects and an integration of concrete hands-on experience with astronomy. Studies of this type will be conducted in the framework of the ongoing European research project COLDEX [9]. Here, we will also try to support another type of connectivity which is beyond the “tool level”: The exchange of interesting results in open-ended learning/problem domains in a large international community of learners. The idea is to start with local face-to-face activities and to stimulate the exchange of locally results on the network.

One main focus in future work will be testing the already given possibilities of cooperation in school. Student groups could share the same model through the network. Further on the possibility of discovering the important formula by the students themselves can be improved. Therefore the students should be able to examine the interactive moon model on their own. A three-dimensional model of the moon could be helpful.

Further on the environment can support learning within other subjects. The measuring of the size of forests or the distances between cities could support geography lessons about the schools environment by using images made by satellites or out of planes. The size of animals or relation of sizes of different components of a biological cell could be measured within a biology lesson.

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