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Designing for Constructionist Web-Based Knowledge Building

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Abstract. This paper describes the iterative design of a web-based collaborative workspace used in educational practice, called *WebReports*. The system's unique feature is that it allows participants to discuss mathematical and scientific concepts using programmed animated and interactive models of their ideas. Rather than focusing on the specific features of the collaboration tool, we analyze it as part of a constructionist activity system. We describe the context in which the system was developed and used and compare our approach to previous research in the field. Further, we then present two scenarios which demonstrate the system in action. Following that, we attempt to map our cases to an activity theory framework. We highlight several issues in the process of the systems' development, where the contradictions between the WebReports system and other elements in the activity system shaped its design, and comment on several issues which go beyond the activity theory framework.

Keywords: Iterative design; Design experiment; Web-based collaboration; Constructionism; Activity Theory;

INTRODUCTION: KNOWLEDGE BUILDING THROUGH CONSTRUCTION

WebLabs is a 3 year EU-funded educational research project oriented towards finding new ways of representing and expressing mathematical and scientific knowledge in communities of young learners[1]. Our work focuses on the iterative design of exploratory activities in domains such as numeric sequences, cardinality, probabilistic thinking, fundamental kinematics, and ecological systems. *WebLabs* utilizes two main media for its activities: *ToonTalk* (a programming environment) and *WebReports* (a web-based collaboration system).

One of the central aims of our work is to extend the idea of knowledge building. Building on the constructionist tradition (Papert & Harel, 1991; Hoyles & Noss, 1996) we combine software model construction activities with web-based collaborative knowledge building. By doing so we expand the range of communication forms learners have at their disposal. Participants can express their ideas as working models, and present these as representations of ideas and arguments in a discussion. Moreover, computational models also allow students to explore aspects of mathematics and science that were simply were not available to study in other representations. This possibility is especially powerful in a multi-cultural environment. When students lack a common spoken language, the availability of a common visual modelling language is an enabling factor for collaboration.

CSCL and knowledge building

A majority of the CSCL work focuses on sharing of knowledge through language. This fact limits the potential of incorporating knowledge expressed through non-verbal artefacts in the process of knowledge building. Moreover, there is an obvious problem with this if one wants to achieve interaction and knowledge building across European countries where students do not share a common spoken language. The paradigmatic computer support for knowledge building is the CSILE system (Scardamelia & Bereiter, 1996). CSILE is basically a discussion board where students can post notes on different topics and then comment on each other's notes. The first interesting aspect regarding the system is its close connection to the so-called knowledge building community model of education and learning. This model builds on sociological descriptions of how knowledge is created and refined in scientific communities (Latour, 1986). It describes learning as a process of collective

[1] http://www.weblabs.eu.com

construction of knowledge. Topics are discussed, elaborated, and continuously refined by a community of learners (or perhaps knowledge constructors). The mutual influences of individuals' actions within a community compel people to adapt to each other. Adaptation is not only a positive contribution to efficient knowledge building, but it is also a necessary requirement for a knowledge building community to arise at all.

CSILE's unique innovation was its scaffolding feature: a built-in structure which guides students to focus on particular knowledge building aspects of their discussions. These scaffolds include prompts that encourage students to clarify problem statements, develop theories, state difficulties in understanding certain issues, tag new information on a topic, and summarize what they have learned. Scaffolds are designed to structure the students' discourse to replicate the work of a scientific research team or a research community. Two issues that the extensive research of the use of CSILE in classrooms settings have shown is the need to focus on community building and on the organisation of learning activities aiming to achieve productive use of the technology (e.g. Hewitt, 2001; Hakkarainen, Lipponen & Järväla, 2001). These two issues have also been addressed in the work discussed in this paper.

Another well-known system based on the knowledge building model is KIE (Knowledge Integration Environment) (Linn, 1995). Whereas CSILE is domain independent, KIE is targeted towards science education and the particular properties of that domain. It is based on an educational model called Knowledge Integration. This model highlights conceptual change, focusing on fostering students' conceptual understanding of scientific phenomena as the integration of facts, argumentation, and evidence. KIE provides software scaffolding for students to build arguments (the SenseMaker component) and to collect and categorize pieces of evidence such as facts and notes in a reflective manner (the Mildred component). With the SenseMaker (Bell, 2002) component, students collect evidence that they connect to claims to either support or contradict the argument they are making, hence, models for scientific argumentation are combined with personal understandings. The Mildred component (Bell & Davis, 2000) focuses on the content of the evidence and the claims that are used to build the scientific arguments. A particular aspect is the meta-cognitive support which encourages students to reflect upon the information they are collecting in their projects.

Designing for systems of activity

Over the last decade, activity theory has been gaining attention as an aid for Human Computer Interaction (Nardi, 1996), CSCL, and the learning sciences in particular (Kaptelinin & Cole, 1997; Jonassen, 2000; Fjuk & Ludvigsen, 2001; Barab et al, 2002). Activity theory spans from the idea, put forth by Vygotsky (1962; 1987), that human actions are directed at *objects* and mediated by *artefacts*. These objects define the focus of our attention, while the mediating instruments shape our perception. Hence, the three form a minimal unit of analysis in understanding cognition and learning. Objects and instruments are artefacts of *culture*, developed through its *history*. A comprehensive analysis of an activity system needs to take these factors into account as well. Cognition and learning are always situated in socio-cultural contexts. Vygotsky's method is dialectic and emphasizes how the different components of the system shape and change one another; it builds on a Marxist tradition and on the ideas of Hegel.

These ideas have been elaborated by Engeström (1987; 1999) and Cole & Engeström (1993), to include the *community* in which the *subject* (acting agent) operates, the *outcomes*, or aims, of the activity, the *rules* which define the subjects relations with the community and the *division of labour* between subjects. Activity theory is never content with describing these constituents in isolation, but focuses on the relations and tensions between them. Indeed, learning is often driven by the need to resolve contradictions within the system.

The novelty of our project lies in the integration of constructionist modelling activities with web-based knowledge building discussions, to support learners distributed across six European countries. For us, this means looking beyond the isolated constituents of educational design, and exploring the *activity system* as a whole. This system includes a combination of components such as technological development, design of novel learning activities, and organizational efforts to support teachers and students in different countries. In the analysis we use activity theory due to its emphasis on understanding human action as systems of activity in social, cultural, and historical settings. By viewing our design efforts not only as particular technological developments (in the form of new ways to support model building and programming or a new system for collaboration) but also as the creation of a system consisting of new educational activities and organisational changes, we intend to show how all these components interact to form the system in which the students are central actors. This allows us a rich understanding of the educational context the students are working in. Note however, that this does not mean that technical developments are not important contributions of our work, but rather that these developments must be understood in the context of the activities and the settings in which they are used. By introducing new technologies in an activity system, the system itself is changed which may be the source of contradictions between the different components in the system. Fjuk & Ludvigsen (2001) discuss how contradictions in the use of such instruments arise from their multiple purposes, and how the particular purpose within one activity system is shaped by the activities that accompany the use of the instruments from another. They demonstrate how contradictions between the different purposes of an instrument may afford contradictory activities. Their analysis suggests that in order to understand the design of educational technologies we need to analyse these within the context of the activity and settings where they being used. This viewpoint has been a guiding element in the analysis of the present paper. Our system was designed in tandem with the educational activities, and the analysis is done in their context. These activities do not occur in a void; we need to be aware of a number of components of the activity system:

- The structure of the community (or communities) of researchers, teachers and students.
- The division of labour between these three groups and within them.
- The social rules which govern interactions between students and between students and teachers / researchers.
- The web of connections which tie local groups and global communities.
- Other instruments in the environment, such as the programming environment and spreadsheets, traditional tools, such as whiteboards and paper, as well as specifically designed objects for collaborative group activities.
- The mathematical and scientific objects which are explored and the educational outcomes of these explorations.

COMPONENTS OF THE WEBLABS ACTIVITY SYSTEM

In the following section we discuss the four central components involved designing the WebLabs activity system: the activity sequences, the WebReports system, the ToonTalk programming environment, and the educational and school settings that are involved in our work.

Activity sequences

Our methodology of activity design has emerged through a process of iterative refinement. Our approach interleaves modelling tasks and discussions (face-to-face and on-line). The former builds intuitions in the domain area, while the later forges these into formal argumentation. Our activities follow a common cycle: first a scientific phenomenon or research question is introduced via a group discussion and specific modelling tasks are derived from it. Students then work individually or in pairs, exploring the question at hand through modelling in ToonTalk. Once done, they use a specialized template to publish (on the web) a written report on their findings. The models they have developed are embedded in this report. These reports are then used as input for a group discussion, which concludes with the publication of a group report. When possible, this report will be reviewed by groups from other countries, working on the same topic, to initiate inter-group discussions.

The evolution of our methodology is in itself an interesting example of the mediating role of technology. At an early stage of the design, we realized that if we wanted to interleave on-line discussion with modelling, the WebReports system (described below) would have to support this practice. Among the required features were streamlined embedding of coded models in a textual report and templates which scaffold students' writing. Only after these features were available did we realize that they enabled us to create a new tool, and a new related practice, which we called *task templates*. These are report templates which include task instructions and questions. The novelty of this tool is that all the tools required for the task are embedded in the template. Students click on the tools they need, work their way through the modelling task, and eventually replace the question text in the template with their own observations.

The ToonTalk programming environment

We see software programming as playing a key role in individual and group learning. Children explore and test their conceptions of the phenomena through programming working models. Furthermore, by sharing programmed models, they communicate ideas in a concrete yet accurate form. We are programming with ToonTalk (Kahn, 1996; 1999; http://www.ToonTalk.com) a language used in the past with younger children to construct video games (Hoyles, Noss & Adamson, 2002). ToonTalk is a computer game, programming environment and programming language in one. In ToonTalk programs take the form of animated cartoon robots. Programming is done by training these robots: leading them through the task they are meant to perform. After training, programs are generalised by "erasing" superfluous detail from robots' "minds".

	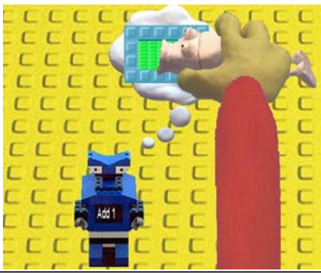	
Train the robot to take a number 1 from the toolbox and drop it on the input, to increment it.	Generalise the program by erasing the value of the input from the robots memory.	Give the robot its input box. The robot will continuously repeat the actions it has been taught.

Figure 1: Training a robot to count

Figure 1 shows three snapshots of what it means to write a program (train a robot) to count through the natural numbers. In fact, we only have to train the robot to “add 1” to a number and then *generalise* it to any number. The robot iterates the actions it was trained to do, for as long as the conditions it expects hold true.

The WebReports system

The individual and collaborative facets of learning are intertwined at all stages of our activities. The *WebReports* system (Figure 2) was set up to support both. The primary aim of this system is to allow learners to reflect on each others work by sharing working models of their ideas. The “atomic unit” of content in the system is a web report: a document containing formatted text, along with multi-media objects, Java applets, and most important – ToonTalk models. These models are embedded in the report as images, which link to the actual code object. When clicked, they automatically open in the reader’s ToonTalk environment – which could be in another classroom or another country. The reader can then manipulate the object, modify it, and even respond with a comment that may include her own model. Note that by including a revised or alternative model the students have several ways of building on each others knowledge. This last point is crucial: rather than simply discussing what each other *thinks*, students can share what they have *built* and *rebuild* each others’ attempts to model any given task or object.

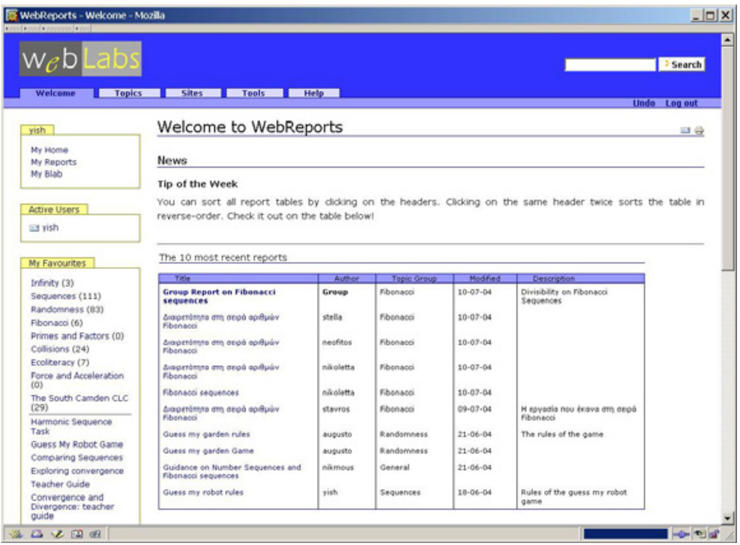

Figure 2: WebReports front page (http://www.weblabs.org.uk/wlplone/)

Since our primary focus was on the design of a system consisting of technology, activities, and organizational interventions we made a strategic decision to use (and enhance as needed) existing “vanilla flavour” open source systems. Our first prototype was built upon JSPWiki (http://www.jspwiki.org) whereas the current system is based on Plone (http://www.plone.org). This led us to focus on the functional and usability design, and minimize our implementation efforts.

Reports are edited using a visual editor. Apart from standard text formatting features, this editor allows users to easily embed media including Java applets of their models as well as objects embedding the ToonTalk code in their reports. Students can grab any program object in their ToonTalk environment, and copy it instantaneously into their report.

Reports are catalogued along three axes: topic, site and function. The first categorizes reports by their subject content (e.g. Infinity, Sequences, 1D collisions). The second lists the reports by the real-world team of the author (school, class or club). The function heading presents content by the way it was conceived to be used (programming component, personal report, tutorial etc.).

School settings

Working across six European countries means having to acknowledge more than language differences. We encounter a wide range of classroom cultures, practices and curricula, which all have to be accounted for in our design.

First, there are pragmatic issues: school times, session length, and firewalls. As mundane as they seem, these had an actual impact on the success of activities, primarily in cases where our design was in contradiction with existing rules.

One such example regards the use of web reports between sites. Our original plan was to have two groups work on a topic in parallel, publish concluding group reports, and then comment on each others' reports. In practice, synchronizing between sites proved impossible: even if one succeeded in scheduling an activity to start at the same time in both sites, the difference in session duration dictated by the local educational system meant that one group would be well into the next activity before the other published its concluding report. This realization led us to shift the emphasis to individual reports, as a means of collaborative knowledge building within groups.

Other issues are much more subtle, and relate to established classroom rules and norms regarding knowledge sharing. The first issue we encountered was that in most educational institutions, sharing knowledge goes against the grain of standard practice; often it is called cheating. This problem was easy to overcome. A much more difficult issue was getting students to publish work in rudimentary form. Our design builds on iterative refinement of knowledge through social interaction. This requires students to publish work that is not "correct" or finished, acknowledge public feedback, and republish. Again, this contradicts standard educational practice. In school, you submit a paper or exam when you think it is right, and the feedback you receive is judgmental.

To our surprise, the main hurdle in this case was put forth by teachers. In some cases, teachers found it hard to accept that students publish scientifically or mathematically incorrect texts for fear that this might be interpreted as a lack of proficiency on their side. Similar conflicts in norms and values will be further discussed below in order to illustrate how activity theory may support designers in understanding how aspects that might appear peripheral at initial stages of design later turn out to be the core challenges.

CASE STUDY EXAMPLES FROM SCIENCE EDUCATION ACTIVITIES WITH THE WEBLABS SYSTEM

Below we present two case study examples from our work. These two differ in several respects and have therefore been important to our understanding of the activity system as a whole. The first activity, called "Guess my robot", focuses on the intense collaboration and exchange between students in England and Bulgaria using small pieces of program code representing number sequences. The collaborative setting here works as a way for students to respond and act on each other's models on a day-to-day basis. The second activity, called "EcoModelling", focuses on students' illustration and presentation of their understanding of foodweb systems. Here, the collaborative setting has more of an indirect role but still significantly shapes the models that the students are building with less focus on day-to-day exchanges. Our analysis is aimed at identifying contradictions in the system. Contradictions are central to the development and changes of all activity systems (Engeström, 1987) and therefore useful as analytical tools (Fjuk & Ludvigsen, 2001).

A comprehensive analysis of the system would need to analyse more cases, comb them meticulously for contradictions, and resolve them by modifying the various aspects of the design. Such an undertaking would be far beyond the scope of this paper. We restrict ourselves to several of the more illustrative issues in each case.

Collaboration and "discussion" in the guess my robot activity

One of the activities we designed was the *Guess my Robot* (GmR) game. This game is a pivotal activity in our explorations of number sequences. Most students enter it with very little formal knowledge of sequences, and minimal ToonTalk experience. After GmR they move on to more advanced topics, such as the Fibonacci sequence, convergence and divergence, and cryptography. See Mor et al (2004) for a discussion of the mathematical-educational context of this game.

In this game, *proposers* train a robot to generate a numerical sequence, and publish its first few terms as a ToonTalk "box" in a WebReport, using a special purpose template. *Responders* build a robot that will produce this sequence, and thus show that they have worked out the underlying rule. As one girl said: "*So, like, the robot is my proof that I got it?*"

We first experimented with this activity in 2002/3 (Mor and Sendova, 2003). Our experience from this pilot informed both the design of the activity and of the WebReports system. In 2003/4 we expanded the experiment, with significantly greater response (Mor & Noss, 2004; Matos et al, 2004). This iteration included far more students and resulted in rich interactions.

We now analyze this case, using the activity theory framework as a guideline. We will focus on the role of the WebReports system, both as an instrument and as an arena for the activity. As mentioned above, the constituents of the system are not seen in isolation, but rather in relation to one another.

Outcome: The proposers' explicit outcome is the challenge, and the responders' the responses. Yet the game had additional implicit outcomes – the collaborative construction of knowledge about sequences. The WebReports system supports both, yet our activity design supported the former, but neglected the latter.

The explicit outcomes are embodied in models of number sequences, as ToonTalk boxes or robots. These can be seamlessly embedded in both challenge reports and response comments. The implicit outcomes are higher level abstractions and arguments about sequences. These are the more important outcomes from the educational viewpoint. They can be represented verbally, or as situated abstractions (Hoyles & Noss, 1996) by ToonTalk models. The system is flexible enough to support both. However, we failed to design the activity in a way that would promote them and make them explicit. To use Wenger's terminology (1998), we failed to foster a sense of joint enterprise (although, in some exceptional cases, this sense emerged from the students' initiatives).

Subject: We wish to focus on two relationships – that between subject and instruments, and that between subject and community.

On the issue of subject and tools, we find Ivan Illich's notion of conviviality a useful benchmark:

> Convivial tools are those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision… Tools foster conviviality to the extent to which they can be easily used, by anybody, as often or as seldom as desired, for the accomplishment of a purpose chosen by the user… They allow the user to express his meaning in action. (Illich, 1973)

Students developed a convivial attitude towards ToonTalk. They used it in ways we had not expected, to test conjectures and express mathematical arguments (Mor & Noss, 2004). However, while some students (and teachers) approached the WebReports with conviviality, bending it to their needs and expressing themselves freely with whatever means it provides, others did not. Students' inability to post challenges and responses in the prescribed way hampered collaboration and undermined the success of the activity. We see the causes in two other aspects of the activity system: insufficient attention to the rules imposed by local settings, and a lack of investment in the roles of facilitation and tutoring.

Object: The objects in focus were numeric sequences. Having those as the play-things in the game eliminated a contradiction often found in educational games, where the learning objects are exogenous to the activity (Squire, 2002).

Instruments: Access to the mathematical objects was mediated by the computational media: ToonTalk programming and Excel worksheets. Each one has its own affordances and constraints. While ToonTalk allows the students to construct surprisingly complex sequences, in many cases they preferred to use Excel as an analytic tool. We are not sure whether this preference originated with the students, or reflected the techno-cultural background of their teachers. ToonTalk's mediating role was facilitated by the WebReports streamlined embedding of models in report text.

Rules: Engeström (1987) identifies rules as mediating between the subject and the community. In our case, the main design challenge of GmR was setting the rules of the game. These rules cannot be designed in isolation – they need to acknowledge existing rules: those which regulate the social system of the classroom, and those which are constructed when students engage with remote peers. In fact, we had supplied the students with very little other than these rules. The activity is defined by the roles of proposer, responder and their protocol of interaction. Indeed, when these rules were observed, the activity followed a productive path. To our disappointment, this happened in less then half the cases (21 out 45 challenges and 15 of 33 responses). We read a very strong message here, which relates to the issue of division of labour, discussed below.

The design of GmR demonstrates a relation which is not usually observed: the mediating role of technology in the construction of rules and their relationship with subjects and objects. As an example, the communication afforded by a web-based system is very sparse compared to face-to-face interaction. This meant that for interactions to be successful, each utterance had to be rich in content. In part, this limitation was overcome by a virtue of the tools: the animated code fragments participants embedded in their texts served as avatars, or proxies, in delivering their ideas.

Division of labour: As mentioned above, the success of the activity was impeded by participants' failure to adhere to its rules. This failure was a result of a contradiction between the designed rules and those which participants had appropriated in common classroom practices. For instance, the emphasis on using code fragments as an element of communication was a completely novelty. In vernacular activity systems, the rules are transparent: they are maintained by consensus of the community, and new members learn them by *Legitimate Peripheral Participation* (Lave & Wenger, 1991). In designed activity systems – such as ours – the rules need to be consciously accepted by all members of the community at once. This creates the need for a *facilitator*, a person whose role is to monitor adherence to the rules. The facilitator regularly scanned the WebReports system for GmR contributions. When they were ill-formed, he would alert the authors to their mistakes, and guide them in correcting them. In other cases he would point participants to contributions which they would find interesting – an action that would have not been necessary had the authors of these contributions observed the rules.

Construction and presentation of eco-system models - EcoModelling

The EcoModelling activity sequence focused on allowing students (5th grade) to program their own models of food webs where an endangered species plays a central role. The students chose to focus on animals such as the giant panda, killer whales, and Siberian white tigers. The specification of the activity sequence include on as well as off the computer activities where students design, program and discuss their models. The activity sequence was presented to the students as having the goal of producing models that could be published as WebReports and that others could try out, discuss, and comment upon. The students also used the WebReports system to report on their progress in the form of diaries that include partial models of the phenomena they are working with.

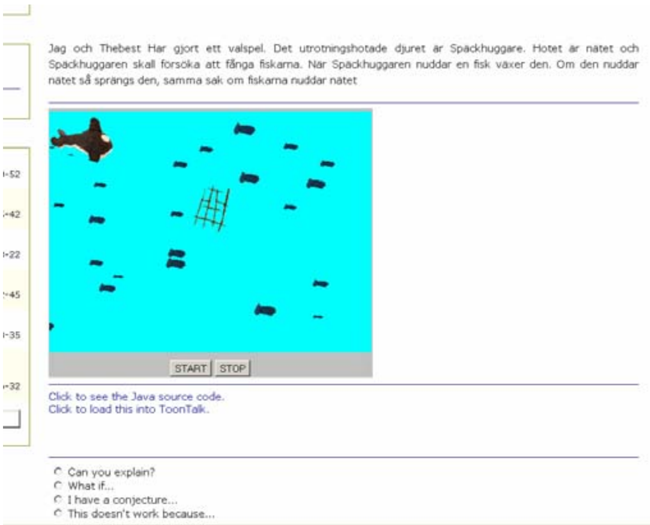

Figure 3: The Whale game by two students exploring the life conditions of killer whales

"I and The Best have made a whalegame. The endangered species is the killer whale. The threat is the net. The killer whale is supposed to try to catch the fish. When the killer whale touches a fish it grows. If it touches the net it blows up, same thing if the fish touch the net"

Goals of activity sequence: The practice that we aimed to stimulate in this activity sequence was twofold. First, to support students in constructing models of their ideas and knowledge about ecological systems. Second, for students to publish their models of these along with textual explanations and description. Receiving students would analyse the models and modify and comment upon these. The intended outcome would thereby be the *joint enterprise* of knowledge production of ecological phenomena. The two central mediating instruments in the production of models and knowledge are the programming tools used for building models and the WebReports system used for publishing models, and commenting and discussing these. These instruments serve dual purposes, both to shape the artefacts but also as mediators in the production of knowledge. Therefore, the students were engaged in two different roles throughout the activities, both as producers of models of ecological systems and as actors in the knowledge production community that we aimed to promote. Moreover, these two roles also occurred at two different levels of collaboration; both at the level of individuals and small groups producing models, and at the community level of knowledge building using the WebReports system.

Community, rules, and norms: The students' model construction and sharing were significantly influenced by the international setting. This was the case even though at the time of this study the WebReports system was just recently up and running so collaboration with students from the other countries only happened to a limited extend. Here, we would like to focus on two relationships that we identified as important sources of the contradiction in the activity system: the relations between subjects and the surrounding community and the relations between subjects and rules and norms. The relation between the students and the surrounding community influenced the models that the students produced as well as the final outcome of the activity in two ways. *First*, the nearby group participants actively contributed to the shaping of the models that the students produced through discussions and comments that occurred in local activities and through use of the WebReport system. Moreover, the local community also affected the students through their own social relationships. This indirectly shaped the final outcome in that students were highly engaged in the particular impressions their models would make on other local community members. The following fragment illustrates this issue. The four students are discussing the model that is being built by two of their friends (Sebastian and Jonathan) which aims to illustrate how a drought may influence the life conditions of rats and sunflowers. Throughout this episode the students have quite a critical tone towards their friends' model.

1. *Tobbe: Their huge sun flower in the middle of the screen is…*
2. *Jonna: Really, seriously speaking their sun flower is kind of …*
3. *Tobbe: The rat is not really that pretty either, do you think*
4. *Tina: Yeah, I thought that*

…

5. *Mimmi: Tina please let our buffalo be part of your game*

The most important thing that happens in this episode is not how the students exchange specific ideas about how to implement a phenomenon in their models, nor that they find specific suggestions relevant to their own work by studying what their friends are doing. Instead, what we find to be most important is that the students relate to and compare what they are doing to the work of their friends on a social level. Most of the influence of the collaboration does not concern the specific scientific content of the models they are building. It is rather about comparing and discussing each one's work in relation to everyone's overall progression. There is also extensive engagement in making sure that what they are building complies with the agreed upon overall norm for what they find the activity to be about. The two girls, Mimmi and Jonna, here come over to Tina and Tobbe to compare with their own work, to discuss the work of the Sebastian and Jonathan, and to try out the game that Tina and Tobbe have built. Hence, the role played by social influences for the modelling and programming of their system is mostly as a motivator for the progression of the activity as a whole, rather than having implications for specific considerations concerning knowledge about modelling of ecosystems.

Second, even though there was only limited immediate interaction between groups of students in different sites, the student's awareness of a larger community significantly influenced how they approached the production of ecosystem models. This relates to a contradiction that we identified in the different ways that the WebReports system may be used. In the EcoModelling activities the students mostly used WebReports as a tool for presentation of the models they had produced (see Figure 3) and much less as a tool for discussion and sharing of knowledge. This is a consequence of a contradiction between the goals that students developed in local group activities and goals at the community level. We see this as an example of a more general issue: the contradictions between motives and goals of the different actors (students and teachers) within educational activities. In our case the students' motives were partly to jointly discuss their ideas and thereby be co-producers of knowledge. However, we discovered that for the students, the goals of joint knowledge production often stood in contrast to the more immediate goal of actually designing and implementing their models in the programming tools with their peer students as the particular audience. These two goals are different in character and may therefore subsequently lead to a different set of sub-activities; the practical activity producing a working computational artefact vs. the activity of discussing the ideas that the artefact represents.

This contradiction has important consequences not only for the activities that students engage in but also for how we as designers of the system should approach the redesign of the different components and sub-activities. We see that a significant source of this contradiction is found in the underlying values of these two activities. The model construction activity has a clear resemblance to the established practice of schooling: performing a task by following instructions, which here involved building a model using this particular tool. On the contrary, knowledge building as a joint activity requires the fostering of a new set of social rules and norms for what the school activity should be about. To resolving these contradictions we would need to redesign the WebReports system and the activity sequence, and also to raise awareness of the unorthodox rules we wish to establish.

CONCLUDING DISCUSSION

We have reviewed two examples of educational activities designed and tested by the WebLabs project. While both cases were fairly successful, they both had their weaknesses. These activities differ in their knowledge domains, but also in how different aspects of of Knowledge Building and Constructionism took form. While GmR had various elements of the traditional knowledge building interactions, EcoModelling focussed more on model building and presentation. GmR used ToonTalk's low level programming facilities, whereas EcoModelling applied a component-based approach. In GmR WebReports served as a platform for discussion, in EcoModelling they functioned primarily as a display medium.

A key result concerns how the students perceived the expected outcome of the different activities in the two case studies. In the EcoModelling activity the students mainly focused on creating their models and presenting them to their peers, both over the web and in group presentations. Thereby, the web-based collaboration did not become an aspect of the actual model building activity. In the Guess my Robot activity on the other hand, the students focused on using the WebReports system to create challenges and respond to each others challenges, and the intense web-based collaboration became a prerequisite for successfully engaging in the game. Thereby, the web-based collaboration provided additional benefits to the outcome of the activity as a whole which local collaboration would not have afforded.

In both our case study examples we saw how the goal of the technologies that we have designed sometimes contrasted with existing classroom practices. The two technologies also introduced a few conflicting goals. Hence, design efforts to a large extent involved helping students and teachers to find ways to incorporate these technologies into their classroom practices. The changes and extensions we made to our systems were hence always accompanied by changes to the activity sequences, particularly as the kind of activity we aimed to foster involved a range of different social (schools, research practice, virtual places) and technological contexts (websystems, programming tools). It has been central to our design efforts to always take this range of aspects into account.

Three themes are common to all our other activity sequences and contributed to their success:

- An attempt to blend ideas of knowledge building, as a social practice, with constructionist modelling, as an individual (or small-group) endeavour.
- A view of designing, and analyzing, the epistemic activity system as a whole: the tasks, their aims, the tools (ToonTalk programming and WebReports collaboration), school settings and community practices.
- An iterative process, in which the activity system evolves through cycles of design, critical evaluation and refinement.

These themes are tightly bound together. An activity-theoretic view leads us to the understanding that the individual-cognitive and social factors of learning are intertwined. In our case, these are reflected as construction and discussion. It also suggests that the historical process of refinement (even at the micro-level of iterative design) is inevitable; Instruments, both concrete and social, are invented for a purpose – but their full potential is realized through use. In our case, testing the activity sequences with one version of the tools led to insights regarding the refinement of both the tools and the activity design.

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