Embedding e-mail in primary schools: developing a tool for reflection

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Abstract

Reflection is a core process of learning in groups. By sharing and comparing ideas through processes of articulation and listening, individual learners can come to a personal understanding of the subject matter. In this paper, e-mail is examined as a means for reflection in the context of learning in groups. In a development research in seven primary schools, an e-mail tool was developed that (1) scaffolds reflective thinking in groups, and (2) overcomes practical problems that hampered the implementation of e-mail in the past. Two prototypes of an e-mail tool were tested. Important design decisions are illustrated from their use in classrooms. We conclude that e-mail can afford personal reflection on task and learning processes when the following scaffolds are added to the regular e-mail program: (1) fixed partnership (2) fixed timing (3) freewriting, and (4) use of an e-mail form.

Keywords: computer-mediated communication; collaborative learning; elementary education

1. Introduction

An important benefit of learning in groups is that it can help learners reflect on their knowledge and skills. For this purpose, the learning task has to invite learners to initiate, execute, and evaluate their learning with others by articulating and listening to each others ideas. By both processes of articulation and listening, the individual learner's thinking is mirrored. When a learner articulates his ideas by talking or writing about them, group members can react on them from their own perspectives. As a result, the learner can think over what he said. Likewise, when a learner listens to ideas of others, a learner can compare these ideas with his own. Derived from the Latin "reflectere" meaning literally "to bend back", this process of mirroring can be called reflection or reflective thinking. In accordance with sociocultural theory, in this study reflection is viewed a learning process essentially occurring in dialogue (e.g. Kravtsova, 1999; Lin, Hmelo, Kinzer & Secules, 1999; Lompscher, 1999). From the same tradition, it is viewed that this dialogue can be with people present as well as with people's writings. After all, ideas can be articulated by talking as well as writing and can become a learner's mirror

even though they come from the past or from distant locations (cf. Bakhtin, 1986). We define reflection as 'talking and writing about multiple ideas in dialogue with other people or other people's writings'.

According to Wardekker (1998) reflective dialogue is the route to genuine concept learning, i.e. the construction of personal knowledge. Concepts are produced in reflective dialogue and carry social and ethical meaning: '[...] 'scientific' concepts are seen as the condensed and externalized products of reflection on (and often on problematic aspects of) a practice, arrived at in actual or virtual dialogue between members of the practice community, a dialogue in which, implicitly or explicitly, the direction of development of that practice (what it should become) is an issue' (p.146). Therefore, they have to be learned in reflective dialogue so that personal use within the social context becomes possible: 'Such concepts will have become a systematic part of the professional speech register of such a practice, and thus it is necessary to learn to use them in order to be able to participate in that practice. Because this use of concepts differs from everyday use of the same terms, learning them requires reflection' (p.146). In this view, reflection becomes the key process of critical participation in society. Such participation not only entails intellectual reflection on content, but also personal reflection and the construction of meaning on the what, how and why of actions. Because we wanted children to reach a personal understanding of scientific concepts and learning processes, this study aims at personal reflection.

Reflection not always comes about easily, however. Children can be so engaged in a task that they forget about the dialogue. In addition, children are sometimes unfamiliar with working in groups and don't know how to share their thinking with others. Group dynamics can also get in the way. This happens for instance when some children dominate a group discussion or when a conflict lowers the overall motivation to collaborate. As a result, reflections may remain implicit and unavailable for all group members to discuss. Support from teachers and peers may be needed to engage children in reflection (e.g. Brown & Renshaw, 2000; King, 1998; Mercer & Wegerif, 1999; Mooij, Terwel & Huber, 2000; Ploetzner, Dillenbourg, Preier & Traum, 1999; Wegerif, Mercer & Dawes, 1999). Besides support from teachers and fellow learners, tools can provide the necessary scaffolds. Lin et al. (1999) indicate that tools for reflection preferably satisfy the following criteria. First, they should display and make explicit reflective processes. Second, they should stimulate the learner to engage in reflective thinking by prompting to do so in different phases of task completion. Third, they should provide examples (modelling). And fourth, they should provide possibilities for discourse so that multiple perspectives become apparent.

E-mail can satisfy those criteria. First, e-mail can invite learners to write about their experiences and make them explicit for others. Second, when use of e-mail is properly embedded in the learning activity, it can prompt them to reflect at specific moments of task completion. In addition, groups can prompt each other to reflect by asking questions, providing answers or responses in the e-mails. Third, the e-mail program provides the format in which to communicate, thus structuring the communication. This can be further modelled by instruction. And finally, e-mail extends group work by adding an external

source to the discourse of the group. The external voice that enters the dialogue each time a message is received, can serve as a mirror for the group. Thus, e-mail seems well suited to support reflective dialogue within a group and between groups. Specific characteristics of e-mail communication support these expectations. First, although e-mail is called a fast medium, speed is limited to the actual sending and receiving. In contrast to chatting, it is essentially a delayed and asynchronous communication channel. This provides the time needed to reflect. Second, e-mail users are at different places. In this research for instance, children from different schools e-mailed each other weekly. Being at different locations might enrich and motivate the exchange. Children might get curious, or might explore their thoughts more freely because of the distance between them. Third, e-mail holds the middle between writing and talking (Baron, 1998). It can be used for formal communication as well as informal conversation. Therefore, we expect children to feel invited to share content-related thoughts as well as personal meanings attributed to them. Finally, writing e-mail messages means writing for a real audience. Using e-mail is expected to motivate children's writing because the message will actually be posted (cf. Cohen & Riel, 1989).

In this article we report on the development of an e-mail tool for reflection in biology lessons in the upper grades of primary schools. Two equally important issues are discussed: development and implementation of the tool. With regard to the first, we concern ourselves with developing an e-mail tool that fits the existing science curriculum and supports reflective thinking as the core process of learning in groups. This means finding ways to fit the tool in a domain-specific, collaborative learning task. It also means finding ways to invite children to articulate their thoughts during group work as well as in communication with their partner group. Implementation of the tool revolves around fitting the tool in existing school settings. Several studies report the risk of practical problems constraining the functional use of e-mail. For instance, schools lack computer facilities, teachers and children lack computer skills and teachers have trouble organizing structural e-mail contacts that don't die after the first exchange of hello's (Riel & Levin, 1990; Smith, Whiteley & Smith, 1999). We adopted a development research approach to work on both issues simultaneously. Seven primary schools were selected to enter the project. The e-mail tool was developed outside the schools and tested and evaluated inside the schools during repetitive periods of prototype testing. In what follows, we describe the development research that was conducted and the learning task in which the e-mail tool was embedded. Next, we present a first and second prototype of the e-mail tool and illustrate important design decisions with findings from the classrooms. We conclude with some reflections that may serve as directives for future research.

2. Development research in schools: the pragmatic and the artistic paradigm

When Fullan, Miles and Anderson (1988) started their project on the implementation of computers in schools, little knowledge was available. They had to capture good practice as it came along. In addition, they stated that regular schools and the schedules they work with were not used to developing materials from scratch. Therefore, Fullan et al. developed an adaptive approach in which the actual design process took place outside the schools and the formative evaluation inside the schools. More recent literature on

development research suggests to take the adaptive approach further into what is called the pragmatic paradigm. The pragmatic paradigm is characterized by the development of several prototypes that are tested and evaluated in practice to specify subsequent design requirements (Visscher-Voerman, Gustafson & Plomp, 1999). This approach can be complemented by the artistic paradigm. In this paradigm the development process is characterized as a process of continuous reflection-in-action, of creativity as part of formative analysis, and a wide range of research methods (ibid.). This approach describes the process of development as follows: 'As a designer moves through the design process, the situation "talks back" to the designer, causing the designer to reframe the problem, often relating the current situation to previous experiences. Obstacles or difficulties in the design situation often provide opportunities for new insights into the problem' (Richey & Nelson, 1996, p.1233). A combination of the pragmatic paradigm with the artistic paradigm was followed in the present study. The pragmatic paradigm dictated separate periods of prototype testing, and the artistic paradigm coloured the nature of the design and evaluation processes.

Central to a development process is the way formative evaluation is handled. As Nieveen (1999) points out, formative evaluation revolves around three quality aspects: validity, practicality, and effectiveness. 'Validity' measures if the tool does what it was designed for. 'Practicality' measures if the tool is usable for its users and can be implemented as expected. And 'effectiveness' measures if the tool has the effects that were expected. Although all measures are extremely interrelated, in three subsequent periods of prototype testing we paid focused attention to one or two of those aspects (see Table 1). In the first and second period of prototype testing we focused on validity and practicality. Main questions about the tool's validity were: Was the tool suitable for working in groups? Was the tool suitable for the exchange of perspectives in the group and with the e-mail partner? Main questions about the tool's practicality were: Did the tool fit different school settings? Could the tool be implemented in such a way that it fitted working in groups and invited reflective thinking within and across the group? In the third period (in which the same prototype as in the second period was used) we focused on effectiveness. Main questions about the tool's effectiveness were: What thoughts did the children articulate and compare and what reflective thinking processes emerged when reading, writing, and discussing e-mails?

[insert Table 1 about here]

Five schools - partly paid for their participation - entered the project with one class each (grade 3-4, aged 10-12). When asked about their motivation to take part in the study, the teachers' primary motive was their interest in (improved) computer use in their schools. But also learning in groups and curriculum revision in science education and the domain biology were mentioned. Schools had to have access to at least one computer connected to the Internet. The teacher had to be familiar with the basics of e-mail software. No further requirements were made. A low threshold for participation would allow schools from different backgrounds and with different experiences to join the project. As we considered all primary schools possible future users of the lessons under development, differences in computer facilities and learning skills were expected to enrich the design

process. Schools were from small urban and rural areas with children from low to high socioeconomical status. One school accommodated children with learning disabilities. Schools differed in computer facilities and experience with ICT use. One school had network access, relatively new computers, e-mail addresses reserved for the project, and some experience with using the computer in class. The other four schools had only a few (3 to 6) computers at their disposal and only some of them were connected to the Internet. They had very limited or no experience with using the computer. None of the seven schools had used e-mail in lessons before.

Several recommendations from Fullan et al. were followed to adapt optimally to local circumstances at schools and to support the emergence of good practices. These recommendations concern the following three issues: training, networking, and support. Computer training for teachers was provided on demand. All teachers received instruction on classroom management of computer use. Furthermore, training programs on e-mail and group work were available to teach the children basic skills. To create a network of collaboration between teachers, they met each other in a face to face meeting before they started lessons. In this meeting, lesson materials were introduced and discussed. Thereafter, teachers stayed in touch with each other through e-mail. There was e-mail contact between teachers and between teachers and researchers to support preparation and evaluation, and to share effective ideas. Experiences were published in a magazine for school practitioners. Also, a project website invited people from a wide audience to react. During the project a researcher was present in each class to provide support. Informal evaluations took place between the teacher and the researcher after each lesson to overcome immediate difficulties and share initial evaluations. We stimulated local initiatives and helped teachers realize them.

The teachers started working with a first prototype of six biology lessons. In these lessons a first prototype of the e-mail tool was embedded. Prototypes were developed outside the schools in a team of instructional designers and subject experts (biologist, teacher educator). This first prototype was presented to the teachers in a face-to-face meeting. After their comments were processed, the teachers started to work with the lessons for a period of six weeks (one lesson per week) in the second half of the school year. A broad range of data was gathered before, during, and after lessons were given. Teachers were interviewed about their opinions on learning in general, collaborative learning, and learning with the computer. Teachers wrote written evaluations after each lesson. Lesson procedures were recorded in observations and by audio-taping group work of some focus groups. Task products, e-mails and writings were collected. We interviewed all teachers and some children for detailed reports of personal experiences halfway and after lessons were finished. From these data we summarized general and more detailed impressions on four major issues: the learning by designing approach, computer use, collaboration, and domain (biology). This report was discussed by the team (including the teachers) to reach decisions for redesign on the validity, practicality and effectiveness of the lessons in general and the e-mail tool in particular. Lesson materials were improved and a second prototype was tested by the teachers at the beginning of the next school year. As a result of the second formative evaluation, final lessons were prepared for subsequent research in four other schools.

3. The task: designing biological communities

Recently, the Dutch national science curriculum - in casu biology - for primary schools reformulated core objectives towards a more constructivistic approach. They want children not only to learn biological facts, but to explore coherence, evaluate meaning, and express personal affiliations. Furthermore, they aim at a strong relation with children's prior experiences, and the development of (meta)cognitive skills (De Vaan & Marell, 1999). Learning by designing fits this new approach (e.g. Janssen, 1999; Kafai, 1995). In learning by designing children design new or existing objects, for instance in poster presentations, computer simulations or by actually building three-dimensional objects. Learning by designing fits the new curriculum approach for several reasons. First, it takes the prior knowledge of children as a starting point. Their input stems from factual knowledge as well as personal experiences. Second, children work with design principles that make them aware of strategies of knowledge building. With the help of a design heuristic the children can explore their own and each other's prior knowledge systematically. Third, the children have opportunities to collaborate with each other. There are many different aspects to a design process, for instance writing, gathering materials, drawing, collecting information elsewhere. Children can make task divisions and make use of each other's strengths. Also, they meet each other's prior knowledge and can reflect on it. Fourth, making a design has to do with 'making it sound' as well as 'making it beautiful'. The children make their designs in ways they like and are invited to express their personal preferences in drawings and written reports. This way, a learning by designing task provides for the context in which expression of ideas is fruitful.

In the domain of biology a design task consists of designing an existing biological system. According to biologists, biological systems can be considered optimal designs (Janssen, 1999). This means that every form aspect (e.g. a nose) has a well-defined function (to smell). In addition, form-function relationships of the smaller system (e.g. a fish) are related to form-function relationships of the larger system (e.g. the lake). You can learn about optimal biological designs by designing those form-function relationships. A serie of six lessons was prepared in which children had to design a biological community. The children worked in small groups of three or four children. The design heuristic consisted of four domain-specific questions (adapted from Janssen) with which form-function relationships could be explored: (1) Who am I? (2) What must I be able to do? (3) What do I have for that purpose myself? (4) What do I need for that purpose in my environment? By answering those questions they for instance design part of a fish: I am a goldfish, I must be able to breath, I need gills for that myself and I need fresh air in my environment. At the end of six lessons groups had designed a whole community (e.g. a lake) in a poster presentation with detailed drawings and written explanations (see Fig. 1).

[insert Fig. 1 about here]

Before and after working in groups, the children entered teacher-led classroom discussion. Furthermore, each lesson groups shortly presented their findings and their design up till then. During these moments unsolved questions were posed, amazing findings explored, and classroom procedures (e.g. working in groups) discussed. Working in groups, working systematically with the design heuristic, and teacher-led classroom discussions invited the children to think reflectively about their own knowledge and skills. This way, reflective thinking became an integral part of the design task. In this setting e-mail was build in as a source for further reflective thinking. We will now turn to this tool to see how it was made for this job.

4. First prototype of an e-mail tool: affording reflective thinking

Most primary schools still work with limited computer facilities and have limited time at their disposal. In addition, they work with young children of whom writing requires considerable effort because it is not yet an automated process (Baron, 1998). But not only the writing process produces severe limits. As most children can't type, producing an e-mail message is a time-consuming affair (Van der Meij & Boersma, 2002). Thus, from an implementation perspective e-mail use had to be scaffolded so that writing, typing and the actual sending and receiving became workable processes despite limited access to the Internet, limited time to spend and limited skills to work with. Furthermore, the use of e-mail had to afford reflective thinking. This means the use of e-mail had to be embedded explicitly within the task. And as working in groups of three or four children behind a computer was expected to limit the sharing of multiple perspectives because of lack of space and lack of opportunities for all group members to take part in the writing process, the process of making explicit your thoughts about the task had to be supported. Thus, the group use of an e-mail program had to be supported in such a way that all group members would get the opportunity to share and compare their task-related thinking. Therefore, we added scaffolds to the regular e-mail program. When we speak of 'e-mail tool' in what follows, we refer to the sum of the e-mail program plus the scaffolds added. The regular e-mail program was MS Outlook™. In the first prototype of the e-mail tool three scaffolds were added that are discussed below.

The first scaffold was 'fixed partnership'. We paired up each group with another group at another school doing the same lessons in the same weeks. As most schools used the school e-mail addresss for the project, groups were asked to start the subject of their e-mail with the group name of the group they were addressing. A fixed partnership constrained choice of addressee and structured the e-mail process by making clear who e-mailed to whom. This is viewed essential for building a cohesive and meaningful work relationship between groups (Riel, 1990; Riel & Levin, 1990). Also, by pairing up schools the teachers too had a fixed partner with whom they could exchange information crucial for a successful e-mail exchange between the children (e.g. when lessons were rescheduled). By e-mail or phone teachers shared ideas, organizational problems, and learning outcomes. The following e-mail between two teachers illustrates this:

> 'Dear Mike, How do you like lessons so far? I do like the content, but I have some difficulties with how we are working. The children, and me too, find it rather difficult to "learn by discovery". And this in combination with working in groups! The children say they "can't do anything". How is that in your class? And do you also use the WWW and books? Best wishes, Eric.

The second scaffold was 'fixed timing' which implied two things: a 'fixed exchange pattern' and 'fixed e-mail moments'. Groups sent and received one message a week, thus a minimum and maximum amount of messages was set. For instance school A sent and received on tuesday, and school B sent and received on thursday. The pattern thus realized is a zigzag pattern characterized by a structural message exchange in which groups receive timely feedback on their e-mails (Van der Meij & Boersma, 2002). Most important reason for adopting this exchange pattern was that it accomodates reflective thinking. In a more incidental exchange pattern, groups can't follow each other and the continuity of the dialogue is at risk. A more frequent exchange pattern isn't desirable, because reflective thinking asks for time to reflect on received information instead of just-in-tine information while working on the task. Other reasons for advocating a zigzag exchange pattern are practical. On the one hand, a more frequent exchange pattern is difficult to realize if schools don't have many computers connected to the Internet and if children can not type very fast. On the other hand, e-mail communication between groups suffers severely from an exchange that is too incidental. E-mail studies showed that if groups did not receive a regular reaction from their partner groups, motivation to send messages was rapidly lost (Van der Meij, 1999; Van der Meij, Van Graft & Boersma, 2001). The second way to fix timing were two 'fixed e-mail moments' in each lesson. Groups received an e-mail before they started working on their designs (first e-mail moment). They discussed the e-mail shortly and made notes or marked what they found important. They then started working on the design task. After working on their designs, they wrote an e-mail (second e-mail moment). As a result, the design task became embedded in two moments of reflective thinking through respectively reading an e-mail and writing an e-mail.

The third scaffold was use of an 'e-mail form'. The e-mail form was a paper format of an e-mail layout in a 'landscape' orientation. At the front the children could glue down the received e-mail and write an answer (see Fig.2a). The back side had space for making notes, and continuing the message. Also, the e-mail form gave tips to encourage the children to share reflective thoughts (see Fig. 2b). Teachers explained these tips in the first lesson and discussed them again in subsequent lessons when children needed support. The e-mail form was introduced for several reasons. Most computer workplaces at schools are small. Writing their e-mail in class provided the children with sufficient working space for all group members to participate. Furthermore, seated at their desks all materials (e-mail history, design products) were at their disposal. Moreover, by having them write the e-mail on paper first, the teacher could organize the actual sending by having fast typists do the typing or by spreading the typing process across spare moments of time in between other lessons. By separating typing from writing, the children could now concentrate on the latter.

[insert Fig. 2a and 2b about here]

We started working with this prototype in the classrooms expecting the scaffolds to afford reflection on task and learning processes. The fixed e-mail partner and fixed exchange pattern would help sustain a working relationship between groups. Fixed e-mail moments would embed the design task within moments of reading, writing, and discussing thus stimulating the comparison of ideas to reach a group conclusion on matters. And the e-mail form would focus the children's attention on the collaborative writing process instead of the technical act of typing and sending. We expected to find personal information and task-related reflections in stories on how the designs developed (cf. Van der Meij & Boersma, 2002). And we expected awareness of learning processes through reports on for example working with the design heuristic and working in groups. In short, we expected cognitive, affective, and metacognitive reflections on a wide range of topics during reading, writing and discussing e-mails, and in the e-mails themselves.

Evaluations of the group process and the e-mail products, interviews with teachers and children, and observations in the classrooms revealed the following findings on validity and practicality of the e-mail tool (see Table 2 for an overview). All schools had been able to use the set up although they worked from different settings. The fixed partnership led to structural contacts between teachers in which they shared e-mail schedules and experiences. Children reported having fun getting to know other children through e-mail. They said it was easy to communicate with unknown children now that they had a concrete task to talk about. All groups exchanged personal information, some groups even added photo's. Fixed e-mail moments structured e-mail procedures and classroom organization. And teachers reported that both moments occurred as natural moments before and after working on the task. Children were motivated to read as well as write e-mails. Off line writing on the e-mail form had the expected advantages for classroom organization. The e-mails were written shortly after working on the design task. Most of the e-mails were sent immediately, but some were sent later that day or the next day depending on the e-mail schedules the schools had agreed on. The form was used during all lessons at all schools, becoming the standard for writing an e-mail. Having to write off line first, did not make it artificial for the children. They were engaged in the process and experienced it as e-mail as became clear from the way they talked about it. In sum, the scaffolds helped create favorable conditions for reflective thinking through e-mail use.

But did groups subsequently succeed in reflective thinking while reading, writing, and discussing e-mails? Groups did write about the task. The following e-mail fragment illustrates how they use the design questions to report on what they found:

> "[...] We have just discovered what a fish must be able to do. The blackbord is full of things we found: he has to breath with his gills, steer with his tail, see with his eyes, feel with his nerves, eat with his mouth, and protect himself with his scales. Have you found other things? Did we find things you had not found? [...]"

Furthermore, they discussed received e-mails. During and after reading aloud a received e-mail, groups talked about meanings of words, recognized newly mentioned topics and discussed content. The following fragment of a group discussion illustrates how they explained knowledge displayed in the e-mail (authors' comment in italics):

> 1: Well, what do we have to do with the e-mail now? *The group finished reading the e-mail, Jessica asks what to do now.*
> 2: Now we have to discuss what is interesting. *Elsa states what they have to do next.*
> 3: They mention 'eat' two times. *Robby brings in something that needs explaining.*
> 4: Yes, why do you have 'eat' two times? *Elsa agrees on this subject to discuss.*
> 5: But look, this is strange. Here they have 'eat-beak' and here they have 'eat-waterplants'. So here they mean environment. That one doesn't belong here. They eat waterplants. *Elsa points to the places where 'eat' is mentioned and suggests that it is mentioned in relation to two different design questions.*
> 6: Seeing is eyes, eating is beak, breathing is gills, thinking is brains, eating is... *Robby thinks aloud by reading the e-mail again.*
> 7: Waterplants, but... *Elsa completes the sentence and opens up to a new thought or explanation.*
> 8: I think they eat waterplants. *Robby starts a more conclusive explanation.*
> 9: Yes, and that's in the environment. *Elsa completes Robby's conclusive explanation.*

What we see in the above fragment is a discussion about something that puzzled them in the received e-mail. The problem appeared to center around the design questions they worked with every lesson: 'what do I have for that purpose myself' (to eat, I have a mouth) and 'what do I need for that purpose in my environment' (to eat, I need waterplants). By discussing the "eat-problem" the children thus thought reflectively about the design questions. And through the "eat-problem" the children touched upon the topic of 'waterplants'. This had large consequences for their work on the design task that day: 'waterplants' became hot. They discussed it six separate times, and each time they worked out another detail. They discussed for example the relationship between waterplants and the sun, between bacteria and waterplants,and between waterplants and air. Thus, the received e-mail invoked reflective thinking about a part of their design.

So in a minority of cases, the e-mail tool afforded reflective thinking. Notwithstanding this positive finding, we also noted some important problems. First, communication was sometimes flawed by unclear connections between groups. In one school groups had been regrouped due to absentism of some children and this resulted in fewer groups than present at the other school. The communication between groups that had to be coupled anew was hampered. While this underlines the principle of fixed partnership, it also signals that it remains a vulnerable point due to sudden changes in schools that can not be foreseen. Second, the e-mail form was too complex. Only one of the sides was used for writing, either the front or the back side. And the tips at the back side provided too much

reading material. Also, gluing down the received e-mail took considerable time that subsequently wasn't available for discussion about the content. In addition, observations showed that in many groups the writing process was dominated by a few children. One or two children got hold of the e-mail form and then dominated the writing process. Working off line instead of behind a computer with limited space apparently didn't solve the problem of equal participation. Third, the e-mails written were rather short (with an average of 89 words) with only a limited number of reports on task (31%) and no reports on learning processes. In addition, the task-related reports consisted of isolated questions and answers on those questions and were no personal reflections on the task. The content was mainly social. Although social talk is essential for communication (e.g. Riel, 1990; Wegerif, 1998; Wenger, 1998) and the children reported having fun getting to know the other children, e-mail was meant to stimulate personal reflections. Teachers were aware of the fact that the groups were supposed to write reflective reports, but still encouraged the children to pose questions. They sometimes even reserved time for whole class discussion to prevent groups from asking the same questions thus detaching the e-mail exchange from the groups. As a result, a game-like posing of questions became central to the e-mail process. Although the questions posed were task-related, most of them were rhetorical. The groups had already found answers, and just wanted to know if the other group knew. Posing questions became a serious quiz game that put the e-mail partner to the test as is illustrated by the following e-mail fragments:

> "[...] We have a few questions, please answer them as soon as possible. Can goldfish smell under water? If they can, how do they do that? How long do goldfish live on average?[...]"

> "[...] Hello, here are the Blubbies speaking to the Eagles. We sent you some questions, but you haven't. So we hope they come soon. Were the questions difficult or not? [...]"

Besides teacher instruction, the quiz game might have been fed by the fact that children were working with a design heuristic of four questions. Thus, an important part of the task consisted of posing and answering questions. But no immediate relation with the special format of the design questions was found. All design questions were what-questions for instance, while the questions posed in e-mails were mostly 'how' and 'how many'-questions.
In one case the question-answer sequence caused a discussion, because the groups didn't agree on the answer. In all other cases, it caused a short and dysfunctional reflection. In the following e-mail fragment the teacher communicates his impression of the e-mail contents with the other teacher. He states that questions aren't answered and that the content of the e-mails lacks any logic:

> "[...] I think the e-mail process is not always going okay. My children have the impression they don't get answers to the questions they pose. I can't discover a straight line in the e-mails they receive. And the same goes for the e-mails my children write [...]"

Summarized, the e-mail tool we designed fitted different circumstances at schools, the children experienced e-mail as related to the task, but the tool only partly afforded reflective thinking. Furthermore, most of the reflections were intellectual rather than personal, dealing with meaning of words or task descriptions. An important influence on the children's writing had been teacher instruction. The tips provided on the e-mail form were explained and discussed in class, but failed to encourage reflection as groups paid no attention to them. Furthermore, not all individuals took part in the writing process, and reports written were short and general (for an overview of findings see Table 2). To stimulate individual writing and reflection, we decided to simplify the e-mail form and instead structure the writing task more heavily.

[insert Table 2 about here]

5. Second prototype of an e-mail tool: personal reflection for different audiences

The first prototype of the e-mail tool underwent two major adaptations. The e-mail form was adapted (see Fig.3). The revised e-mail form consisted of a front side only. We left out the tips that children had not used. Furthermore, we left out the space to glue down received messages. Instead, children kept written and received e-mails in a folder. This way, the entire e-mail history of sent and received e-mails was kept available in a group portfolio. The e-mail form now was a regular A4 in 'portrait' orientation instead of 'landscape'. We expected the revised e-mail form to function more easy, because it now provided only the necessary structure for writing an e-mail message and so it did (see table 3). The revised e-mail form was easy to use according to both teachers and children. The portfolio was successfully managed by one of the group members and appeared to be a good alternative for gluing down incoming messages. Thus, the revised e-mail form structured the actual typing and sending of messages as it did before, now leaving out unnecessary, time-consuming activities.

[insert Fig. 3 about here]

To stimulate personal reflection by all group members, we inserted an individual freewriting exercise before the group started writing an e-mail. Children thought about the lesson during three minutes of absolute silence in the classroom. Thereafter, they wrote down their thoughts associatively for five minutes (procedures adapted from Elbow, 1973). The children were asked not to pay attention to grammar and spelling and not to think too long about what to write. Instead, they were instructed not to take their pens off their papers and to keep writing associatively. After freewriting the children took their writings to their groups to compose an e-mail together. Through freewriting we structured not only the children's reflective thinking, but also teacher instruction. Now all teachers led their children into similar processes of reflective thinking.

The process of freewriting as we implemented it, cooresponds in several ways with findings from other studies. Research found that a combination of individual preparation and group work positively influences the amount of ideas discussed in a group. It also

results in more equal participation by group members (Brown & Renshaw, 2000; Dysthe, 1996; Van Boxtel, Van der Linden & Kanselaar, 1997). With freewriting children now wrote individual reports before entering the group. Furthermore, research found that a combination of writing and talking positively influences diversity of views and results in more explanation, consolidation, and internalisation of knowledge (Dysthe, 1996; Mason, 1998; Mason, 2001). By the freewriting exercise children could start to combine these two modes of expression in new ways, for instance by discussing freewritings before writing an e-mail. Thus, we expected freewriting to have a positive influence on individual expression, group discussion, and group writing. Children could now enter reflective dialogues with different audiences: themselves (individual writing), group members (group discussion and group writing), and with another group at another school (the e-mail exchange itself). These different audiences were expected to invite the emergence of multiple perspectives and subsequent reflective thinking.

Freewriting was used in five classrooms (second and third round). Two schools that worked with the first prototype participated with the same teachers, but with other children. Three new schools entered the project in the third period of prototype testing. Again a wide range of qualitative data was gathered, including interviews, observations, emails and writings. Freewriting was evaluated positively by both teachers and children. Teachers were sceptically in advance, especially about three minutes of silent thinking. But afterwards they stated that freewriting had structured and smoothened the writing process. Children were motivated to write down their thoughts. Writing an e-mail now took less time and produced richer stories. There were more personal reflections on a diversity of lesson-related subjects. After the sixth lesson Etiën wrote:

> "We had to present a poster about our subject. I liked doing that very much. I had written a text and I got help doing that. At the end I wrote everything down in small pieces and what everbody had to read aloud during the presentation. If you found something in the text that was wrong, you could rewrite it. We divided everything in small pieces. During the presentation one of us pointed at the poster and the other told about it. We did several animals, we chose the ditch with frogs. At the end we got remarks and questions. They asked for instance: why is there an owl in your design? This was a report about the presentation."

Individual writings were used as a source for group writing. With the individual preparations at their disposal, children had more to discuss. And so they did. They read each others writings (aloud and for themselves), cited and discussed them, and compared ideas. As a result, the e-mails became longer (with an average of 134 words instead of 89 words) and covered a wider range of subjects. Children wrote about the task (44%), for instance what they had done and what they had learned that lesson. But they also wrote about learning processes (18%), for instance how they had been working together, what classroom procedures had been followed, and what their feelings about the lessons and about e-mailing were. Thus, more personal reflections occurred. They were interwoven in social talk. The following fragment of Etiën's group e-mail illustrates this "new style" and simultaneously shows that a new quiz game didn't get the chance to emerge:

> "[...] We had to present our poster today. We divided tasks. One was pointing, the other told about it. We did this in turn. We all found it very difficult, but nice to do. Why do you ask something you already know? Of course frogs can't live in the desert, because it is too dry there. You ask what we are going to do in our holidays. Mark and Pascal are going to do nothing, Robby is going to Italy, and Susanne is planning to shop aaaaaaaaaa looooooooooot! [...]"

Freewriting did lead to more diverse input and more discussion, but did it also lead to more equal participation? Analyses of writings and e-mails revealed that it did. The content of most e-mails was composed from all individual writings present in the group. Groups often started with a simple cutting-and-pasting from one or two writings, but in a matter of weeks the composing process evolved into a complex cutting and pasting from all writings. They encircled important parts in each writing and copied these parts to the e-mail form. Sometimes they copied literal sentences, but lots of times sentences were slightly adapted. The children then summarized individual writings into a group opinion. For instance, Etiën wrote that he liked doing the presentation. But groupmate Robby wrote: "I liked doing the presentation, but I was nervous". And groupmate Patricia wrote: "I liked our presentation, but it was difficult". Together, these opinions were summarized in the e-mail as follows: "We all found it very difficult, but nice to do". This process of realizing a group opinion is also nicely illustrated by choice of personal pronouns. Etiën used 'I' when writing about himself, and 'you' when referring to a groupmate. In the e-mail however, the children mainly wrote about 'we' referring to the group as a whole. This is in line with research from Brown and Renshaw (2000) who found that children changed their perspectives when they switched between individual and group work: 'The small group processes that follow this individual work are designed to move students to an agreed representation (or set of representations) of the task. Here the speaking positions alternate between explaining or defending personal representations and moving towards a common view. There is a movement from "my ideas" and "your ideas" to "our ideas" ' (p.58).

Summarized, the revised e-mail form together with the freewriting exercise effectively dealt with the validity and practicality problems of the first prototype (see Table 3).

[insert Table 3 about here]

6. Conclusion

Earlier studies have explored what e-mail can bring to a learning situation. They have shown that it can promote writing and literacy skills and that it can stimulate personal and social communication (Cohen & Riel, 1989; McKeon, 1999; Michaels, 2001; Riel, 1985; Yost, 2000). Moreover, e-mail can promote the appropriation of writing styles (Van der Meij & Boersma, 2002). But studies also report that children have difficulties finding topics to write about (e.g. Michaels, 2001). Therefore, the use of e-mail should be

embedded in learning activities so that its use becomes necessary and satisfactory. In the present study, use of e-mail was embedded in science education, in particular in the domain of biology. Furthermore, e-mail use was embedded in group work to stimulate reflective thinking. Special attention was paid to implementation of the e-mail tool in local circumstances present at schools. The validity, practicality and effectiveness of an e-mail tool was examined in three rounds of prototype testing. Four scaffolds for use of a regular e-mail program were developed and evaluated: fixed partnership, fixed timing, freewriting, and an e-mail form. The scaffolds afforded reflective thinking in the groups as illustrated by the task-related and learning process-related reports the children produced, by their discussions of each other's writings and received e-mails, and by the reappearance of ideas from these discussions in their design tasks. Reflections were personal discussions on a wide range of topics. Thus, we conclude that through use of the e-mail tool children entered reflective dialogues with themselves, with group members and with their partner group.

Formal and informal interviews suggest that the combined pragmatic-artistic paradigm worked well for the teachers. Working with prototypes produced schedules in which periods of developing, using, and evaluating materials were alternated. The input of schools focused on using and evaluating prototypes. During periods op developing they could prepare and plan things, which in many cases meant rearranging lessons and teachers. Furthermore, the teachers were asked to do what they were good at and liked the most: being a teacher and evaluate from this perspective. In this process, both the teacher's pragmatic and artistic input was recognized and stimulated. They followed guidelines putting them to the test, but also initiated new procedures and improvised in unexplored ways. As a result, the project yielded new insights about computer use in the participating schools. They reported a change of attitude and new school policies. The combination of pragmatic and artistic guidelines had advances for the research team as well. By adopting an artistic approach we could be creative from a scientific perspective. But Visscher-Voerman et al. (1999) state that the artistic paradigm has a great disadvantage: 'On the one hand, depicting developers as artists does justice to the fact that they bring their own values, ideas, and judgment to the development process and that they use their creativity while shaping the solution. On the other hand, it tends to place these developers on a pedestal, which makes it hard to reveal the underlying structure of the development process' (p.23). The pragmatic approach revealed the structure needed. In short, combining the artistic selves with the pragmatic selves of both teachers and researchers provided the structured freedom necessary for development of an e-mail tool.

At the end of this study new questions about effectiveness of the e-mail tool become apparent. Questions are three-fold: (1) What is the exact nature of the reflection taking place? (2) Are these processes of reflection different for the modes (reading, writing, talking) in which the group reflected? (3) How did reflective thinking add to learning biology? Related to the first matter, several studies describe frameworks in which lower and higher levels of reflection are distinguished (e.g. Hawkes & Romiszowski, 2001; Kember, Jones, Loke, McKay, Sinclair, Tse et al., 1999; Rodgers, 2002). An important distinction made is between reflections that describe and reflections that explain. Within the definition of reflection used here, it is important to find out how the distinction

between descriptions and explanations relates to processes of articulation and comparison of ideas within and between groups of children. For instance, does description lead to comparison or is giving an explanation more inviting to react? Second, we let children reflect by reading, writing and talking. Each of these activities relates to specific actions, such as reading aloud a received e-mail, constructing sentences aloud, or debating an issue. In addition, motivations differ for each of them. Mason (1998) reports that children find talking more easy and attractive than writing although they value both. Thus, we need to examine the processes within different modes of interaction to find out to what extent they differ. Finally, we need to know if and how reflections contribute to the children's understanding of the subject matter. Vosniadou and Brewer (1992, 1994) showed how mental models of for example the earth can be described, and conceptual change can be measured. In our study, children designed biological communities in groups and were post-tested individually on a transfer task. Analysis of the mental models underlying both the group product and the individual test results, could show if conceptual change took place for all children. Subsequently, we could try to relate these changes to moments of reflection found in the data.

In a research on appropriation of ideas between groups in the same science classroom, Windschitl (2001) found that 'In contrast to the increasing homogenity of thought within groups, profoundly different approaches to problem solving evolved between groups. The diversity of approaches adopted by different groups was the key underlying condition for interactions between groups that were not possible as intra-group phenomena' (p.32). In this article, we have focused on reflective processes occurring "at one end of the line", i.e. within one group. But of course, we expect e-mail partners to influence each others thinking and they thank each other for that:

> Dear Missies, we have just held our presentation about the lake, how it would look like and what we thought about the last lesson. We think that the perfect lake should look like this:
> 1 It should be 2 meters and 4 meters in lenght
> 2 There have to be a lot of plants and stones, because the fish need to be able to hide.
> 3 There must be males and females in the lake.
> 4 He also needs enemies otherwise there will be to many goldfish, but not too many because then they will all be eaten.
> This was our last e-mail. Thank you for everything, it was great fun to work with you.
> The Goldeens

The e-mail exchange itself needs examination, because The Goldeens do not thank The Missies for nothing.

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Figures

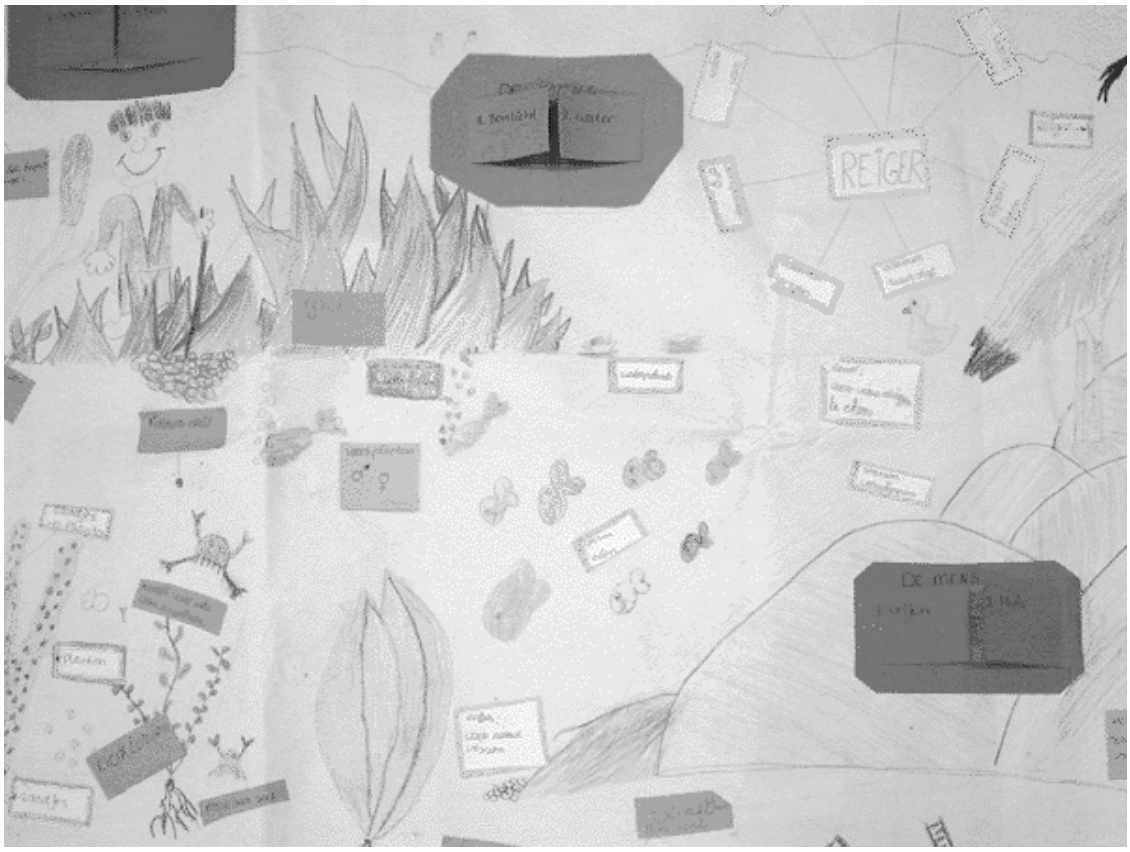

Fig.1 Example of a design: animals, plants and human beings in a lake (fragment).
The design shows drawings, small tags that describe form-function relationships, and 'windows' this particular group invented for their personal comments on the role of humans in this community.

E-MAIL FORM LESSON..	GROUP NAME:
Glue down the message of your partner group here.	**Write your answer to the partner group here.**
	To: Cc: kidNET research team Subject:
	Message: Not enough space? Take another piece of paper!

Fig. 2a Front side of e-mail form

TIPS FOR DESIGNERS	
You can help each other! Your partner group is also helping the professor to solve the design problem. They might think of solutions you have not yet payed attention to. Or do you know something they don't know?... **How can you help each other?** Tell them your problems! Also tell them your solutions! Ask questions! Answer their questions! Tell them what you think of their solutions! Think together!	Space for notes:

Fig. 2b Back side of e-mail form

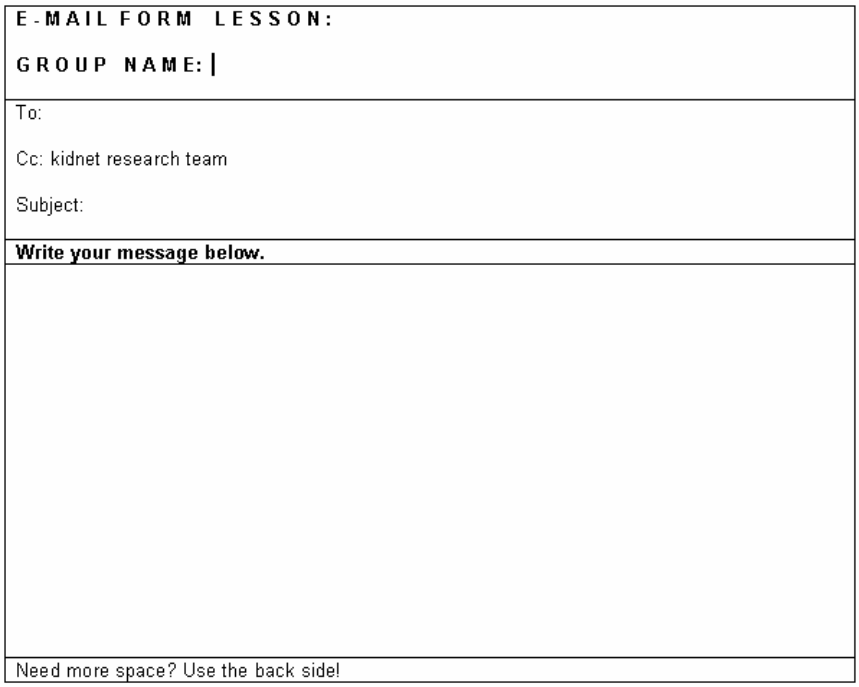

Fig. 3 Second prototype of the e-mail form

Tables

Table 1 Overview of the development process

Time	**Cases**	**Prototype of tool**	**Quality measure**
First round (May-July 2001)	2 schools	1: fixed e-mail partner, fixed e-mail moments, e-mail form	validity & practicality
Second round (Oct-Dec 2001)	2 schools (same as in first round)	2: fixed e-mail partner, fixed e-mail moments, e-mail form, freewriting	validity & practicality
Third round (Febr-May 2002)	3 schools (all new to the project)	2: fixed e-mail partner, fixed e-mail moments, e-mail form, freewriting	effectiveness

Table 2 Main findings of a first prototype (+ and – indicating positive and negative evaluation)

Supportive measure	**Validity**	**Practicality**
Fixed partnership	+ structural contact between teachers + motivated and personal contact between groups	+ usable across school settings – vulnerable due to sudden changes within schools
Fixed timing	+ embedded design task resulting in task-related reports + natural moments of reading and writing (motivated children) – no reports on learning processes	+ structural exchange patterns + structured classroom organization
E-mail form	– unequal participation – no use of tips – short and general written reports – short and superficial discussions – game of questioning and answering	+ easy format that became standard across all school settings + structured typing and sending – only one side used for writing – time-consuming to glue down received e-mail

Table 3 Main findings of a second prototype (+ indicating positive evaluation)

Supportive measure	**Validity**	**Practicality**	**Effectiveness**
freewriting	+ motivated writing + structured the writing process + more explicit multiple perspectives	+ workable procedures + less time needed for writing e-mails	+ writings about learning task and learning processes
e-mail form	+ more equal participation + reports on a wider range of subjects + more elaborate discussions	+ more easy format	+ reading and discussing each other's writings + complex cutting-and-pasting summarizing a group opinion