The Chemistry of Group Learning

Inquiry-based learning in small groups for undergraduates Science and Engineering at the University of Aveiro in Portugal

Carolina van Puffelen
University Twente
Faculty of Behavioural Sciences
Educational Science and Technology
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University of Twente
The Netherlands

UNIVERSIDADE
de AVEIRO

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Summary

This study explored the process of inquiry-based small group learning of undergraduates participating in a mini project Chemistry. The Department of Chemistry at the University of Aveiro, confronted with an increasing number of undergraduates shifted to a more student-centered approach to preserve the quality of learning and teaching in cooperation with the Department of Didactics and Educational Technology,. The course units Chemistry I and II for undergraduates were redesigned and concentrated on interactions between teachers, students and task. Learning environments were created to stimulate question posing and inquiry-based mini project were organized around actual Chemistry topics to interest students for the subject matter. Until now research mainly focused on the number and kind of questions asked during the mini project and the presentation. Little is known about the inquiry-based learning process and interactions of the group members while making progress in the project execution. One group of students was observed during all group sessions and the final presentation. Even though the study has its limitations because it concentrated on one case, findings strengthen the theory that group composition and interdependence of the group task play an important role in small group learning. In this case study verbal interactions and formulating questions proved to be indicators for successful completion of group work.

Keywords: inquiry-based learning; small group learning; interactions; questioning; higher order thinking.

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1. Introduction

In the 90's of the last century the Commission of European Communities strongly advised new learning approaches. She realized that a technology-based, international society needed creative, problem solving people working in teams. At the same time the National Science Boards of Australia, the United Kingdom of England, Wales and Scotland and the United States of America started reforming science education and recommended inquiry-based science teaching. This was the starting point for many innovations at all levels of education.

1.1 Relevance of the research

The Department of Chemistry at the University of Aveiro (UA) confronted with an increasing number of undergraduate students Science and Engineering at the beginning of this century, was concerned about the quality of learning. She investigated in cooperation with the Department of Didactics and Educational Technology of the UA inquiry-based teaching and learning approaches and started the project Questions in Chemistry (QQ). The QQ project innovated the curriculum of the course unit Chemistry I and II for undergraduates with conference lectures, question-asking sessions, seminar-tutorial sessions, practical laboratory sessions and mini projects. The concept behind these innovations was that by increasing the interaction between learner, teacher and the task the quality of the learning experience would improve (Teixeira-Dias, Pedrosa de Jesus, Neri de Souza and Watts 2004). Learners' questions can be a driving force to develop the quality of learning and the understanding in chemistry, therefore it is important to create a learning environment where question-posing is an integral part of interactions between teachers and learners (Pedrosa de Jesus, Teixeira-Dias & Watts, 2003). In the QQ project students' questions are collected, categorized and used for further studies (Neri de Souza, 2005, Pedrosa de Jesus, Almeida, Watts, 2004). The project so far concentrated mainly on interactions between learners and teachers, questions and final presentations of the mini projects.

1.2 Purpose of the research

Mini projects in the QQ project at the University of Aveiro have been audio recorded and analyzed in the academical years 2000/2001 and 2002/2003 but with emphasis on students' question posing. General outcomes of the accomplished mini projects so far are positive in terms of an increasing number of quality questions during sessions with the teacher and at the final presentations (Teixeira-Dias, Pedrosa de Jesus, Neri de Souza and Watts, 2004; Pedrosa de Jesus, Almeida & Watts, 2005). Students and teachers are motivated and presentations in general are of good quality. Mini projects have become an established part of the undergraduate course unit Chemistry II. Results from a meta-analysis about small group learning (Springer, Sanne & Donovan, 1997) suggest that small group learning in undergraduate courses has a positive effect on student's achievement in learning. Participation at the mini projects is on voluntary base but the possibility exists that in the near future mini projects will be a compulsory part of the curriculum for undergraduate students. A detailed study of the process of groups at work in the mini project can be of importance to gain more insight in the interactions between learners, the questions raised and the inquiry-based learning process.
The study explores interaction patterns in the inquiry-based learning process in small groups by means of audio/video recordings and complementary notes taken during group sessions. The findings can be a contribution to theory development about inquiry-based learning and may give indications when and how to assist the learner in the inquiry process.

1.3 Research approach

To be able to study the process and interactions during a mini project the choice has been made for a single-case study design. This design offers the opportunity to extensive observations of student behaviour during the mini project and the recorded observations can be analyzed in detail. Yin (2003) stresses the point that in collecting data from case studies it is important to use multiple sources of evidence. He identifies six sources of evidence:

- § Documents
- § Archival records
- § Interviews
- § Direct observation
- § Participant-observation
- § Physical artifacts

In this study documents, archival records, direct non-participant observation, interviews by e-mail and complementary notes will be used for data collection.
The main case question is:

What characterizes the activities in mini projects?

To find an answer to this general question the following sub questions have to be answered:

1. How are the members of the group interacting with each other?
2. How are the students undergoing and experiencing the different phases of the learning process? (indetermination-investigation-creative and concluding phase)
3. What kind of questions do the group members ask?

An observation form has been developed to combine reports from audio and video recordings, question analysis as well as notes taken during observation. The sources of data collection are analyzed on relations between questions, interactions and phases of the inquiry-based activities. Video and audio recordings make it possible to distill quantitative data from the data collection.

1.4 Overview of the thesis

This study is embedded in a theoretical framework, described in chapter two, that emphasizes the following points:

- Knowledge is constructed by the learner in interaction with his environment (2.1).
- Through the dynamic process of inquiry new knowledge can be build on previous knowledge (2.2).
- Learners need to develop metacognitive skills to reach higher order thinking levels (2.3).
- Working in small groups stimulates learning (2.4).

The chapter starts with the paradigm shift from behaviorism to constructivism in the second half of the 20th century and the innovative movements in education that followed upon it. Inquiry-based learning in all its aspects is extensively treated on since this is the base of innovations in science education. Small groups, cooperative learning and its applications in science education form the last part of this chapter.
Chapter Three, methodology, starts with an extensive description of the context for this case from al at university level to project level. Selection of the participants, the design of the case study, collection of data and methods of analysis are set out in detail in the last part of chapter Three.
Chapter Four reports about the five sessions the observed group organized and gives an account of the final presentation. The case report is a combination of summarized transcription taken from the audio recordings, complementary notes and e-mails of students. After every session report an overview of interactions and activities is given as well as the questions asked. The report concludes with the results from student assessment by means of an assessment form developed by the Department of Chemistry and answers on questions sent by email.
The findings of the case study are reported in chapter five and discussed in chapter six. Conclusions and suggestions for further applications in chapter seven conclude this paper.

2. Theoretical framework

In the first half of the 20th century three people in different countries, Lev Vygotsky in former Russia, Jean Piaget in Switzerland and John Dewey in the United States of America, developed theories of childhood development and education, that led to another perspective on knowledge: the constructivist view within cognitivism. The influence of this constructivist view on education is described in paragraph 2.1. Inquiry-based learning is not new but was emphasized within the constructivist approaches of learning and teaching. Paragraph 2.2 gives an overview of the main models of the inquiry process and the role of teacher and learner. The importance of higher-order thinking skills is explained in paragraph 2.3. Cooperative learning and working in small groups is described in paragraph 2.4 and studies about implementations of small group learning in science education conclude this chapter.

2.1 Constructivism and education

In the first half of the 20th century educational theories and research were dominated by behaviourism that saw learning as a process of forming connections between stimuli and responses. At the same time Vygotsky (1896-1934), Dewey (1859-1952) and Piaget (1896-1980) developed and researched their ideas about thinking, understanding and learning. In *Experience and Education* (1938) Dewey outlined a philosophy of experience and its relation to education. He mentions as two essential components of education the experience of the learner and critical inquiry. Piaget was since the 1920s researching the development of cognition with children. In his work *The origins of intelligence in children* published in English only just in 1952 he argued that a child constructs understanding through exploring and experiencing in his own environment. Vygotsky's ideas became known in the western world when his work was translated and published in the United States of America. In his *Mind in Society* (1978) he states that social interaction plays a fundamental part in the development of cognition.
In the 1950s cognitive views of learning became more dominant. Bruner inspired by Piaget developed a theoretical framework (1960) with the major theme that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. Changes in teaching and learning practices in the last 15 years originate from this shift of behaviourism towards a constructivist view within cognitivism. Dalgarno (2001) argues that the constructivist view is based on three principals:

§ Each person forms his own representation of knowledge, building on individual previous experiences (Dewey, 1938).
§ Learning occurs when the learner's exploration uncovers an inconsistency between their current knowledge representation and their experience (Vygotsky, 1978).
§ Learning occurs within a social context, and interaction between learners and their peers is a necessary part of the learning process (Vygotsky, 1978).

The focus in the learning process moved from teacher-dependent knowledge transmission to student-centred knowledge construction and brought new learning and teaching strategies. In the *situated cognition strategy* attention is given to activity and perception prior to conceptualization. Brown, Collins and Duguid (1989) argue that learning methods that are embedded in authentic situations are essential. The anchored instruction strategy of the Cognition and Technology Group at Vanderbilt (CGTV) used learning materials based on generative learning, anchored instruction, and cooperative learning. Learning is arranged by creating realistic, complex and ill-structured situations (CGTV, 1990, 1993). Jonassen (1999) introduced a model for designing Constructivist Learning Environments (CLE) in which learners need to explore; articulate what they know and have learned; speculate/hypothesize; manipulate the environment for constructing and testing their theories and eventually reflect on what they have done and learned.

2.2 Inquiry-based learning

Socrates believed that knowledge was vital and could only survive in a dynamic environment of human inquiry. Inquiry is a key factor of constructivism. Many constructivist approaches are rooted in Dewey's philosophy about learning as written down in Experience and Education (1938) and Logic: The Theory of Inquiry (1939). The present study was carried out on the assumption of the theory that knowledge is constructed by the learner in interaction with his environments

2.2.1 Dewey's Theory of Experience and Inquiry

Dewey believed that all genuine education comes through experience. In Experience and Education (1938) he emphasized the continuity of experience, arguing that every experience takes up something from those, which have gone before, and modifies in some way the quality of those, which come after. Every experience has two aspects: the experience is agreeable or not and its influence upon later experiences. Thus experience arises from continuity and interaction: each experience a person has will be of influence on later experiences and interaction comes from the influence the situation has on one's experience. Education, Dewey said must be based upon experience in order to accomplish its ends for the individual and for society. Dewey developed his Theory of Inquiry over a long period. In his book 'Logic: the Theory of Inquiry (1939) he defined inquiry as: '*the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole.'* (p.108). For Dewey learning is a product of a person's interaction with his environment. He saw inquiry as a developing activity and distinguished three stages:

- Indetermination. This situation turns into a problematic one after the problem is identified.
- By exploring the surroundings where the problem originated from any resolution - idea or hypotheses- to the problem must conform to prior knowledge and circumstances (facts).
- In the final stage the hypotheses must be tested and after justification the activity can be renewed.

He saw this process of inquiry as a continuous spiral and the only way to understand how we attain knowledge, common knowledge or knowledge arising from scientific inquiry. He argues that education must be a social process because the development of experiences comes about through interaction. Educators should see to it that students are confronted with problems that grow out of conditions being had in the present and within the range of their capacity and that the problem arouses an active quest for information and production of new ideas.

2.2.2 Kolb and experiential learning

Kolb describes in *Experiential Learning (1984*) the models of the experiential learning process as developed by Dewey, Piaget and Lewin. He found many similarities among the models and used them to develop his structural model of learning: the four- stage cycle. This cycle describes the process of experiential learning with four adaptive learning modes: concrete experience; reflective observation; abstract conceptualization and active experimentation. Kolb defines learning as 'the process whereby knowledge is created through the transformation of experience'. He argued that the learning cycle should be approached as a continuous spiral and learning can begin at any point. Problem finding, asking questions, seeking, answers and portrayal of knowledge describe the process of scientific inquiry. The process of problem solving is characterized by incorporation, incubation, insight, and verification.

2.2.3 Model of Progressive Inquiry

Based on the ideas postulated by Bereiter and Scardamalia (1996) about progressive problem solving and knowledge-building discourse the Research Group of the Department of Psychology at the University of Helsinki developed a model of progressive inquiry (Muukkonen, Hakkarainen and Lakkala, 1999) The Model of Progressive Inquiry (PI) emphasizes the importance of engaging students in a process of question- and explanation- driven inquiry of a socially shared character. Students engage in formulating questions, searching for answers and again formulate questions based on their previous knowledge while at the same time also questioning each other. This continues until they are ready to draw conclusions. The process is supported by a network learning environment and coached by the teacher. Dividing the task and assigning roles to students stimulate the process of collaborative learning. The elements of progressive inquiry as described by Muukkonen, Hakkarainen and Lakkala (1999) are:

- Creating context to anchor the chosen issue to conceptual principles of the domain of knowledge or to complex real-world problems.
- Engage in question-driven inquiry. Conceptual problems arising from students 'own attempts to understand and explain have a special cognitive value in the process of inquiry.
- Generating one's own working theories. This guides students to systematically use their background knowledge in understanding new phenomena.
- Critical evaluation of knowledge advancement. Evaluation helps the learning community to direct and regulate joint cognitive efforts toward new understanding.
- Searching new scientific information. The search aims at facilitating transition from reference to problem-centred knowledge.
- Engagement in deepening inquiry. Generating more specific questions, searching repeatedly for new information and in the end being able to answer the initial main question.
- Constructing new working theories

Important similarities of the above-described models are that they are based on the philosophy that knowledge is constructed and inquiry is a dynamic progressive process based on interaction.
In this case study the following phases in the inquiry process will be used for indicating the learning process:

- Indeterminate phase when the learner experiences uncertainty in a situation where prior knowledge or understanding is not sufficient to solve the problem.
- Investigation/exploration phase when the learner is intrigued and curiosity drives him to investigate by asking questions, making observations, interpretations, and generating assumptions.
- Creative phase in which the learner develops new understanding through data collection, interpretation and reflection
- Concluding phase where new concepts are discussed in interaction with other learners and teachers and applied in new contexts.

2.2.4 The role of teacher and learner in inquiry-based learning

The teacher is no longer a transmitter of knowledge but changes into coach and facilitator, monitoring the process of the learner (Jonassen, 1999). To be able to take up that role teachers need guidance, support and training (Choi & Hanmafin, 1995). When innovations in the curriculum are introduced and teachers are not involved or informed well enough they can delay or obstruct the process. Studies of teachers' practices suggest that, when change is voluntarily engaged in and undertaken by teachers, rather then imposed on them by others, teachers are changing their practices all the time (Richardson, 1994).
In progressive inquiry learning the teacher sets up the general frame of investigation whereupon students engage themselves in a process of question generation (Muukkonen, Hakkarainen, & Lakkala, 1999). The teacher facilitates, explains and externalizes the intuitive conceptions of the students. Instead of knowledge transmission the teacher now participates in knowledge building of the student.
In a study investigating the effectiveness of a collaborative learning network, undergraduates in educational sciences participated in a course undertaken collaboratively by two universities (de Jong, Veldhuis-Diermanse & Lutgens, 2002). Results showed that teacher involvement was most needed in the deepening phase when students are studying literature and external resources. Teacher involvement should include articulating prior knowledge and students' theories relating to the interests of the student and the questions they pose. An important role was the coaching of students in weekly meetings. Meloth and Deering (1999) argue that in collaborative learning the teacher can influence student cognition in three areas: direct instruction prior to group discussions; monitoring of the group and teachers' belief regarding cognitive benefits of collaborative learning.
Not only coaching and stimulating are important teacher activities, good domain knowledge is required as well. Simons (1993) argues that teachers in a constructivist-learning environment should teach the learners how to learn and how to organize.

In inquiry-based learning *the learner* is active in constructing his own knowledge building on prior knowledge in collaboration with other learners. To comply this he will need structure and support either by the teacher or by computer-supported cognitive tools. Van Joolingen (1999) argues that the learner needs discovery skills like hypothesis generation, experimental design and data analysis and regulative skills like planning and monitoring. This type of learning can be difficult and should be supported by cognitive tools. In problem-based learning learners develop their expertise on the area under study by working with cases and problems representing real life situations. They are organized in groups and guided in the various phases of the learning process (Lakkala, Ilomäki, Veermans & Paavola, 2003). Students sometimes take up the role of tutor when working in small groups with peers. In the process of progressive inquiry learners have to take on an active attitude and make use of self-directed strategies. They need to systematically generate their own research questions; construct their own working theories; evaluate; assess; search new information and engage in progressive generations of questions. They need complex thinking skills, also referred to as higher order thinking skills to complete their quest.

2.3 Higher order thinking

The role of educators nowadays should be helping students to become better learners by acquiring and developing skills necessary to handle data, develop new knowledge and to solve problems. Students in general but especially in higher education have to analyze new information, combine it with prior knowledge and create new knowledge, in short thinking on a higher level. The qualities that most often emerge in the literature discussing higher order thinking are the capacity to be an autonomous thinker, to go beyond the information given, to adopt a critical stance, to evaluate, to have metacognitive awareness and problem solving capacities (McLoughlin & Luca, 2000). Literature about higher order thinking refers to the Taxonomy of Bloom (1956). This classification of thinking levels is after 50 years still common use. Bloom was leading a group of educational psychologists. They developed a system for categorizing the thinking levels required by specific questions, problems or exercises. They identified six categories in the cognitive domain as described in Table 2.1. The categories, since then named as Bloom's taxonomy are listed in increasing order of complexity. In knowledge construction all categories are involved but the last three categories are considered to take place on higher-order thinking level

Table 2. 1*: Bloom's taxonomy*

Category	**Description**
Knowledge	Recall of prior knowledge
Comprehension	This involves the lowest level of understanding
Application	Application of ideas, principles, methods and theories to concrete situations
Analysis	This involves breaking down a concept or object in meaningful elements
Synthesis	This involves developing an innovative pattern or structure from elements
Evaluation	Qualitative/quantitative judgments about the value of ideas, methods, and solutions

Many research studies investigated higher order cognitive processes. Findings indicate that interactions with peers in small group learning support students' engagement in higher order thinking skills (King, 1998).

2.3.1 Higher-order thinking skills

Literature is very extended and diverse on the subject of higher-order thinking skills. Agreement can be found on the following skills:

In the *analysis* category learners are able to:
- see patterns
- organizing parts into one pattern
- recognize hidden meanings
- identify components

In the *synthesis* category learners are able to:
- use old ideas to create new ones
- generalize from given facts
- relate knowledge from several areas
- predict, draw conclusions

In the *evaluation* category learners can:
- compare and discriminate between ideas
- assess value of theories, presentations
- make choices based on reasoned argument
- verify value of evidence
- recognize subjectivity

Metacognitive skills and questioning are important in the inquiry process but not necessarily limited to the levels of analysis, synthesis and evaluation. Questions can be categorized into high and low levels and metacognitive skills remain in the lower categories until they are developed into higher levels.

2.3.2 Activities stimulating higher-order thinking

With the entrance of constructivist approaches to learning researchers concentrated on learning strategies: what do learners know, what happens in the learning process and which contexts are stimulating learning. Researchers investigated learning strategies that stimulate and support higher order thinking skills (Scardamalia, 1989; Brown, Collins & Duguid, 1989; Papert, 1993). Activities that students should engage in to foster these skills are:

- Cooperative or collaborative activities in which students explain their ideas and concepts to others.
- Activities that require more than rehearsal or routine actions.
- Open-ended activities with several 'right' answers.
- Activities that facilitate transfer of knowledge across contexts.
- Planning will help to maintain the attention of the learner to cognitive goals.
- Motivate students to organize their knowledge in alternative ways such as mapping, making graphs and timelines.
- Learning to learn through reflection, formulating questions and giving feedback.

By participating in these kinds of activities the student will get autonomy over his learning, can apply his knowledge in different problematic situations and will be able to create new ideas. However to participate with positive results the student needs to develop his metacognitive level.

2.3.3 Metacognition

Metacognition is awareness of your own thinking, being able to describe what you know and what you need to know (Costa, 1988). The term 'metacognition' was first used by Flavell (1976), he defined the concept as: "Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, for example, the learning relevant properties of information and data" (p.232). A recent definition more tailored to learning is: "An individual's ability to reflect on one's own thinking and to monitor one's own learning". To reflect on one's own thinking refers to the declarative knowledge of persons. They can describe their plan of action before they begin to solve a problem and sketch the strategy they will take (Costa, 1988). In order to reach the higher-order thinking level it is important to develop one's own metacognition. Metacognitive development is not related to age but to experiences of the learner in new problematic situations (Brown, 1980). Metacognition is integral to a learner's ability to "actively partner in his/her own learning and to facilitate transfer of learning to other contexts" (Bransford, Brown & Cocking, 1999). Metacognitive skills are: planning, monitoring, selecting, assessing and reflecting by self-questioning.

2.3.4 Questioning

'It is the question of the learner that will lead to learning; teacher questions serve other purposes.' (Dillon, 1990). The ongoing research work in the Department of Chemistry and the Department of Didactics and Educational Technology at the University of Aveiro aims at improving the quality of the learning experience focusing on stimulation of the formulation of questions by students.
When a person finds himself in an ill-structured, ambiguous situation which cannot be explained by prior knowledge and understanding he will experience a cognitive conflict. This stage indicated as indetermination (Dewey, 1938) or perplexity (Van der Meij, 1994) will generate questions, internal or out loud, thus making the first step into the process of inquiry. Dillon (1990) also noted that differences in questions asked could sometimes be seen in the type of cognitive process behind the question which is consistent with the findings of Dori and Herscovitz (1999) that questioning differentiates between learners with high and low academic levels therefore serving as an alternative evaluation method. When the task is completed students often don't take the time to reflect. Reflection is very useful and can be done by self-questioning on content and on the learning process. Strategies for assessing metacognitive skills are often in the form of questions. Students can be trained to formulate what, when, why and how questions while working on a task (Veenman, 2004). Fountain and Fusco (1991) report how they successfully used nine questions to practise metacognition over a wide range of ages. Table 2.2 shows the questions and the process that follows the question.

Table 2.2: *Questions to practice metacognitive skills*. (Source: Fountain & Fusco 1991)

What am I doing?	Create a focus (access short term memory)
Why am I doing it?	Establish a purpose.
Why is it important?	Create reasons for doing it.
How/where does it fit in	Recognise other contexts (access with what I already know? long term memory)
What questions do I have?	Discover what is still unknown.
Do I need a plan to learn this?	Choose a structure or method
How can I use this information in other areas?	Consider applications (connect into long term memory)
How effective have I been?	Evaluate progress
Do I need to do more?	Monitor need for further action

2.4 Cooperative learning

Extensive research in the past three decennia has demonstrated that cooperative learning can be a learning strategy that under certain conditions can lead to positive learning results. Johnson and Johnson (1987) define cooperative learning as: ' Students working in small groups while the teacher is ensuring that all members master the assigned material.' The four basic elements needed to make small-group learning cooperative are:

- Positive interdependence. This may be achieved by:
  - Goal interdependence (mutual goal)
  - Task interdependence by division of work.
  - Resource interdependence by dividing materials, resources and information.
  - Role interdependence. Students are assigned different roles.
  - Reward interdependence. Joint reward or assessment
- Face to face interaction. The interaction patterns and verbal interchange among group members affect the educational outcomes.
- Individual accountability. Every group member is responsible for learning the material. If each group member masters the material they can support and assist to one another.
- Interpersonal and small-group skills. Social skills for collaboration such as communicating, leadership, conflict managing, decision making and trust.

Slavin (1995) defines cooperative learning methods as students working together in four-member teams to master materials initially presented by the teacher.

Cohen (1994) on the other hand defines cooperative learning as students working together in a group small enough that everyone can participate on a collective task that has been clear assigned without direct and immediate supervision of the teacher. The three definitions agree on work and group size but differ on task and teacher role. Research groups from universities all over the world are studying different applications of cooperative learning methods. Slavin (1995) compared eleven major cooperative learning methods and found that the majority uses a form of group goals and individual accountability. Differences were found in task specialization and size of groups varying between two to ten members.

2.4.1 Learning outcomes of cooperative learning

Johnson and Johnson (1987) conducted an extensive research comparing cooperative learning with competitive or individualistic learning. They found that cooperative learning promotes reasoning strategies and critical thinking, higher levels of self-esteem and positive effects on motivation and interpersonal relations.

Slavin (1995) concluded on the base of extensive research review that group rewards based on individual learning of all group members play an important role in positive achievement outcomes. It was also found that by teaching students cooperation skills or effective learning strategies positive learning outcomes could be achieved.

Cohen (1994) did an inductive and conceptual review of research focussing on interaction-task relation. She brings three important factors under the attention that positively influence discourse patterns during group work:

- Group task. A task can be labeled as group task when it requires resources that no single individual in the group possesses and has to be solved with the input of other members.
- Training students for cooperation. Students require preparation and instruction for the level of interaction that is needed for the task.
- Teacher role. The teacher should adjust the amount of supervision to the group task at hand. If the task is an ill-structured problem where interaction between group members is important the teacher should decrease the amount of supervision.

She argues that cooperative learning is a legitimate method of instruction and instead of concentrating on ideological conflicts the focus of future research should be on above-mentioned factors.

2.5 Inquiry-based learning and science education

The Commission of the European Communities stated in a white paper (EU,1995) on education and training that European countries should concentrate on a new learning society with emphasis on scientific knowledge and information. At the same time National Science Boards of Australia, the UK and the USA started reforming science education and recommended inquiry-based science teaching. In the declaration on science and the use of scientific research (Unesco, 1999) published during the World Conference on Science in 1999 it was proclaimed that science education is a fundamental prerequisite for democracy and for ensuring sustainable development and the need to develop and expand science literacy in all cultures and all sectors of society as well as reasoning ability and skills.

Edwards, Leising and Parr (2001) argue that science taught in school is often too abstract, lacking sufficient real world connections and relevant context necessary for students to learn science concepts and principles adequately. Inquiry also refers to the activities of students to develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Scientific learning can be made more meaningful and motivating by integrating actual issues in society such as environmental and technological problems into the science curriculum (Dori & Herscovitz, 1999).

2.5.1 Implemented inquiry-based strategies in science educations

An extensive study on publications about science education (Edwards, Leising & Parr, 2001) concluded that learning environments supporting an inquiry-based approach show promising results for improving student achievement in science and have a positive influence on students' attitudes about science. Research findings point to laboratory settings as a successful learning environment for

inquiry learning in the domain of science. Learning in small groups collaborating and investigating in case studies supports scientific learning and stimulates higher-order thinking (Dory & Herscovitz, 1999; Hofstein, Navon Kipnis & Mamlok-Naaman, 2004;).
Kaartinen & Kumpulainen (2002) investigated in a study with undergraduate students the mechanisms of explanation building in small-group discourse. Results indicate that social science-learning situation provided the students with increasingly opportunities to elaborate their explanations, and reflecting practical, theoretical and applied understanding.

2.5.2 Inquiry-based learning in chemistry

In the ongoing debate between traditional and constructivist chemistry educators Harrison (2003) is pleading for a place of constructivism in the epistemology and philosophy of chemistry. He argues that most chemical models are negotiated by experts and teachers and are interaction products of prior knowledge and experiences, current problems and evidence. Chemistry students are not expected to experience all the factual information chemistry contains but should participate in tailor made experiments designed by teachers. Students should be taught **in** science not **about** science and should not be overloaded with content. Harrison further argues that the findings of an extensive chemistry research demonstrate the benefits of open-ended learning, the prevalence of alternative conceptions that inhibit learning and conceptual change strategies that encourage meaningful learning.
In an experiment (Hofstein, Navon, Kipnis and Mamlok-Naaman, 2004) with 12^{th} grade high-school chemistry students, participants were divided in an inquiry (experimental) group and a traditional laboratory-type group. Two aspects were investigated: the ability of high-school students to ask questions related to their own observations and findings in an inquiry experiment and the use of high-school chemistry in applying the ability to ask question after critically reading a scientific article. It was found that the inquiry group that gained experience in asking questions in the chemistry laboratory was able to ask more and better questions than the control group.
Springer, Stanne and Donovan (1997) carried out a meta-analysis of research on college students in science, mathematics engineering and technology (SMET) between 1980 and 1996. From the 39 studies that were analyzed results demonstrated a significant and positive effect of small-group learning on achievement, persistence, and attitudes among undergraduates in SMET. Five of the 39 studies were carried out with undergraduate chemistry students and all had an effect size larger than 0.50 on achievements. Significantly greater average effects sizes were apparent when achievement was measured by non-standardized exams of grades than when achievement was measured with standardized tests. A possible interpretation for this effect is that non-standardized exams and grades are less objective than standardized ones. Another interpretation is that the standardized tests used in these studies tend to assess content knowledge rather than higher-order thinking skills.

3. Methodology

General information about the Portuguese Higher Education system that differs with the Dutch system and specific information about the Department of Chemistry at the University of Aveiro outlines the context for this case study of undergraduate students. The design of the study and justification of the methods used and information about students in the observed group is explained in the next paragraphs. A description of the sources of information for data collection and the methods to analyse collected data concludes this chapter.

3.1 Context of the study

In contrary to the Dutch system the Portuguese system of Higher Education knows an entrance exam for first year students. This system will be explained in 3.1.1, information about courses for first year students Science and Engineering in 3.1.2 and chemistry as an undergraduate course unit specifically.

3.1.1 System of admission to Higher Education in Portugal

Public and Private Universities, Polytechnic Schools and Private Institutes form together the Higher Education system of Portugal. The entrance qualifications for higher education are subjected to a system of numerus clausus. Each course has a limited amount of places and admission is arranged by means of a contest on national level. The major part of students entering university does so by participating in the National Contest for Higher Education. This context is organized yearly by the Ministry of Science and Higher Education. Through this contest and with their candidate grade equal to or higher than 95 on a scale from 0 to 200 candidates line up and are placed (or not) in the course they have applied for. To be able to participate in the contest the candidate needs a certification from a secondary school with proof of the required grade for the course units needed at the university disciplines. If, after participation in the national contest, their grade is below minimum they have the opportunity to improve their grade in the second phase. Private Institutes organize their own contest but with the same rules as the national contest.

3.1.2 Undergraduate program at the University of Aveiro (UA)

The UA together with four Schools of Higher Education in Aveiro offers 58 undergraduate degree programmes: bachelor programmes of three years, 41 ‘licenciatura’ programmes with a duration of 4/5 years and 17 polytechnic degrees. At present there are about 11000 undergraduate students divided over the 17 academic departments. The undergraduate degree programmes at the UA attribute a pre-determined number of credits to each course unit (subject). This conditions the number of course units in which a student can be registered as well as the number of course units he leaves open for tests when continuing to the following year. The credit units (UC) weight the final average grade for each course unit. The European Credit Transfer System (ECTS) is attributed to each course unit facilitating the mobility of students between European institutions of higher education. The contact hours of the course units are distributed among theory classes (T), tutorials (TU) and practical classes (P). Students are required to be present in at least 75% of all practical classes.

3.1.3 The Chemistry course unit for undergraduates in Science and Engineering

To improve the quality of learning for an increasing number of undergraduates Science and Engineering the educational approach for the course unit Chemistry I and II was redesigned. The Department of Chemistry in cooperation with the Department of Didactics and Educational Technology explored ways to motivate students, to stimulate active learning and improve interaction between teacher and learner. The project ‘Questions In Chemistry’ (QQ) innovated the discipline design with conference lectures, question-asking sessions, seminar-tutorial sessions, practical laboratory sessions and mini projects. The idea was that by increasing interactions between learner, teacher and task the quality of the learning experience would improve. An indication for improvement of interaction would be an increase in number and level of student-generated questions. Students’ questions are collected electronically, and by means of question boxes in laboratories. Taxonomy of questions are developed distinguishing between confirmation questions and transformation questions.

To interest and motivate students in the Chemistry course the objectives are explained in a guide for students and a student's manual.

Mini projects

The Chemistry I course unit with 3,5 UC's in the first semester consists of two hours theory classes per week, one hour per week tutorial and two weekly hours of practical classes. Chemistry II in the second semester has the same amount of hours and UC's but offers the option of participation in mini projects. This voluntary participation, with a study load of 12 hours, offers students the possibility to earn extra three points on a scale of 0 to 20 for theory exams if the presentation of the project has been satisfactory. The objective of the mini project is to stimulate and motivate the average student, to upgrade his/her level on the subject matter and to arouse his/her curiosity for the contribution of chemistry in actual technology. In the academic year 2000/2001 a pilot study started. Students from one of the seminar-tutorial classes participated. Within a period of six weeks they had to develop a project on a self-chosen topic of chemistry.

The second year of the project other classes were invited to participate resulting in 13 projects with 42 students. Apart from informal group sessions each group had various sessions with the teacher. Students asking questions and the teacher not answering but giving guidance and advice how to find answers on their questions determined the content of these sessions. The mini projects have become part of the first year curriculum for the second semester with participation on voluntary base.

The academic year, 2004/2005 shows some changes in the mini projects. To avoid outdated and over exposed topics students will be given a topic when they sign up their self-chosen group of three. They get at random the title of a article from Scientific American. This article will be available in the university library where they can copy it and distribute among the group. Normally students from the theory stream with the teacher who initiates the mini projects can participate in the mini projects. This year the two theory streams have the same teacher so students from both streams (N=208) have the possibility to participate. Table 3.1 gives an overview of the disciplinary background of students who participated this year.

Table 3.1:*Participants in the Mini Projects 2005*

University course	*Female*	*Male*	*Number*
Biochemistry and Food Chemistry	**9**	**2**	**11**
Chemical Engineering	**3**	**2**	**5**
Chemistry	**2**	**2**	**4**
Environmental Engineering	**7**	**3**	**10**
Geology Engineering	**1**	**-**	**1**
Materials Engineering	**1**	**4**	**5**
Meteorology and Physics Oceanography	**1**	**3**	**4**
Physics and Chemistry Teacher Training	**-**	**1**	**1**
Physics	**1**	**3**	**4**
Physics Engineering	**-**	**3**	**3**
	25	**23**	**48**

3.2 Research Design

To be able to study the process and interactions during group work the choice has been made for a single-case study design. This design gives the opportunity to extensively observations of student behaviour during the mini project thus giving insight into the learning process and social interactions. Yin (2003) stresses the point that in collecting data from case studies it is important to use multiple sources of evidence. To comply with this methodological triangulation this study made use of documentation, direct non-participant observation and complementary notes for data collection. Students are sent questions by email and after the final presentation they can assess the project and their own participation by means of an assessment form developed by the Department of Chemistry. . An observation model has been developed to combine reports from audio and video recordings, question analysis as well as notes taken during observation. Recordings of group learning activities can be analysed on interactions, questions, and phases of the learning process. Video- and audio recording make it possible to collect quantitative data in counting frequency and duration.

3.3 Participants

Selection of participants

Chemistry is an obligatory course unit for undergraduate students from different courses. Because of the high number of students there are two theory streams, T1 and T2 with different timetables and two teachers taking care of the lectures. In the second semester of 2004/2005 T1 has 110 students and T2 has 98 students. Normally only T1 students can participate in the mini projects but this year both streams have the opportunity because one teacher is lecturing both groups. From a total of 208 students from 10 different courses (see table 3.1) 48 are participating, they subscribed for the mini project in self-chosen groups of three and received at random the title of an article from Scientific American. This article had to be looked up, copied and studied as theme for their group. In the first week of the study 8 out of 16 groups already had their first meeting with the teacher and from the remaining 8 groups four were observed for selection. A master student studying questioning behaviour of the T1 stream recommended the group of the students P., B. and L. because of the mixture of achievement level and their active question posing. The first session with the teacher was with a group from the T2 stream who had another article from Scientific American but related to their theme. After that session the teacher decided under time pressure to combine groups with the same theme so groups of six instead of three continued in the process.

Participants

The members of the observed group with an age range of 18-19 formed originally two groups from different theory streams. Their grades from the National Contest for Higher Education and semester grades can be seen in Table 3.2. The final mark is an average of the theoretical component obtained from 2 regular tests, 16+ tests, the assessment of the mini project and the practical component from laboratory work.

Table 3.2: *Chemistry grades of the observed group*

Student	***Course***	***Entrance Grade (out of 200)***	***Semester I Grade (out of 20)***	***Mini Project (Out of 3) added to the theory test***	***Final Grade (out of 20)***
P	**Physics**	**181**	**16**	**-**	**15**
B	**Physics**	**114**	**13**	**-**	**12**
L	**Physics**	**182**	**17**	**3**	**19**
V	**Chemistry**	**119**	**13**	**-**	**12**
Pr	**Biochemistry & Food Chemistry**	**116.8**	**12**	**1.1**	**13**
O	**Biochemistry & Food Chemistry**	**120.5**	**12**	**0.7**	**11**

3.4 Data collection and analysis methods

To find an answer on the case question '*How are the members of the group interacting with each other?'* all group sessions were recorded on video and audio. The recordings together with notes taken during the sessions were meant to answer the question '' *How are the students undergoing and experiencing the different phases of the learning process?* The phases used in this study are:

- § Indeterminate phase when the learner experiences uncertainty in a situation where prior knowledge or understanding is not sufficient to solve the problem.
- § Investigation/exploration phase when the learner is intrigued and curiosity drives him to investigate by asking questions, making observations, interpretations, and generating assumptions.
- § Creative phase in which the learner develops new understanding through interpretation of data collection and reflection.
- § Concluding phase where new concepts are discussed in interaction with other learners and teachers and applied in new contexts.

The questions asked by the group members were derived from the recordings and categorized. Details about collecting and analysing are described in the next four paragraphs.

3.4.1 Recording and sampling method

Video recordings were obtained using a video camcorder (Mini Digital Handy cam Sony) with USB and Fire Wire streaming for direct transmission to the computer. Videotape analysis was carried out with the software program Windows Movie Maker. Audio recordings were obtained using a Sony Walkman NetMD Mini Disk with USB streaming.

3.4.2 Category System of interactions and activities

The focus in this case study is on group behaviour during the fulfilling of one common task. The category system to differentiate and measuring interactions and activities is based on Bales' Interaction Process Analysis scheme (Bales, 1950) and Flanders system of Interactional Analysis (Flanders, 1970). The two main categories Verbal Interactions and Non Verbal activities are subdivided as follows:

- Verbal (task related)
  - Questioning
  - Explaining
  - Discussing
  - Answering
- Verbal (not task related)
  - Other study subjects
  - Private
- Non verbal (task related)
  - Writing
  - Listening
  - Reading

Non verbal (not task related)
- Writing
- Reading

During all observed sessions not task related activity occurred only twice; therefore this item was removed from the category system. The category listening was problematic to use because of the high degree of inference. Two others items were added because of frequent occurrence: Verbal Reading aloud and Non verbal Surfing the Internet / Reading Websites. Although the members do comment on what they see on the websites this activity is categorized as non-verbal because it had the same characteristics as reading or browsing through articles. The category writing was changed into making notes /sketching. The changed category system with the codes used in the observation form is as follows:

- Verbal (task related)

o Questioning (VQ)

This category was used for all questions asked by teacher and students during the session.

o Explaining (VE)

The category explaining is used when teacher or students share their knowledge content or not content-related with the group members, all or not supported by writing or demonstrating.

o Discussing (VD)

The concepts negotiating, bargaining, conversation and debating come under the categoryThis category

o Answering (VA)

Answering on questions asked by the teacher or group members or on hypothetical questions.

o Reading aloud (VRa)

This category is meant for the action of students reading aloud from notes, books, articles and websites with the purpose to inform others or for their own learning purpose.

- Non verbal (task related)

o Taking notes/Sketching (NVMn).

Notes from articles, books, conversation or from websites. Sketching or drawing while explaining or an alternative to note taking.

o Reading (NVR)

Students reading alone or with someone else articles or passages from books or notes.

o Reading Websites (NVRc)

Under this category comes the behaviour of students surfing the internet or one students surfs and others are looking. The category becomes Verbal when conversation takes place with the site as subject.

3.4.3 Observation form

Figure 3.1: *Example of the observation form (partially)*

Date:		Session:		Start:	End:
Location:		Videotape:		Audiotape:	
Time	**(Inter) Action**	**Activity**	**Content**	**Process**	**Complementary Notes**
2:05 2:55	L _ O (VE)	L explains molecule	Informing others about the theme	investigating	Pr. shows impatience, she wants to continue

Information about interaction, activities, questions and learning process with a time schedule for measuring duration are brought together in the observation form. The first three columns can be filled in when watching the videotape for the first time; the next three are for reviewing and analyzing.

Explanation of the example:

During 55 seconds L. is *interacting* (VE) with O when she *explains* the use of molecules as is written in the article of Scientific American (content of that moment). This action takes place when L. summarizes the subject of the article for the other members and O. remarks that she doesn't understand the molecule part of the theme. This phase of the learning *process* is the investigation phase. Another group member, Pr., seems not to like this interruption, she looks at her watch and wants to continue (complementary notes).

3.4.4 Complementary notes and e-mail correspondence

Complementary notes are taken during the session and are meant to complete the transcriptions of the video recordings in noting the atmosphere and attitudes of group members that are difficult to detect on a recording. Remarks to the observer and interactions before and after the session can also be noted.

After the second session, the third and the presentation questions by e-mail were sent to the members to have a better impression of their view on the process.

An assessment form made by the people responsible for the mini project was given to all participating students after their final test. Part of the assessment form where the students give their opinion about the theme, the poster preparation and the sessions is used in the Report section 4.3

3.4.5 Categories of questions

To categorize questions in higher/lower level thinking the system as used in the QQ-project (Teixeira-Dia, Pedrosa de Jesus, Neri de Souza and Watts, 2004) is maintained. It is a bipolar taxonomy distinguishing between confirmative and transformative questions.

Confirmative questions look for clarification of previous knowledge, differentiate between fact and speculation aim at solving specific difficulties and ask for illustration and/or definition. Examples:
" Who knows how to work with PowerPoint?" and "What do we know about DNA?"

Transformative questions aim at reorganize and/or restructure knowledge and comprehension of the learner suggesting he is familiar with the subject and able to hypothesize and deduct. Examples:
" What is the objective of computation with DNA?" and "There are similarities between the two themes?"

Transformation questions are considered to be of a higher value and quality than confirmation questions.

3.5 Procedure

All sessions, five in total, except the last one took place in the same theory room in the Pedagogical Complex where undergraduates have lectures and practical classes. Before the group entered the room the video camera was positioned on a tripod 1 meter above table level and the observer was already present. Recordings were downloaded into the computer, transcribed and time marked. After reviewing/listening several times the transcription was translated into English and further analyzed.

4. Case Study Report

In paragraph 4.1 a chronological record of five sessions and the final presentation account for the activities in the observed group.

4.1 Observations of the sessions

To get a good impression of the group process every session report starts with a short description of the context and the actual layout of the situation where the session takes place. Observation of the video recording, notes taken during the sessions and transcription of the audio recording form the base of the session reports. Group members were sent questions by email after the second and third session to get an impression of their view on the group process; their answers have been used in the session report 2 and 3.

4.1.1 Session 1 April 13th 2005

Context

The participating groups, sixteen in all, have been to the administration office and given at random a number corresponding with a number on the list of articles from The Scientific American. Before coming to this meeting they had to copy the article and if possible read it or leaf through it.

Table 4.1: *Chemistry II. Themes of the Mini Projects*

Themes	***References (Scientific American)***
Computing with DNA / Computing with Molecules	**August 1998, p54 / June 2000, p86**
Superconductors of High Temperatures	**September 1995, p162**
Conducting Polymers	**July 1995, p82**
Intelligent Gels	**May 1993, p82**
Catalysis on surfaces	**April 1993, p74**
Solid-acid catalyst	**April 1992, p82**
Zeolites	**July 1989, p82**
Aero Gels	**May 1988, p68**

During this first meeting with the teacher two groups with the same article will be briefed in a 30-minute session about the objective and the outline of the project. This pair of groups is the only one with different articles although both themes are of importance for the future of computer technology. The meeting takes place in a theory room in the Pedagogical Complex of the university.

The magazine articles

Group T1 (P, B and L) L.Adleman, the author of the article '*Computing with DNA*' (1998), is a mathematician and computer scientist. He created DNA strands that could perform the solution to a mathematical problem called the Hamiltonian Path Problem. Although there are still many technical problems to overcome he has demonstrated that computing with DNA molecules is possible and offers exciting possibilities for the future.

Group T2 (V, O and Pr) Mark Reed, Professor of Engineering and Applied Science and James Tour, a synthetic organic chemist, are collaborating on molecular electronic research. In the article '*Computing with Molecules*(2000)' they describe how organic molecules can perform simple logical operations. If the difficulties in making molecular circuits can be overcome then extremely tiny computers can be made in the future.

Situational Layout

As can be seen in Figure 4.1 the six group members are sitting opposite the teacher; the observer; a master student and a doctoral student all involved in the QQ-project. All students except the two male students have the article in front of them.

Figure 4.1: *Group T1 (B,P and L) and Group T2 (V,O and Pr) listening to the teacher structuring the project*

Content of the conversation summarized from the transcription
Professor Teixeira Dias (T) introduces Aurora and Carolina (C) both master students. He explains that C is interested in the process of group learning and asks permission to record on video and audio. He asks the students to write their e-mail address on the list and establishes that all students have managed to copy the article. He tells them that the article is a starting point for studying a subject:

T.: The articles are written for a large public, dealing with topics at the borders of chemistry. They are not easy to read but at this moment in the project it isn't necessary to understand everything besides the fact that the illustrations will be helpful as well. The importance of the mini project is the opportunity to work together on a chemistry topic, as you will do in your future work with colleagues. The article "Computing with DNA" is about a subject that may be realized in the near future and "Computing with molecules" is about something that maybe within twenty years or not at all.
P.: What is the main objective of the project?
T.: The objective is to elaborate a poster and discuss it. You have to present the topic on a poster and give a presentation for your fellow students, they will ask questions and then you present, explain and answer questions.
P.: To elaborate a conference on the subject?
T. : Yes but on the congresses there is a great variety of themes for a large public *(interrupted by his mobile going off)*. What I wanted to say is that since many years at all congresses in the world a large part of communication happens by means of posters and as others do that, in fact they present it at the end and in short…it is not only a poster but in many congresses they will do it that way. Usually they have a presentation in front of the poster. You have only two, three minutes to pay attention to the poster. In a congress it is the same; there is no opportunity. There are many participants; the posters are in a special place. Now in your case you have 10 minutes to present your topic, to explain what you have discovered. In these 10 minutes you have to do the presentation. All the members of the group have to be there, they can assist you. There has to be a poster, but you can use Power Point and other things as well. But this part of the project at this moment is not something to worry about.

T. suggests the students to read the article, if possible read it together and make notes of the concepts they don't understand and the questions they have. It will be useful for the two groups to meet again in a brainstorm session. The objective of a brainstorm session is to change ideas and to orientate on the topic. They can meet in this room because the session will be recorded and, ten to fifteen minutes will be enough. The students deliberate about the brainstorm session and mark date and time: April 27th at 15:00 in this room.
P. asks about the dimensions of the poster and the possibility to see some examples. T. is not sure about the size but that will be explained in the meeting halfway through May.
L. refers to dimensions like the posters in the laboratories and T. agrees on that.

End of Session 1. Duration 25 minutes

General impression taken from complementary notes
The students sit and listen attentively without interacting with each other. P. is the only one who makes an unquiet impression leaning backwards and forwards. The atmosphere is that of a class lecture with the teacher doing the talking and students listening and/or taking notes. When the teacher asks them to set a date for the brainstorm session the two girls, one from each group, take up the role of spokeswoman and the two of them settle day and time between their group members.

Interactions and activities
The two groups are from different theory streams and have not met before. There have not been many interactions observed apart from the interaction of the teacher with students asking questions and some interaction among and between groups in the last minute while setting a date for the next meeting. Of the total time the teacher used 76% for explaining and answering questions, students asking questions accounted for 12% and students organizing time and date for the next meeting spend the remaining 12%. Two students, L. and Pr. take notes frequently.

The learning process
This is the start of the project and students don't know what is expected of them. Apart from browsing through the illustrations they haven't read the article. The questions raised during this session are not content-related but about organization and objectives. This phase can be considered as the indeterminate phase of the inquiry process. After this meeting, when reading the article they can build on prior knowledge and raise questions about concepts.

Questions

Table 4.2: *Questions asked during session 1*

Person	*Confirmative*	*Transformative*
P.	What are the sizes of the poster?	What is the objective of the project?
L.	Which email address should be used?	

***4.1.2 Session 2** April 27th 2005*
Part A
Context
Originally this session was planned as a brainstorm session. In between the first and second meeting the teacher came to realize that the amount of 16 groups would give him too much time pressure and organizational problems and there was the risk of getting resembling posters for the same theme. He notified the students by e-mail on 28th of April:

"Following the suggestion of one of you I want to make a proposition consisting of presenting only one theme per poster and not two as initially was planned. One poster for six students, three of each two groups with the same theme. As far as I can see there should not be any inconvenience for you and it even has distinct advantages: (i) It is now possible to duplicate the maximum time for poster presentation from 10 to 20 minutes and at the same time reducing the total time for presentation and discussion to 25-30 minutes. (ii) The presentations can be realized on the same day (23th May). (iii) Assessment of the poster will be better because the number has been reduced by half and comparing poster look-alikes with the same themes can be avoided".

Before this mail was sent, the two groups with different themes were notified that the teacher would be present before the brainstorm session to clarify a change of program. The session will be described in two parts: part A with the teacher present and part B without the teacher.

Situational layout
The session takes place in the same theory room that was used before. The two groups are seated opposite each other and the teacher in between the groups.

Figure 4.2: *The teacher explains the combining of two groups*.

Content of the conversation summarized from the transcription of the audio recording
T. starts telling that it will take a few minutes to explain the change in program. A six minutes discussion follows between T. and P. about combining the two themes.

T.: As you know there are two groups from the two streams with the same topic. Only in your case the theme is slightly different, in fact more to the front. Your theme *Computing with molecules* strangely enough is more physical and your theme *Computing with DNA* is probably more science fiction. The theme *Computing with molecules* is still fiction but may be realized within ten years.

He continues telling them that the groups are joined into one, they make one poster and give one presentation.

T.: The only thing that will be different in your case is that two groups will have to share one poster. You are with six on two different subjects and the others have one poster, one topic.

He tells about the advantages of combining two groups with the same theme like he mentioned in his e-mail. He asks the opinion of the students and directs his question to L.

T.: What do you say? L.?
L.: I don't know. I have to know more about their theme first.

T. explains that the themes differ in realization in the future and continues:

T.: Now we can do something that is a compromise. We have only one poster and the conditions have to be the same as the others. You can put the subject together in one poster
P.: It is obvious that the two themes in detail are summing up that is to say almost. But when it comes to application in real life their theme is a lot different from ours. Ours is more applicable in hardware and on a level specific for information, theirs is more applicable at a social level I think.
T.: no, no .. no, no
P.: About DNA
T.: Take notice that on the specific levels of software and hardware it will be. .no, no this theme is closer on the level of realization.
P.: But I am talking about the application level, theirs is different in relation with ours.
T.: Yes, the themes are slightly different, slightly different but the problem is that a DNA molecule holds more information than other molecules.
P.: But about computing of DNA I have heard...
T.: Computing **with** DNA

P.: Computing with DNA. For example they want to make a card with these DNA molecules with personal information..
T.: No, it has to do strictly with computers

Now T. continues for another minute emphasizing the possibilities of DNA to store enormous, unimaginable quantities of information. He suggests them to divide the poster in two equal parts.

L.: But there are similarities?
T.: Exactly, there are similarities parts.
P.: But I have the feeling that computing with DNA has the capacity to stall more information and therefore it will be easier and faster than…
T.: No.no…no,no *(pause of 9 seconds)*
P.: The concepts..
T.: The concepts are different but take care; there are many things to be realized (…)

Once again T mentions the incredible storing capacity of molecules. He announces his departure and gives an advice about group meetings: "They only function when you feel at ease, it is very important you feel at ease, there should not be any problem between you." As far as the video- and audio recording and the presence of the observer he states: "The recorder is here but forget about it. Mrs. Carolina knows Portuguese but not that much that she can understand everything. She will only take notes and does not participate."

T. leaves the room. End of session 2A. Duration 14 minutes.

General impression taken from the complementary notes
They all seemed to be ready for the brainstorm session with everybody except B. having the article in front of them. When T. tells about combining the two groups L. and P. show signs of discontent. The others just sit and listen.

Interactions and activities
The discussion between T. and P. dominates the session with 40% of the total time. L. interrupts twice in the discussion and Pr. tries to speak to T. and P but no notice is taken of her.
There are no nonverbal activities and all the talking is task related. T. uses 85% of the total time for explaining and discussion, P. takes up 10% of the time for discussing and L. uses 1% for interrupting and answering a question.

Table 4.2: *Verbal interactions during Session 2A over a period of 14 minutes*

Person	*Kind of verbal activity*	*Percentage of time*
T.	**Explaining, discussing**	**85**
P.	**Discussing**	**10**
L.	**Questioning**	**1**

The learning process
The two groups are confronted with a new uncertain situation not only task related but also socially. From working in a self-chosen group they now have two cooperate with three other persons they haven't met before. The original task, reading and explaining the problems as exposed in the article and then presenting expands to another article with a related but different subject.

Questions

Table 4.3: *Questions asked during session 2A*

Person	*Confirmative*	*Transformative*
L.		**There are similarities between the themes?**

Part B

Context

The teacher has left the room and the students are left behind with the task to get more information about the theme of the other group and finding a way to combine the work for the presentation of the poster.

Content of the session summarized from the transcription

After a short silence L. proposes to explain their themes to each other and asks the other group to start. V. explains that their theme is about DNA chemistry and the manipulation of its elements. When she cannot get the names right Pr. helps her out looking for confirmation in the article and reading the first letters 'ATCG'. V. continues and tells how the author of the article, fascinated by DNA, started working in a laboratory to find out what could be done with the components of DNA.

V.: He managed to create DNA with his own hands
L.: *Create DNA?*

V+Pr+O nod at the same moment

O.: Yes, he created DNA with his own hands

V continues, following the line of the article, how the author got an idea about computing with DNA inspired by reading the books of Watson and Crick. L. asks what that idea was and V answers that it has to do with the capacity of DNA to replicate itself. L. asks how this replication works. There is a pause in which the three girls of group T2 look at each other. Pr answers about combinations of the elements and several options referring to the illustration in the article where the Watson-Crick pairing (replicating) is shown.

Figure 4.3: *Pr. explains with gesturing DNA reproduction*

Pr.: Yes, it goes from ATCG to CATG
V.: Yes, for example they suggest that if you have to fly by airplane from Atlanta to Detroit..
L.: By what?
V.: Non-stop flights (…) passages and trips with DNA that is repeating
O.: You have several nodes, I am here (drawing while explaining) there are the nodes and you have to go from here to there but cannot go back….

V. takes over and tries to explain, L asks another question but the recording was poor and it could not be transcribed. There follows a silence of almost 20 seconds after which L asks another question:

L.: and the computing? How did they do that with the two parts (gesturing with her hands referring to

the DNA strands) ?
O.: I think that.. (she stops and starts browsing in the article)

Figure 4.4: *Looking for an answer in the article*

There is a silence of almost 30 seconds while the three girls are leafing through the article. Taking turns they try to explain but all of them end up in unfinished sentences.

O.: We did not understand it very well
Pr.: Can you tell about your theme?

L. looks at P. and B. and then starts explaining. P interrupts but L. says to P: 'May I? 'and continues her explanation. She tells about the scientist Moore he predicted that the fabrication of transistors on chips would double every two years and his prediction turned out to be true. Circuits are made smaller every time but the limit has almost been reached and they are experimenting with organic molecules:

L.: (…) And that is why, as an alternative for this system they are using molecules to do this. In 2000 they started doing this. Molecules were glued taking the same form putting on a certain tension or different potential holding back or letting pass electrons.
P.: (…) I don't know if you have heard the story of the machine of (?) How it started was that the computers were little lamps first, going on or off, well the organic molecules will be functioning more or less this way, blocking or not that electrode. It is just that we will go from a lamp to transistors to get the minimum and to obtain computing with molecules.
L.: Yes (she looks at her papers, murmurs something)
P.: A very small thing (indicating the size with his fingers)
L.: It is that…they also managed to get things, that instead of letting pass or not, could retain something for some time(…) So disadvantages to begin with, is that they only managed to do this with enormous molecules and still cannot organize them. Here (points to her article) you have one circuit here, others here and the molecules go around on their own. They resolved it by gluing them didn't understand this part very well. It is a kind of self-assembly.

She explains, while gesturing and pointing to the illustrations of the article, the process of self-assembly of the organic molecules and:

L.: Ah, I forgot to tell that this thing (molecule) has two terminals but the transistor has three and a molecule enters on one side and leaves on the other so only two terminals are present. A transistor needs three. I don't know if they managed to solve that problem. I even informed at the university in Lissabon and asked some professors in chemistry and mathematics. They didn't know what kind of development there is in this area meaning it is something still very much under construction.
Pr.: So there is not much known about the subject?

L.: It exists in the USA but in Portugal, I don't know.

P. talks about computing in other countries and L mentions the scanning tunnelling microscope in connection with atoms. V. starts talking about what parts the two themes might have in common.

P.: About the work. What we can do is do the work more or less separate and later we arrange a kind of connection.
O.: Yes you have molecules and we have DNA so that is more or less the same.
P.: We have to realize a plan (?) so we have to make a division. We can talk about computing and similar parts…

No one reacts on P's suggestion. O. takes notes; L surfs on the computer and Pr. and V. are reading the article. After a pause L. remarks to O that they have to know more about each other's subject and to P. that the chemistry part of their article needs attention. B. suggests exchanging articles so they can Xerox it and read it. L. asks B. to exchange his article. Pr. suggests coming together after reading and discussing the theme again. The next three minutes are used up on setting a date and time. The coming week is Academic Week, a traditional event when classes are suspended and students organize cultural and sport activities. The next meeting is set two weeks from now on Wednesday the 11th of May, after the general poster meeting.

End of session 2B. Duration 19 minutes.

General impression taken from complementary notes
The group T2 with the three girls gives the impression of a real group. Twice they answered as one on a question asked by L. and when one stops the other takes over. When asked later, they admit that they've known each other from the start of the first semester and have met in between the first meeting and this meeting. They show much uncertainty about their subject, sticking to what is explained in the illustrations. The group T1 gives the impression of three separate individuals with L. taking the lead. L. confirms this in her e-mail: "We didn't meet in between as a group in a formal way. We talked several times about the mini project but always informal. This first phase we investigated individually." The beginning of this part of the meeting passed a bit laborious but at the end the atmosphere was more relaxed and open.

Interactions and activities
Group T2 interacted with each other deliberating about their theme and indicating paragraphs in the article. When explaining to the other group they direct to L. The members of group T1 don't interact with each other as a group apart from the remark of L. to P. about chemistry on which he doesn't react. B. directs himself to L when suggesting the exchange of articles. O. interacts with L. explaining that they don't understand their subject very well and twice with P in agreement on his suggestions. Table 4.4 and 4.5 give an overview of the activities of the group members. Of the total session time 88% was used for verbal interactions. The time that was needed for setting the date is not included.

Table 4.4: *Verbal interactions in session 2B over a period of 16:83 minutes*

Person	*Kind of verbal activity in order of frequency*	*Percentage of total time*
L.	Explaining, suggesting, questioning and organizing	35
P.	Explaining and suggesting	10
B.	Suggesting	1
Pr.	Explaining, reading aloud and questioning	17
V.	Explaining and suggesting	20
O.	Explaining	5

Table 4.5: *Non-verbal activities in session 2B in order of frequency*

Person	Kind of non verbal activity
L.	Reading, drawing and surfing the internet
P.	None
B.	None
Pr.	Reading
V.	Reading
O.	Reading, sketching and note taking

Learning process
P. and L. seem to understand the essence of their theme and can explain it clearly to the others. They need to investigate about the chemical parts and applications in the future. V, Pr and O admit that they don't understand the subject of computing with DNA very well. Their explaining depends heavenly on the illustrations in the articles.

Questions

Table 4.6: *Questions asked during the second part of session 2*

Person	Confirmative	Transformative
L.	He created DNA? What was the idea he had? Are you talking about the scheme in the article? There is not much known about the subject?	How did that go, the computing with DNA?
Pr.		

Opinions of the students sent by e-mail
1. About the content of the article from The Scientific American
Pr
We didn't understand the theme 'Computing with DNA" very well because we didn't have any other books to get information from. But we are trying to understand the text that was assigned to us.

V
As far as the mini project I as well as my fellow students didn't understand quite well what exactly is computing with DNA caused mainly by problems with the English language.

P.
I understand what the objectives are. Now as far as the details, there are a few that are difficult to understand caused by a language somewhat complicated and that I am not used to.

L.
I understood the general content of 'Computing with molecules'. I could have missed out on some details with respect to concrete examples but I think I understood the essential part. Now I have to look for more information about the subject (including recent developments).

2. About combining the two groups
V.
Concerning presenting the poster together the only problem I see are the different timetables caused by the fact that we are in different theory streams.

P.
As far as combining the two groups I don't think it will be easier or more difficult. We will have to work in a different way and we will distinguish different things from which all will profit.

L.
As far as the combination of the groups, I will have to analyze the subject of their theme.

I had the impression that they didn't get the essential of the article, they have fixated on details (maybe because of the English). I will be able to answer this question next week.

4.1.3 Session 3 *May 11th 2005*

Context

Before this session there has been a general meeting of 20 minutes in the amphitheatre with the teacher and all participants of the mini projects. The meeting had an informative character dealing with the size of the poster, the layout, time and date of handing in at the administration. The poster has to be handed in while all members of the group are present on the morning of the presentation. In the lecture hall Pr., V. and O. sit together L. and P. are sitting on different places and B. is not present. It is 16:15 when this meeting starts in the theory room of the same building.

Situational layout

During this session the two groups are no longer sitting opposite each other. One of the girls sits beside P. and all are gathered around L. who brought her notebook computer. B is absent without notification.

Figure 4.5: *Gathering around the computer*

Content of the session

The group starts looking at sites on the Internet and the observer asks them if they have found suitable Portuguese sites. P. answers that there is not much concerning the subject in Portuguese. The observer hands out articles in Portuguese she downloaded from several websites. The next eight minutes they spend reading through articles and surfing the Internet. V. and O. read together once in a while commenting on something in the article. V. hands the first article to Pr. who starts reading. P. reads with her for a few seconds. L. surfs the net and P. is looking together with her. After four minutes L. also starts reading while P. continues surfing the net. O. starts taking notes from one of the articles. After browsing through the articles Pr., O. and V. have a short discussion about the use of the articles for the poster:

Pr.: We can use the article ' *The future of the Internet* ' I think it is better.
O.: I don't know. To me it is all very complicated.
Pr.: At the presentation we have to talk about that illustration from the article (Computing with DNA).
V.: You mean that of (makes a circling sign with her hand) DNA.
Pr: We have to talk about what we will do with the poster.
V.: We can do that later.
O.: We have to investigate more about these points.

Eleven minutes after the start of the session P. suggests they start working on the poster:

P.: Let's see. We have to act more on the level of the poster. We can already arrange some

information.
L.: We have information about the computations, about Moore's Law, we already have a lot (…)
P.: To explain what?
L.: The molecules, something about that theory that the units of DNA repeat themselves, circuits that are becoming faster and smaller every time, advantages in common and DNA and molecules.

V.: Every one of us has to explain?
L.: Yes. That is possible, you can talk about communications, limitations..
Pr.: Advantages
V.: the future
O.: What is the objective of computation with DNA?
P.: I think there are a lot of advantages. I think it is better if we compare the advantages. For example why don't we do it like this: we are going to suggest, we are going to say that there are advantages and then we obtain (…). I think that will be easier.
L.: Yes, I think that is better because we have two combinations so it could be..
P.: Yes, about DNA and molecules.

A conversation follows between V. and P. about the type of software program to use for the poster. P. thinks Adobe Photoshop has more possibilities. V. admits she doesn't know both programs very well. Pr. asks how they are going to divide the subjects with six people, L. answers that they have the themes, the common part, the limitations and other options. She takes a sheet of paper from her bag and starts sketching the layout of the poster. The others start looking for images on the Internet. After finishing the sketch L. explains it to the others.

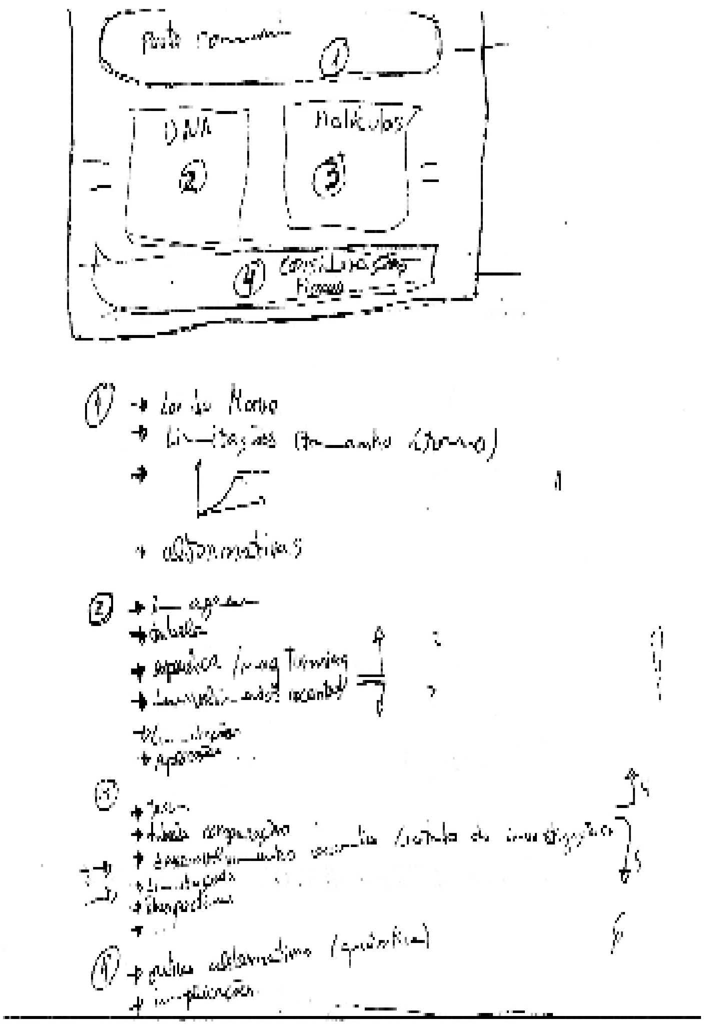


Figure 4.6: *L's sketch of the poster layout*

L.: Similar Part: Moore's Law, limitations, evolutions, applications of DNA, table of cities, experiences and the machine of Turing, recent developments.
O.: Which table do you mean?
L.: That one of the computers.
Pr.: The one from the article *Computing with DNA.*
Pr.: Can we use illustrations?
L.: Yes, for example one of DNA and one of the travels.
L.: you also want to talk about that history of the author..
Pr. and O.: no, no history
L.: and about the machine of Turing
O.: Yes

P. finds a website that compares standard computers with 'molecule' computers.

P.: Look here about comparing the cost to fabricate, investments…..
V.: also about that man Shapiro? (from the Weizmann Institute)

P. finds the site of the Weizmann Institute from which one of the article is downloaded. V. starts the discussion about how to do the job because they already have too many study obligations to attend to the coming two weeks.

P.: It has to be in the weekend (printing of the poster). We go over there in the evening. We do the poster in PowerPoint, go to the print shop and ready.
Pr.: We have tests the whole week.
V.: I have a mini test
O.: We can meet in the weekend.
P.: No, that is impossible, that is to say I have to work and…
L.: and on Friday

P., Pr. and O nod in agreement, V is copying the sketch of L. Pr., O. and V discuss who will do what in the presentation but they don't come to a conclusion.

L.: We spend a lot of time doing this work
O.: and the presentation?
Pr.: how are we dividing? And the material
O.: we have to decide…
P.: We have 15 minutes for six people. That is 2.5 minutes per person so that means…
L.: So that means?
P.: I talk, I stop, then the other…….prrrrrrrr (indicating fast talking).

V, Pr. and O. talk about their subject. P. suggests dividing tasks before they start with the poster then bring it in and adapt to the size. L. points out the division on the sketch: two persons for the first common part and two people for the last, one for DNA and one for molecules.

Pr.: I don't know how we should divide. We already have a lot of things that we will do and with illustrations you can talk and demonstrate
P.: And the presentation if we are using PowerPoint?
L.: I don't know we are still at the point of orientation.
Pr.: I think that at least some points are still missing.

They set the next meeting for Friday May 20th and decide to bring the poster on Saturday to the copy shop at the campus for printing. They distribute articles for copying, L.P., and Pr. surf the Internet for another two minutes then they all leave.

End of Session 3. Duration 36 minutes.

General impression taken from complementary notes
With L. and her notebook computer sitting in the middle, they look more like a group then the previous session. They are reading and surfing the Internet for long periods and although they make a good start for poster preparation, they all feel the pressure of time at the end of the session. The coming two weeks are the last weeks of the academic year with tests and projects to complete.

Interactions and activities
Verbal interactions, 41% of the total time, as can be seen in Table 4.7, take place mainly between the original groups, especially between V, O and Pr. L. interacts with P. when surfing the Internet and with the others when explaining and answering questions. P. interacts with the whole group when he makes suggestions concerning the poster, the presentation and division of the work load but all the other time he spends with the computer. The group as a whole spends time together behind the computer (12%) and in discussing the task (21%). During this session all students spend a

considerable time on non-verbal activities such as reading the articles and looking at websites (see table 4.8).

Table 4.7: *Verbal interactions during session 3 over a period of 36 minutes*

Person	***Kind of verbal activity in order of frequency***	***Percentage of total time***
L.	Explaining, answering and discussing	7
P.	Explaining, suggesting and discussing	9.5
Pr.	Discussing and questioning	10
V.	Discussing, explaining and suggesting	7.5
O.	Discussing and explaining	7

Table 4.8*: Non verbal activities during session 3*

Person	***Kind of non verbal activity** in order of frequency*
L.	Surfing the Internet, reading and making a scheme
P.	Surfing the Internet
Pr.	Looking at websites and reading
V.	Reading, looking at websites and copying notes
O.	Reading, note taking and looking at websites

The learning process

At the beginning of the session the students admit that they didn't manage to get much information about the themes. The moment the observers hands over the Portuguese written articles V,Pr and O start reading and looking for helpful passages that can explain their theme more clearly. P is not looking for new information about his subject but looks for useful illustrations for the poster. L. reads through the articles looking for factors the topics have in common. They start working more as a team and take steps in organizing the task. A draft layout of the poster is made with a division of the two themes. They now act as two groups with two themes but with common parts. The next step should be analyzing the information, discussing the content, concluding and 'filling in' data on the poster.

Table 4.9: *Questions asked during the third session*

Person	***Confirmative***	***Transformative***
L.	You also want to talk about how Adleman got the idea? Are the articles in Brazilian or Portuguese?	
P.		
V.	Every one of us has to explain? Who knows how to work with PowerPoint?	
Pr.	How are we going to divide data and themes with six persons? Can we use illustrations?	
O.	What are we going to decide about the presentation?	What is the objective of computing with DNA?

Opinions of the students sent by e-mail

About the third session

Pr.

The meeting with the others, even though both groups did not prepare it very well, was good in defining what to do and what to look for in addition to the poster. I didn't stick to a particular part of the poster I'm still looking for more information about the proposed objectives for the poster. I hope to help out but unfortunately I have not much time this week. We have a lot of lectures and presentations of other course units but we will put a maximum effort in organizing ourselves to make a good poster.

P.

It was a meeting that nobody wanted to have since we were all tired but when we started to work things developed in a good way. The dialogue was easy and I think we already have certain things in mind. I did not have the chance to read the article *Computing with DNA* but I have some ideas from what I have seen and heard. Concerning the poster I will do the graphic part and maybe moderate what we are going to put on the poster. I can already say that we are going to use Adobe Photoshop (a program that is very suitable for image editing) instead of PowerPoint. As far as the presentation there is a division, not very accurate, but we are not going to subdivide the task.

V.
As far as the meeting, that was interesting because we got to know each other a little more and we began to plan a bit about the structure of the poster. Concerning the other theme "Computing with molecules", I had a look at it to see what it was about and also to see what the similarities and differences were with my theme. My part in the presentation is not fixed but I think the main idea is to make the poster, to understand the subject and then divide the tasks.

L.
Sorry for the delay. It suits me better to answer the questions at the next meeting. If that is not possible I will try to respond today or tomorrow morning.

4.1.4 Session 4 *Friday May 19th 2005*

Context
The meeting is planned at 17:00 in the same theory room where the other sessions took place. The coming week is the last week of lectures and will be followed by an examination period in June. Coming Monday the poster has to be handed over with all members of the group present. At 17:20 three members of the group enter the room, Pr., V and O. The other members are absent without notification.

Situational layout
They sit beside each other with L. and her notebook computer in the middle. Pr. and O. have brought several articles and L. has the layout of the poster in front of her (see fig. 7), made during the third session.

Content of the session
After installing the notebook computer they start with part 1 of the poster. Pr. reads aloud passages about limits of actual computation from the Brazilian article *The Future of the Internet,* L. writes summarizing sentences (see Fig 8) that can be added to the poster later on.
O.: Aren't we going directly joining limitations and advantages?
L.: No, no, we'll do that later.

L. starts surfing mumbling: "dates, dates, dates." Every now and then Pr. reads phrases from the article, O. starts reading through another article.

L.: Let's see other limitations (to O.) this is on the level of computations, the level of limits.
O.: and the communal limits and advantages?
L.: That will go in the final part

L. reads aloud what she has written down: "At this moment transistors are getting to the size of an atom. The density cannot be augmented". She explains to O. the Law of Moore that predicted doubling of circuits every 18 months and asks Pr. for other limitations. Pr. reads from the article about the limitations of microprocessors. The first of the four parts of the poster has been taken care of and they make a start with the second part about DNA. Pr. reads out loud a passage from another article about the capacity of DNA to store information and to make an immense amount of parallel calculations.

L.: I also have something about that subject. We have to explain that.
O.: (hands another article to Pr.) this one explains it very well. We have to explain how a DNA computer works.
L.: (after reading an article) So it is like this: a molecule passes, a molecule passes, goes back and pronto. Basically it is like that. They pass or they don't pass.

Pr.: How can we explain this?

The next 15 minutes they look at a website where the process of DNA replication is demonstrated in illustrations. L. thinks out loud while sketching on paper, the other two watch and every so often commenting.

Pr.: Do we have to talk about the passages (annealing of DNA)?
L.: Of course we have to. We have to know how DNA works.
O.: DNA has two strands, one goes here and the other there and the combinations…
Pr.: One string stays and the other goes that way.
O.: I don't understand that part of the cities (Hamilthonian Path)

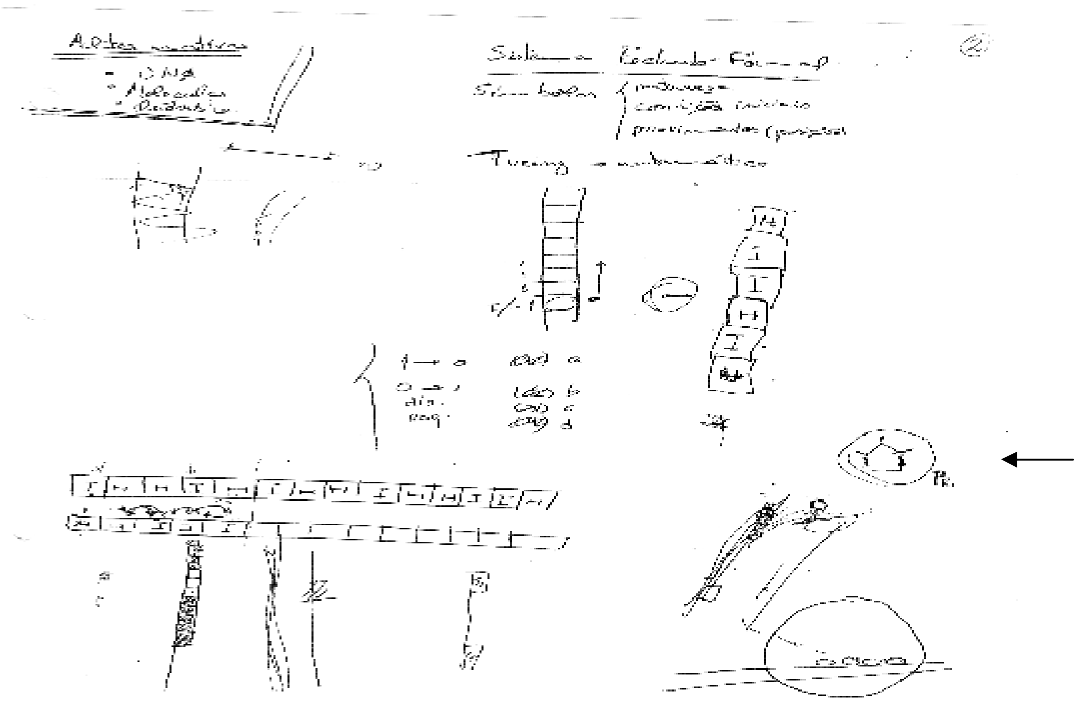


Figure 4.7 *The principle of the Turing Machine sketched by L. and a drawing of the DNA molecule by Pr.*

L. reads another article and surfs on the net, O. is browsing through her articles and Pr. is watching. L. remarks that if they find out how the Turing Machine works they will also know about computing with DNA. Pr. reads the passage from the article *Computing with DNA* where the author managed to compute with the DNA molecule based on the idea of Turing and the theory of Watson and Crick. Pr. and O. tell L. that they don't understand the principle of the Turing Machine. L. continues reading and surfing the Internet, O. reads passages from different articles and Pr. looks at the websites L. is looking for information and finds a website that explains by means of illustrations, the principle of the Turing Machine. The next 15 minutes she thinks and reads aloud while making drawings and sketches on paper (see figure 4.8), O. and Pr. look and listen. Pr. suggests that during the presentation they talk about the Turing Machine and mention that computation with DNA is based on that idea. O. doesn't agree and L. remarks that it is the chemical part they have to understand before explaining.
O. and L. start reading and browsing through the articles, Pr. waits and watches.

Pr.: We already know a lot about DNA and its applications. DNA is able to contain more information than chips, we can talk about the advantages.

L.: Yes, Yes (continues reading then after two minutes). *What exactly does this DNA look like as a molecule?*

Pr. draws a molecule on the paper of L. (see figure 4.7) “not very good”, she remarks, but she can’t explain the chemical parts and when asked O. also admits she doesn’t know. L. continues reading and surfing the Internet meanwhile Pr. and O. talk about continuing with what they already know.

O.: Why don’t we go to another part (of the poster)?
L.: What we can do is we begin with the part about the molecules. Statistics say that one quantity can contain 10^{12} times more information than normal transistors.
The other advantage is the price.
Pr.: Why the price?
L.: It is cheaper to use molecules than constructing regular computers.
Pr.: In the end, what is the system of a molecule computer?
L.: That is simple; they pass, duplicate and make the right combinations.
Pr.: That means that we have to talk about the DNA process.

L. reads the interview with E.Shapiro, the ‘molecule’ researcher from the Weizmann Institute in Israel.

L.: But here they explain how computing with molecules work.
O.: Yes they explain about software and the use of ATP (adenosine triphosphate).

Figure 4.8: *Looking for answers*

L. surfs the Internet for information about ATP and takes notes while O. and Pr. look. Since the start of the meeting, more than one hour has passed. L. asks the observer if she knows about DNA chemistry. The observer informs them that Chemistry is not her discipline; she is interesting in the process of the group. She asks them about the poster and dividing the tasks of the presentation but they are indecisive as what to do because of the absent group members. L. continues surfing but Pr. wants to stop because she has to study for a difficult Calculus exam on Monday. They agree to meet again the next morning, Saturday morning, at 09:00. Pr. and O. are going to look in the university library for chemistry books related to the subject.

End of Session 4. Duration: 1 hour and 20 minutes.

Five minutes after they have left the girls come back asking me if the next meeting can take place in the apartment of Pr. instead of in this theory room. Professor T., meets them on their way out and emphasizes the fact that all members should be present on Monday not only for the presentation but as well for handing over the poster.

General impression taken from the complementary notes
O. and L. are very persistent in looking for information or answers to the question ‘how does DNA work and how can you compute with DNA.’ Pr. has in this session an attitude different from the other

two group members. She doesn't read or look for information but just waits and tries to break through the silent periods suggesting they have enough information to continue.

Interaction and activities
Of the total session time 28% is used for verbal interactions, the remaining time consists of periods of silence used for reading or browsing through the articles, watching/reading websites and looking for information on the Internet. Interactions are centred on L. who, from the start takes the lead in organizing information for the poster. Pr. and O. interact when they are looking for passages in the articles they copied or when the article from The Scientific American comes up. The main activities are reading, explaining and looking for information.

Table 4.10: *Verbal interactions in session 4in order of frequency*

Person	*Kind of verbal activity*	*Percentage of time*
L.	Explaining, answering and discussing	13%
Pr.	Reading aloud, suggesting, discussing and questioning	12%
O.	Questioning, discussing	3%

Table 4.11: *Non verbal activities during session 4*

Person	*Kind of non verbal activity in order of frequency*
L.	Reading, surfing the Internet, and sketching
Pr.	Looking at websites
O.	Reading, note taking and looking at websites

Learning process
At the previous meeting there were two groups with two themes and some common parts. Now only three members are left and they concentrate on the content of theme T2 *Computing with DNA*. L. from T1 hasn't read the article, the other two have read several articles and understand the advantages of computers and DNA but they are still looking for an answer on the deeper question about the chemistry of DNA suitable for replication and thus computation. They have enough information but L. as well as O. realize that they cannot step into the concluding phase before they understand the DNA process. Pr. wants to continue to the final part leaving the DNA problem behind her.

Table 4.12: *Questions asked during session 4*

Person	*Confirmative*	*Transformative*
L.		
Pr.	Do we have to talk about the passages?	Why do we talk about the price as an advantage?
O.	Aren't we straight away joining limitations and advantages?	How does the Machine of Turing work?

4.1.5 Session 5 Saturday May 20th 2005
Context
On request of the three girls present in the previous meeting this session will take pkace in the apartment of Pr. We agreed to meet at 09:00 in front of the university building. On the way to the apartment Pr. and O. tell me that, since T. told them yesterday that all members have to be present they think it isn't worth the effort to continue especially when there is so much other work to do. They thought this Mini Project was different and not so time consuming and the attitude of members not showing up is a disappointment to them. L. is waiting near the apartment and they decide to give it another try. Pr. and O. show me the books about DNA they got from the library.

Situational Layout
There is just enough space for three people at one side of the table. L. and her computer notebook are seated in the centre. The observer sits out of camera view but at the same side of the table so she can observe the computer screen.

The conversation summarized from the transcription
After starting up the computer, L. scrolls through downloaded information from previous sessions:

L.: What about DNA?
Pr.: I think it is better if we start preparing the poster then later we will see.
L.: I can't stand that thing about DNA.
Pr.: We have information and illustrations and what they explain.

L. makes on screen a layout true to scale of the poster but she doesn't manage very well. She doesn't have the program PowerPoint on her computer.

O.: What are we going to put in the poster?
L.: What do we have about DNA?
Pr.: We have a lot about DNA: illustrations, information..
O.: Today we have to find out what we understood so far.
Pr.: If we can explain. We have the first part the common part. I think we have to talk about the velocity of the computers and the applications, comparisons, tariffs and so on.

They decide to swap computers because the one of Pr. has PowerPoint installed on it. Pr. connects her computer and L. talks with O.

L.: Did you understand that thing (pointing to yesterday's notes)?
O.: The thing I don't understand is that DNA thing, the energy source and the chemistry. These things I don't understand and they are fundamental.

L. doesn't know how to work with PowerPoint that well and Pr. takes over for some minutes. After 20 minutes they have the layout and the title and make a start with the common part. L. divides the common part in two and says she wants to put a graph showing the principle of Moore's Law in the centre. O. doesn't understand why the part the themes have in common is split up:

O.: Are you making a part in common and a part about Moore's Law?
L.: No, it is like this, we put the graph in the middle here
O.: So we have common part 1 and 2?

L. and Pr. explain to O. that the graph indicates the importance of finding new solutions for storing information. The computer is plugged in on the Internet and they look for graphs describing Moore's Law using the browser Google Images. They find many graphs picturing Moore's prediction. One is downloaded and L. dedicates almost 25 minutes adjusting it with the help of the programs Microsoft Picture Manager and Paint. The graph is put in the middle of the first part. The limitations of actual computers are put on the left. On the right side L. types in a summary in short sentences after Pr. has read aloud passages from articles about molecule transistors and microprocessors. O. sits and watches the screen. More than an hour has passed before they come to the second part of the poster the part about DNA.

L.: Now we go to the DNA part.
Pr.: Here they talk about the actual system….
O.: I think it is better if we talk about the DNA computer:
Pr.: Of course but here they talk about the differences and the similarities of the two.

L. fills in text from her notes while Pr. reads the article aloud. During seven minutes they look concentrated at a downloaded PowerPoint site showing images of the replication of DNA. Pr. as well as L. talk out loud explaining and commenting on what they see.

O.: I still don't understand how they (the strands) do this. I still don't understand

L.: They explain it here.
Pr.: Ah, this splitting is the replication of DNA, the strands of DNA undergo chemical changes and then they split and form a new DNA strand. They double and turn and continue.

They continue reading aloud (Pr.) note taking (L.) and looking at the site.

O.: I still don't understand this coming together, the DNA goes inside (gesturing with her hands) and..
L.: Exactly, that is the chemical part we try to understand and we look for it here.
Pr.: (disappointed face) and they don't explain that here (O. and L. laughing).
O.: I think it is very important to know this
L.: Pronto. The theoretical part where they talk about this…let's see

She asks the article of the Scientific American and starts reading it, Pr. looks for a short while at the site and an article in front of her.

Figure 4.9: *Still looking for answers*

Pr.: I think we have to talk about what a DNA computer is made of.
O.: That means you have to tell what DNA is made of and…
Pr.: Well, things appear in molecules and DNA molecules…

Pr. starts reading again, L. is still reading, studying the website and taking notes and O. leafs through articles. Pr. reads aloud a passage about molecule computers but the others don't pay attention. L. asks Pr. to tell about the elements of DNA, how it works. Pr. summarizes the parts she understands so far, being the characteristics of DNA molecule with its four bases, double helix, how it splits by biosynthesis and how it replicates through DNA polymerase. While explaining she becomes aware that this must be how the Watson-Crick model is used in the computing. L. tells that she tries to understand how the ligase and nuclease works. They all start reading the articles again.

End of the videotape. Duration 1 hour 30 minutes. The session has not ended but there are no more tapes available for recording. The following summary is taken from the complementary notes.

After reading for some minutes Pr. suggests that they continue working on the poster. They leave the DNA question and look for something else to put in the section of the poster allocated for DNA. They overlook the information they already have. O. suggests to make a table in which traditional computers are compared with DNA computers as can be found in one of the articles. L. remarks that the title DNA computer is not correct and should be changed in molecule computers. After that they make the table with comparisons, later to be added to the PowerPoint layout. This takes some time because they have to take in mind that the text as it will appear on the poster must be short, meaningful and readable from a distance. By the time the table is made to every one's satisfaction it is well over 12:00 and the group is tired.

They stop and arrange to meet for the next morning. The PowerPoint layout can be taken to a Copy shop nearby and printed on poster size paper (the copy shop like a lot of other Portuguese shops are open on Sunday morning).

End of Session 5. Duration 2 hours 45 minutes.

General impression taken from complementary notes
O. didn't want to have this meeting. She doesn't participate much during the first part of the session. Several times she emphasizes that without understanding the basic things she cannot explain the subject to her fellow-students. Only in making the table of comparison she becomes active again. L. on the other hand persists in getting the problem solved and Pr. takes the lead when it comes to working on the poster. None of the girls has much experience in PowerPoint or working on a layout and a lot of time is lost because of this inexperience. The temperature that day is high (30˚ C) and after two hours of hard working everybody feels hot and thirsty. The meeting ends in a depressive atmosphere, not only because of the unfinished task but also for O. and Pr. because of the study load in the weekend. The same evening Pr. and O. cancel the meeting; they decide not to continue with the presentation.

Interactions and activities
Pr. and L. have many interactions because Pr. handles PowerPoint better and takes more initiative in working on the poster. L. interacts with O. when she explains something and they interact as a group about the content of the poster. From the 90 minutes recorded 16% is used for verbal interactions, 50 % in making the poster on the computer and the rest of the time in non-verbal activities.

Table 4.13: *Verbal interactions in session 5 over a period of 90 minutes*

Person	*Kind of verbal activity in order of frequency*	*Percentage of time*
L.	Explaining, answering and discussing	3.5
Pr.	Suggesting, discussing and explaining	10.5
O.	Questioning, discussing	2.5

Table 4.14: *Non verbal activities during session 5*

Person	*Kind of non verbal activity in order of frequency*
L.	Reading, surfing the Internet, and sketching
Pr.	Looking at websites
O.	Looking at websites Reading, note taking and

Learning process
In this session they take a step forward in solving the problem of DNA. Pr. and L. have analysed the DNA annealing but to make the connection with computing they need to understand more. Pr. and L. are both seeing patterns and trying to interpret what they understand each in their own way, Pr. by reading and summarizing aloud and L. by explaining and drawing or taking notes at the same time. O. is still exploring the question about the characteristics of DNA , the strands and the replication., she reads the same passages over again, persisting in her quest.

Questions

Table 4.15: *Questions asked during session 5*

Person	*Confirmative*	*Transformative*
L.		What do we have about DNA?
Pr.	What do we put as a title?	
	Can we use illustrations	
O.	What are we going to put in the poster?	
	Do we have a common part and a part about Moore's Law?	

4.1.6 The presentation May 23rd 2005

Context

The presentation will take place in one of the amphitheatres of the Pedagogical Complex from 16:00 to 19:00. Ten minutes before the start Pr., L. and O. come to notify me that they will not attend the presentation. After almost three hours at the end of the last presentation Professor T. announces that there is one more group, incomplete, who will present their subject. L. and Pr. had decided, after consulting with T. just before the start of the presentations, to persist and prepared their presentation during the past two hours.

Figure 4.10: *Explaining on the white board*

Situational layout

The presentations are given in the amphitheatre. The posters can be seen attached on the green felt boards on the left side, beamer and screen are on the right side and the whiteboard in the middle. The camera is placed right from the centre. The two girls are standing at the left side in front of the poster board or the whiteboard. Instead of the poster and PowerPoint presentation they use pieces of paper pinned on the poster board and L. makes use of the white board.

Content

Professor T. introduces Pr, and L. informing the audience that, even though not the whole group is present, these two girls worked hard and prepared themselves and they should be listened to and asked questions. Pr. opens with informing the audience that they have two different themes but they combined some parts. L.: "Why are we talking about computing with molecules and computing with DNA?" She pins the graph of Moore's Law on the board (see Figure 4.11) and explains the theory of Moore that predicts that the amount of transistors that can be put on a chip will be doubling every two years until the limit is reached. "That is why they are looking for alternatives such as Computing with DNA", Pr. continues explaining the elements of the DNA molecules; L. takes over and explains while using the whiteboard how a mathematical problem, the NP-problem (Hamilthonian Path) could be solved by using the characteristics of DNA. Back at the poster board Pr. says that because of the capacity of DNA replicating itself several combinations can be made. By turns, L does the 'technical' part and Pr. The chemical; they explain (see Figure 4.11) how strands with different DNA combinations can be made (following the line of the SA article).

Figure 4.11: *Taking turns in explaining*

L. continues talking about how to get rid of all the molecules with the wrong combination in the test tube making use of the polymerase chain reaction (PCR) raising and lowering the temperature of the mixture in the test tube. Pr. concludes the DNA theme, summing up the applications of DNA computation so far. In the next three minutes L. talks about her theme 'Computing with molecules' explaining how large numbers of molecules were attached to a golden layered surface by making use of the self-assembly capacity of molecules. A layer of conductive molecules was made with electric current passing or not passing through it acting as a device and circuit.

L.: " Comparing traditional computing with computing with molecules and DNA we are looking at things a hundred time faster, denser, smaller in size and cheaper to produce than the traditional chip. A chip has to be fixed on the inside and molecules you just pour them in.

Professor T. asks a question (recording came out poor) and L. responds that this is still in the initial phase. Pr. concludes the presentation by informing the audience that the Turing Machine was the onset to traditional computing as well as computing with DNA. T. asks her a question (?) but her answer doesn't seem very convincing. One student from the audience asks a question about DNA replication and L. can give a satisfying answer.

End of the presentation. Duration 18:34 minutes

General impression taken from complementary notes
The presentation of Pr. and L. came as a surprise to the observer. Although they didn't have a poster and/or a PowerPoint file to support their presentation they explained their themes in an effective way with an efficient use of time. L. made a nervous impression but presented her subject well. Pr. made an uncertain impression that effected her presentation. All in all their presentation was in a way more impressive than all the previous poster/PowerPoint presentations because they presented a difficult subject without proper preparation and without illustrations to support their explanations.

Interactions and activities
Pr. and L. act as a team taking turns and completing each other's dialogue with L. talking 77% of the total presentation time and Pr. 21 %. The rest of the time is spent on pinning the pieces of paper on the poster board.

Learning process
In this concluding session or presentation they concentrate on what the main question was during the last two sessions 'the replication of DNA and how to use that for computing'. The other theme 'Computing with molecules' explained shortly during the presentation by L. was never subject of learning. L. solved alone the question of computing with DNA by applying a mathematical formula but left out the chemical part. Pr. came to understand more of the chemical substances of the DNA molecule building on her prior knowledge. O. didn't manage to understand neither the chemistry nor the computing with DNA as she already expressed in the second session and all sessions after that.

5. Findings

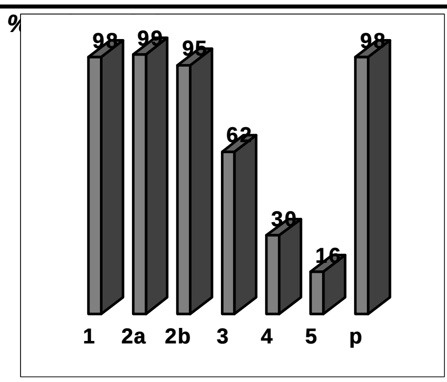
This exploratory study initiated with the question: *What characterizes the activities in mini projects?* The session reports were divided into sections to be able to give an answer to the three sub questions.

5.1 Interactions, activities and questions

1. How are the members of the group interacting with each other?
Interactions and activities as observed during the sessions and divided into verbal/non verbal categories.
2.*What kind of questions do the group members ask?*
Questions divided into the categories confirmative and transformative as has been used in the QQ-project.
3.How are the students undergoing and experiencing the different phases of the learning process ?
Complementary notes together with the transcribed recordings were used to analyse the phase of the learning process that characterized each session.

1. How are the members of the group interacting with each other?
The amount and nature of verbal interactions as a total from the session time can be seen in table 5.1. The nature of verbal interactions is given in order of frequency. Note that at session 1 and 2A-2B all members were present, during session 3 there was one member absent, at session 4 and 5 three members of the group participated and the final presentation was done by two students of the group.

Table 5.1: *Amount and nature of verbal interactions*



Session	Nature of activity in order of frequency
1	**explaining, questioning, answering and organizing**
2A	**explaining and discussing**
2B	**explaining, questioning and organizing**
3	**explaining, discussing, suggesting and organizing**
4	**explaining, reading aloud and discussing**
5	**discussing, reading aloud**
presentation	**explaining and answering**

Table 5.2 shows the course of verbal activities for all members and at the same time indicates which members were present during the sessions. The teacher was present at the first two sessions therefore is his part of verbal interaction included as well.

Table 5.2: *Verbal interactions per person in % of time during all sessions (=not present)*

Person	Session 1	Session 2A	Session 2B	Session 3	Session 4	Session 5
T	76	85				
P	8	10	10	9.5		
B	-	-	1			
L	4	1	35	7	13	3.5
V	-	-	20	7.5		
Pr	-	-	17	10	12	10.5
O	-	-	5	7	3	2.5

Non-verbal activities in order of frequency are noted in table 5.3. The presentation is left out because non-verbal activity at that occasion was not of significance.

Table 5.3: *Non-verbal activities during all meetings*

Session	*Nature of activity in order of frequency*
1	Note taking
2A	-
2B	Reading through articles, note taking
3	Surfing the Internet, looking at websites, reading articles, note taking, poster preparation
4	Surfing the Internet, looking at websites, reading articles and sketches for explanation
5	Poster preparation in PowerPoint, looking at websites, reading articles

As can be seen in Table 5.1 the verbal activity is decreasing as the sessions continue. Partly that can be explained by the unexpected absence of two group members after the third session. The remaining three students were not motivated to continue because the teacher set the rule that all should be present at the presentation. Another reason for the decrease of verbal activity is the lack of information about DNA and its functioning. Pr., V and O didn't understand their topic and were looking for more information and L. only started reading the article "Computing with DNA" in the last session (Table 5.2). The focus of the conversation during session 1.2 and 3 was on organizing the poster and how to do the presentation with two groups. The group didn't take time to discuss the content of their topics.

2. What kind of questions do the group members ask?
The questions were taken from the transcription of the audio recording placed in one of the two categories and counted. Table 5.4 depicts the persons and the categories with the questions.

Table 5.4: *Questions asked during the project*

Person	Confirmative question	Transformative question
P	1. We have to elaborate a conference on a subject? 2. Where can we see posters to orientate us? 3. What is the size of the poster? 4. Is that the same size as an A2? 5. Are the articles in Brazilian or Portuguese?	21. What is the main objective of the project?
L	6. Are they more or less like the poster in the laboratory? 7. Do we have to use the email address of the university? 8. He created DNA? 9. What was the idea he had? 10. Are you talking about that scheme in the article?	22. There are similarities between the themes? 23. How did that go, computing with DNA? 24. How does that work? (DNA replication) 25. What exactly does this DNA look like? 26. What do we have about DNA
V	11. Every one of us has to explain? 12. Who knows how to work with PowerPoint?	
Pr	13. There is not much known about the subject? 14. How are we going to divide data and themes with six persons? 15. Can we use illustrations? 16. Do we have to talk about the passages?	27. How does the system of a molecule computer work? 28. Why do we talk about the price as an advantage?
O	17. What are we going to decide about the presentation? 18. What are we going to put in the poster? 19. Aren't we straight away joining limitations and advantages? 20. Do we have a common part and a part about Moore's Law?	29. How does the Machine of Turing work? 30. What is the objective of computation with DNA?
	Total of questions 20	***Total of questions 10***

Questions in their context
P.
Q21. *What is the main objective of the project?* T. has just told the students about the importance of the themes and of working together but not what the rationale behind the project was. In his answer it becomes clear that it is a preparation for future work as a scientist.

Q1 *We have to elaborate a conference on a subject?* P. asks for confirmation of what he understood was right. T. answers with an extensive explanation of the use of a poster.

Q2, 3 and 4 are raised because in his answer on question 21 and 1 the emphasis is on the poster as the final product of the project. He doesn't give a clear answer but directs to a coming meeting dedicated especially to the poster.

Q5. *Are the articles in Brazilian or Portuguese?* Brazilian originates from the Portuguese language but there are differences. It could be compared with the difference between English and American. When the answer is 'Brazilian' P. remarks: 'yes, there is a lot in Brazilian.' Indicating that he looked for information and found it on Brazilian websites but didn't considered it useful enough to download.

L.
Q6 is confirmative and can be answered with a simple yes.

Q7: *Do we have to use the email address of the university?* is a matter of choice and T. answers: 'the one you use frequently.'

Q8 and 10 are a direct reaction on the explanation given by the other group. The others confirm but don't give extra explanation.

Q9: '*What was the idea he had?'* after V. told how the author of the article woke up in the middle of the night because he had an idea but doesn't mention what that idea was (how to solve the Hamilthonian Path Problem). This question can be interpreted also as a transformative one. Answering that would have showed understanding of the theme. It is categorized as confirmative because L. first had to know **what** the idea was before asking **how** he would solve it. The answer was: 'he got an idea how to compute with DNA'

Q22: '*There are similarities?'* follows after a discussion between P. and T. about the differences in the two themes. P. thinks the themes are different in their application but T. explains that they have things in common as well. He confirms that again in his answer on L: 'Exactly, there are common parts'

Q24 is the leading question for the group T2 but in the end L. herself has to answer that question.

Q25, 25 and 26 are all about DNA and the answers will lead to an answer an Q24. The other group members cannot give answers. When L. asks: *'what do we know about DNA?'* Pr. answers by naming the facts they know about application, advantages and limitations.

V.
Her questions: *Every one of us has to explain?* and *Who knows how to work with PowerPoint?* demonstrate her concern of preparing for presentation. The first question is confirmed with a simple yes and the second is answered by P. who tells her that he knows how to work with it but prefers another program.

Pr.
Q13 *'There is not much known about the subject?* This is a reaction on the explanation of L. and her search for information at the university in Lissabon. She answers: 'It exists in the USA but in Portugal I don't know.'

Q14 and 15 are asked during the third session when the group is making a start for the poster presentation. L answers both questions: Q14 with yes and Q15 with an explanation supported by her sketch (see Figure 4.6).

Q16 *'Do we have to talk about the passages'* refers to how the author solved the mathematical problem of going from one point to another without passing the same places in between twice. He used the sequences in the DNA molecules of adenine, thymine, guanine and cytosine (ATGC) and their complements to solve this (Hamilthonian Path) problem. Pr. doesn't understand the problem and hopes she can just skip it but L. answers: '*of course we have to, we have to know how DNA works.*

Q27,Q28 'How does the system of a molecule computer work?' and *'Why the price?.* These question are related to the theme of L. 'computing with molecules'. In the fourth session after an hour of searching the internet and reading articles Pr. is pushing L. towards filling in parts of the poster. L. summarizes the advantages of molecule computers. The fact that the material of a molecule computer in the end will be cheaper answers Q28.
The answer L. gives for Q27 states facts instead of an explanation: *'That is simple: they pass, duplicate and make the right combinations.'*

O.
Q17, 18 19 and Q20 all deal with uncertainty about the presentation. The subjects have been discussed before indicating that she was either not listening or she really didn't understand how the poster was divided.

Q29: *'How does the Machine of Turing work'*
This question is a reaction on a remark of L. some minutes earlier: '*If we find out about the Turing Machine we will understand also about computing with DNA'.* Pr. as well as L. admit that they don't understand the principle of the Turing Machine. After three minutes O. comes with this question but nobody answers.

Q30: *'What is the objective of computation with DNA?'* She asks this question in the third session. In this session there is an open cooperative atmosphere with many interactions. P. answers: *'I think there are a lot of advantages. I think it is better if we compare the advantage (…).*

From the 10 transformative questions two are answered by the teacher, high-level achievers answer three and five are not answered at all.
As can be seen from the kind of questions asked (Table5.4) the three students who didn't understand their topic were not able to analyze the subject in parts that could have been understood with prior knowledge from secondary school. They didn't know how to formulate productive questions and were fixated on the end result of computing with DNA. The questions asked by L. are all productive and demonstrate that she is analyzing the problem. Her number and mix of confirmative and transformative questions makes her a high quality questioner (Pedrosa de Jesus, Teixeira-Dias and Watts, 2003). The questions asked by P. are aimed at the poster preparation and the final presentation. O. demonstrates insecurity in her questions and seems to lack the prior knowledge of the subjects that are discussed in the last two sessions.

How are the students undergoing and experiencing the different phases of the learning process?
The learning process was pursued through analysis of the recordings, transcriptions and complementary notes and is reflected in Table 5.5.

Table 5.5: *Phases of the learning process during the mini project*

Session	indeterminate	Investigation	Creative phase interpretation	concluding phase
1	*			
2A	*			
2B		*		
3		(V,Pr,O)*	(P,L)*	
4		(L,Pr,O)*		
5		(O)*	(Pr,L)*	
Presentation			(Pr)*	(L)*

The mini project was a new item for all group members and the first session was meant to give structure. They agreed to read the article and come together for a short brainstorm session. Instead of that they were told during the first part of the second session that they had to combine their topics in one presentation. The rest of the session time was spent on investigating and exchanging information about the themes. Before coming together in the third session they would read the article of the other group and then discuss the common parts. None of them did as promised because of time pressure (as they admitted by e-mail) and V., Pr. and O. were still looking for new information about their subject. P. and L. had no problems in understanding their topic and therefore where able to progress to the next learning phase in the third session. P. found common parts for the themes and L. made a rough division of tasks during presentation. In the fourth session with only three students left L. had to investigate the other topic which she managed to understand in the last session and by studying at home before the presentation. Pr. stimulated and helped by L refreshed her prior knowledge about DNA and could continue with the second part of thetopic: the combination of computing and the DNA characteristics. O. was persistent in looking for an answer on the question “How does the computing with DNA work?” As she could not reformulate the main question in sub questions she stayed in the investigation phase.

5.2 Student assessment of the Mini Project

After completing the final test all participating students were asked to answer questions on an assessment form developed by the chemical department. They could assess on a scale of 1 to 4 about their own exploration of the theme, their own preparation of the poster and presentation and about the sessions. The outcome of the analysed forms from the observed group members is described in 5.2.1. They were also sent an email by the observer asking their opinion about working in a group. Four out of six persons responded to the email and their answers can be read in 5.2.2

5.2.1 Students (self) assessment

The form contained 16 questions divided over three parts: exploration of the theme and preparation of the poster and presentation (see Table 5.6) and meetings with/without teacher (see Figure 5.1 and Figure 5.2). Every question had the possibility to assess the other group members as well. This part of the assessment was only used for the questions about preparation of the poster and presentation.

Table 5.6: *Self assessment of the group members*

	P	*B*	*L*	*V*	*Pr*	*O*
Assessment of preparation / exploration of the theme						
I understood the article from The Scientific American.	3	3	4	3	2	2
The article raised my curiosity.	4	3	4	3	4	4
I searched for new information. (bibliography suggested by the teacher)	3	2	3	4	3	3
I showed a critical attitude. (reflection and development from your view on the theme)	3	2	4	3	3	3
I contributed with original/creative ideas for exploration of the theme.	4	2	4	2	3	2
Assessment of the preparation of the poster and presentation						
Did you select and treated on text and images? (poster)	3	1	2	2	4	4
Did you contribute to the graphical aspect? (poster)	2	1	1	2	3	3
Did you demonstrate creativity/originality? (poster)	1	1	1	2	3	3
Did you contribute to the preparation of the presentation?	3	1	3	3	4	4

Note: 1 = not at all; 2 = a little bit; 3 = sufficient; 4 = a lot

Assessment of the group sessions
Student assessment of the sessions is split up in sessions with and without the teacher. The first three questions about sessions with the group about number, presence and duration of the sessions have been answered in section 4.1 of the report. Figure 4.15 shows the individual scores on the remaining question: “Did you profit from the sessions with the group?” The assessment of sessions with the teacher came from the following questions: 1. Did the sessions clear your doubts? 2. Were the sessions in line with your expectations? 3. Were the sessions in proportion with the preparation of the task?

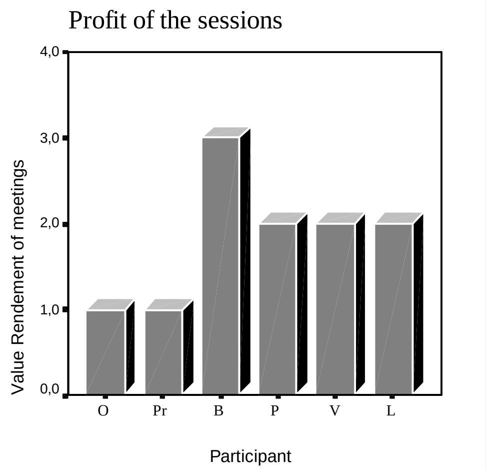


Figure 5.1: *Opinion of the group about the sessions*

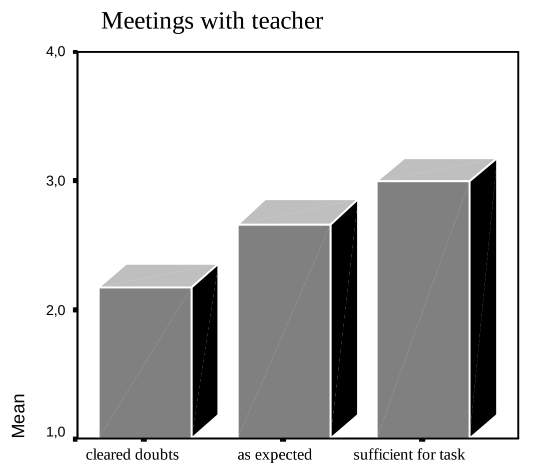


Figure 5.2: *Opinion of the group about sessions with the teacher*

Note: 1= nothing; 2=a little bit; 3=sufficient; 4= a lot

The assessment form offered also the possibility of assessing fellow students on their preparation of the theme, the poster and the presentation. As to the preparation of the poster none of the members of the observed group rated the contribution of the other members as sufficient on the scale of 1 tot 4. An overview of the assessment of the students by their fellow students can be seen in Table 5.7.

Table 5.7: *Average ratings students received from the other group members for participation in preparation of the poster and the presentation*

P	*B*	*L*	*V*	*Pr*	*O*
1.94	**1.31**	**2.94**	**1.69**	**2.19**	**1.81**

Note: 1 = not at all; 2 = a little bit; 3 = sufficient; 4 = a lot

5.2.2 Questions and answers send by email after the presentation

What knowledge have you acquired by participating in this mini project?
P.
I think it was a task just like any other only the subject was a very actual one and not much developed in comparison with the other themes. This is of some influence in capturing the interest.
L.
Apart from the knowledge I gained about the theme I also learned something about working in a group. For example you cannot choose light-heartedly a group to work with and you don’t necessarily have to choose from close friends. Before you approach your project task you have to work on the functioning of the group.
Pr.
I now have a good idea about how to make posters and some idea about computing with DNA in relation with the structure and characteristics of the DNA

O.
My excuses for not responding on the other questions (after the 2nd and 3rd session) but I don't use email a lot. As far as the mini project it was exciting and interesting work but the truth is that some people in the group were not interested and if that happens the task cannot be done. That is my opinion and the reason of my malcontent

Do you think there was enough opportunity to give your opinion and bring your ideas?
P.
I think we were limited in some way from the beginning. That was because we investigated in the experimental investigations of others. But in fact that brought us in contact with an experimental and theoretical world.
L.
yes
Pr.
To be honest the presentation was not planned at all and therefore it didn't go well. Simple ideas were exposed in a complex form and complicated ideas were not explained very well.
O.
I think I had the opportunity to manifest myself although I didn't use it. It is obvious that for a part I have to blame myself for the lack of success. If I don't agree with the way the rest is working I should have shown my disagreement better.

If there had been a specialist on the subject available to answer your questions would that have made the process easier?
P.
We would have been let to something and we would not have learned how to get there.
L.
Yes. But I didn't manage to meet someone who is working on this subject in Portugal.

Pr.
Somebody who knows enough about this theme would have been able to facilitate the learning process.
O.
 -

Was the content of the article at your level of Chemistry?
P.
I think that all articles were on a superior level. But if we want to be ambitious we have to get used to this level and in the course of our study we will reach that level with the acquired knowledge.
L.
In general yes. I asked a friend who is doing genetic research to explain me the process of PCR (Polymerase Chain Reaction) but I think the rest was easy to understand.
Pr.
Yes.
O.
The theme was difficult but with some effort we could have overcome that problem.

Why did the group fail to present?
P.
Normally an overload of extra curricular activities on Friday and Saturday does not give me any opportunity to go to marked meetings. I think the other group felt a bit deterred by the lack of time and therefore they thought it better to give up. I have thought in doing the work but we had to work as a group and therefore I stick to my decision. On Monday my fellow student L. wanted to present something of the work. I didn't want to be present and help because I took the decision not to and apart from that it didn't feel good because the others completed their work and our group did not. I

think I understand that part. I also have a particular way of working in a group and I think the other group was not used to that, I like to do things under pressure because ideas are clearer that way and I can concentrate on the work only.

L.

I have already answered this question.

L . *came the week after the presentation to have a talk with me. She told me that after the 5th meeting on Saturday evening Pr. called to tell that O. and she didn't want to continue. Since the professor wouldn't let them do the presentation without the other members and the fact that they had to prepare for an important test coming Monday they saw no sense in continuing. Sunday P. phoned and told her that on second thought he wanted to do the presentation. L. thought that with all the work done by O. and Pr. it would not be fair to have the presentation with P. Monday just before the presentation they met with the professor and were told that as an exception they could present with only three persons. O. desisted because she still didn't understand the basic DNA and felt incapable presenting and explaining.*

Pr.

Because not everybody was interested in the project and the theme, being different and complex called for more time than we had and more dedication of everybody.

O.

My sincere opinion as I have said before there was not the slightest interest but the worst thing was the lack of responsibility of those persons knowing they have committed themselves but don't show up. When the work that has to be done is of common interest they don't come without even a notice or an explanation. I know that our attitude of not presenting the poster was not very correct but it was the most sensibly thing to do. I don't think it is right to stand in front of our fellow students and not being able to present our work in the way it should have been done. I came to the conclusion that our two groups had a different and incompatible way of working.

As can be seen in Table 5.6 the participants were satisfied about the topic and positive, except B. and O. about their contribution to the exploration of the theme. The opinion of L about her contribution to the poster presentation is remarkable because she was the one who made the layout for the poster.

The sessions with the teacher were considered sufficient for the task (Figure 5.2) but the group sessions were assessed as having hardly any value for the task except for B. who dropped out after the second session. This opinion is not difficult to understand since the two self-chosen groups were forced into one group with different magazine articles. O. and Pr. did not feel that they had any profit from the sessions because it did not really help them to understand the problem. Other factors playing a role in their assessment were the failure of the other members to continue, time pressure and workload.

6. Discussion

In search for an answer on the case question: ***How are the members of the group interacting with each other?*** the most striking findings were the decreasing amount of verbal activity and the high amount of task-related behaviour.

The cause for the decrease of verbal activity can be found in a new category labeled as Non Verbal Reading computer (NVRc). This new category indicates the activity of surfing on the Internet and looking at websites by a group member alone or one member surfing while others are watching. The category was added after the second session (2B). In search for information, explanations and answers on question this NVRc category increased at the cost of verbal activities. Apart from comments on quality or utility of the websites no discourse took place. Another fact was that the video camera was not in the position to record the sites. Verbal interactions are needed in all phases of the learning process for exchanging information, generating ideas, interpreting possible solutions and reflecting on them. Cohen (1994) argues that when the problem is ill structured and the task is a group task productivity depends on interaction.

Remarkable also was that only once, with duration of less than a minute, non-task related behaviour could be observed. For this reason the category non-task related was removed from the system. This high task-related behaviour can perhaps be explained by motivation and interest of the students. From the aspect of cooperative learning and interaction session three can be interpreted as the most successful one. Although V., O. and Pr. interacted as a group they also made suggestions and discussed ideas with L.and P. and worked as a team in organizing the layout of the poster.

After this session only three members continued and two of them presented the theme to their fellow students. The amount of verbal interaction decreased as the sessions continued. There were moments of interaction when something was explained on a website but the notebook computer was predominantly used as a silent source of information.

What caused the failure of group work? Conditions for cooperative interaction and learning were present. *The composition of the group* according to size, gender, high-low ability level and different study background complied with recommendations from research findings (Johnson & Johnson, 1987; Cohen, 1994; Slavin, 1995).

The *time factor* was of importance in this case. Slavin (1995) indicates a four-week period as a minimum to achieve effects of cooperative learning. Between the first meeting and the presentation was a period of almost six weeks but after joining the two groups less than four weeks was left. Johnson and Johnson (1987) argue that the shorter the available time, the smaller the learning group should be to have effect and in this case the opposite happened. Apart from time pressure the different timetables of two theory streams and the academic week within the project period complicated the organization of the meetings.

Another reason could be the *group task* itself. Cohen (1994) indicates a relation between group task and interaction. A group task requires resources from the members of the group and cannot be completed individually. Group members are interdependent because they need each other for resources such as information, skills and knowledge to complete the task. The task in the mini project was: “read an article and explain with the help of a self made poster the theme to your fellow students.” Initially before joining the two groups, the task could be completed individually as P. remarked: “I have thought in doing the work myself (the poster) but we had to work as a group.” The instruction given during the second session was: “make one poster about the two themes.” This new task was indeed a group task because they had to exchange information about their articles, explain their theme and answer questions. This kind of interaction was observed in the second half of the second session (2B) after the teacher had left and in the third session when they already started organising for the poster. In the fourth and fifth session when the group decreased in number it became an individual task again. The theme ‘Computing with molecules’ was no longer a group item because L. a high-achieving student understood her article and now concentrated on the other topic. O. and Pr. both low-achieving students, could not explain their theme but they had to understand how computing with DNA works in preparation of the presentation. L. decided to investigate this problem, reading articles and surfing the Internet for information all non-verbal activities therefore reducing the amount of verbal activity. Whenever she found some helpful information she explained it to her self and the others by speaking out loud and sketching.

The second case question "***How are the students undergoing and experiencing the different phases of the learning process?***" could be answered only by observing the behaviour and not by testing the process in another way. The first session had an informative, structuring character. The objective of the project was outlined and the groups went from a state of uncertainty into the phase of investigation.

The first part of the second session brings them back into the indeterminate phase: how to organize the task; what is the subject of the other group about and how is it related with their subject. With these questions, verbalized by P. and L., they start the second part of the session. Explanations form the main part of the process but only L. and Pr are asking questions. The explanation given by V., O. and Pr. is not very clear, and although L. asks several questions they cannot answer any of them. Pr. in her email after the session: *We didn't understand the theme 'Computing with DNA" very well because we didn't have any other books to get information from. But we are trying to understand the text that was assigned to us.*" and V. writes: "*As far as the mini project is concerned I as well as my fellow students didn't understand quite well what exactly is computing with DNA because the English was difficult for us to handle."* L. and P. explain their theme quite well but only one question is asked in relation to their subject.

The lack of information mentioned by Pr. has not been resolved when they have the third session and they spent long periods of reading new material. P. and L. are moving into the next phase of the learning process because they managed to understand the basics of their theme. With this new knowledge about computing with molecules and some understanding of computing with DNA they look for similar parts and succeed. With this success P. and L. stimulate the others in organizing for the poster.

Even though O. is expressing her uncertainty about the theme: " *It is all very complicated to me"* and "*We have to investigate more about these points,"* she doesn't ask any questions. There is some discourse in this session but not on the high cognitive level that is needed for high-level learning (King, 1999).

L. manages to understand the principle of the Turing Machine that inspired the author to computing with DNA. Her habit of explaining out loud and elaborate with sketches is predicting achievement (Slavin, 1995, King, 1999).

In the fifth session Pr. with the help of library books recalls some prior knowledge about the elements of the DNA molecule and in explaining to L. she begins to understand more of the replication process. She has the habit of reading out loud passages from articles, which helps her to verbalize the problem.

O. stays throughout the sessions in the exploring phase hampered by lack of prior knowledge about chemistry (as she herself remarked outside the sessions) and not skilled enough to formulate the right questions. She persists in reading over and over again passages from articles but doesn't ask the right questions to gain the necessary knowledge.

During the presentation L. demonstrates her newly gained knowledge when she explains the computing with DNA leaving the chemistry part out but using mathematical formulas. She will be rewarded with the full 3 points to gain from this project. Pr. on the other hand only demonstrates factual knowledge and is rewarded with 1.7 points.

The answer on the third case question ***What kind of questions did the group members ask?*** was analyzed from a collection of 30 questions. One third of the questions belongs to the transformation category. This is consistent with earlier findings in the QQ-project (Teixeira-Dias, Pedrosa de Jesus, Neri de Souza and Watts, 2004) when during the second semester of 2001/02 questions were collected from the question box and via the software system. From a total of 204 questions 30% fell in the transformation category. From the 20 questions in the confirmatory category 75% were oriented toward organizing the final product. This is characteristic for this group. From the first session onwards the group directed their actions towards preparing the poster and didn't discuss the content of the themes. In sessions with the teacher only the two high achievers, P. and L. ask questions. L. asks the highest number (10) of questions equally divided over the two categories. As she is the only group member, from the remaining three, who achieved learning on a higher level this seems to strengthen

the theory that questioning is a necessary skill in the process of inquiry and higher order thinking (Zoller, Dori & Lubetzky, 2002). It is also consistent with the qualifications of a high quality questioner as is explained by Pedrosa de Jesus, Teixeira-Dias and Watts (2003). A high quality questioner demonstrates a sensible mix of confirmative and transformative questions directed at constructing knowledge.
O. keeps asking the same question not able to break that down in more productive ones. This strengthens the theory that question-posing capability can serve as a diagnostic tool to differentiate among academic levels (Dori and Herscovitz, 1998).

7. Conclusions and recommendations

With the question *what characterizes the activities in mini projects* this study started its exploration. One group of undergraduate students was selected and observed in their activities during the six-week project period. They set out with three members, expanded to six in the second session, had one drop out after the second session, two more after the third session and in the end two students improvised their final presentation at the last moment. Of course this is not exceptional for project work. From a total of eight groups, three groups presented their theme with an incomplete number of students.Joining self-selected groups with different themes two weeks after the start can raise a lot of problems in time, motivation and organization. The fact that participation is on a voluntary base makes dropping out easier.

Apart from these possible obstacles it can be concluded from the analysis of the recorded observations that *group composition, group task* and *social and cognitive skills* play an important role in the small group learning process. The group of three girls, all low-achieving students had the more difficult of the two themes and even though they were interested and studied the article they didn't manage to understand the theme. This seems to support the theory that a group should have members with different ability levels so the high achiever can explain problems benefiting and the low achiever.

The group task should not be one that can be completed by one individual, as was the case in this project but one that needs the cooperation of all group members. If a task is not really group-interdependent the final product will not necessarily be the result of group work.

Students having no experience with group work should be trained in social skills like leadership, communication, trust and conflict managing. Metacognitive skills such as planning, looking for and selecting sources and asking productive questions are important for group learning and must be developed. The teacher should monitor the group processing and see to it that groups have the social and cognitive skills to complete the project successful.

As a result from this study practical implications for the teacher can be summarized as follows:

- The teacher using the mini project as a cooperative learning strategy should decide on the size of the groups, the selection of the group members and the time given to complete the project work.
- The teacher should monitor the learning process and support the learner when cognitive and social skills are insufficient and hampering the learning.
- Observing the groups and collecting data has proved to be a useful tool in coaching the learner.

This study has shown that case study can be a valuable research design when using a mixture of qualitative and quantitative data. It can also be a useful tool for predicting learning outcomes and for learner assessment.

In 2007 the UA will comply with the Bologna Agreement and adapt the curricula conforming the agreement. The intention is to implement the mini project as a compulsory part of the undergraduate course unit Chemistry. Only one case was explored with an outcome not typical for all the participating groups. To compare outcomes a multiple case approach study is needed. Group task, group composition as well as the role of the teacher in group processing are elements of small group learning that need further exploration before the mini project is implemented as part of the undergraduate curriculum.

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