Understanding the task: How is agency distributed between tools, students and teachers in technology-rich learning environments?

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Understanding the task

How is agency distributed between tools, students and teachers in technology-rich learning environments?

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Abstract: In this paper we explore how students' agency relates to openness and structure within technology-rich, student-centred learning environments. This is done by analysing how students' understandings of tasks evolve through their activities in relation to the representations in the learning environments. In our interpretation of the sociocultural approach, we emphasise human activity as mediated by artefacts, where the output of the activity has to be understood by including human action and artefacts in the unit of analysis. We conclude by arguing that the relation between openness and structure is not a fixed point in spite of the level of structure and the agents' achievement in their interaction. The process of understanding a task is often complex and not transparent.

Introduction

Attempts to construct new learning environments that promote in-depth learning are often labelled student-centred learning environments (Land and Hannafin, 2000). These types of learning environments are contrasted with traditional instructional approaches, which are heavily criticized by the formers, who claim that students do not develop deep conceptual knowledge or cognitive flexibility within learning environments that are characterized by the IRE structure (Sinclair and Coulthard, 1975; Cazden, 1988). The idea behind student-centred learning environments represents an epistemological shift, where concepts like interpretation, construction, meaning making and socially negotiated, shared, meditated articulation frames how learning and the development of knowledge should be understood. Underlying this epistemological shift are different theoretical approaches. The main difference lies between constructivist approaches, where the individual is the unit of analysis, and socio-cultural approaches, where the unit of analysis includes agents in interaction with artefacts (for elaboration see Packer and Goicoechea, 2000).

During the 1990s there has been a systematic effort to develop and improve different kinds of student-centred learning environments. At the same time, there have been extensive changes in the technologies available for designing new learning environments. These technologies have the potential to influence the way students participate and engage. Hence, the purpose of this paper is to study how students' agency relates to openness and structure in student-centred technology-rich learning environments. This will be done by analysing two different learning environments that can be characterised as technology rich and student centred: a 3D learning environment that can be typified as highly structured, and a multimedia-learning

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environment where the design is open-ended. The aim of studying openness and structure in these environments is to contribute to the understanding of how tasks are understood in relation to the representations in the learning environments. It will be shown empirically that competing views often exist between participants during the process of understanding a given task. Further more, it will be shown that the technology influences the task as well as the process of understanding the task and the ensuing talk.

Different labels have been used to categorize attempts to construct new learning environments, whether they are technology rich or not, but the term 'guided discovery' (Brown et al, 1998) seems to capture a basic assumption. In environments built on the supposition behind guided discovery, the relation between openness and structure is not a fixed point. Rather, the analysis here will show that this relationship is dependent on several aspects:

- the complexity of the task;
- the subject domain;
- how the technological environment is designed;
- what kind of learning resources are available;
- the students' level of engagement;
- how the students work together;
- how the teacher is engaged in the activity.

In line with the assumptions behind the term 'guided discovery', it is possible to see the relationship between the openness and structure of a technology-rich environment not as dichotomies, but as the relationship between how a learning environment is designed and how the students work together.

The connection between openness and structure seems to capture a fundamental problem for learning in educational settings. To a certain degree, the knowledge is a given, being based on the curriculum, but there are certain degrees of freedom in how to teach subject areas and how to use different kinds of work formats. Interdisciplinary approaches could also be developed. The basic problem can therefore be seen as the relationship between the given knowledge, and the knowledge constructed in situ as part of student activities, where the given knowledge is only one important aspect. We argue that to explain this relation it is of vital importance to study the students' agencies in relation to the openness and structure of their learning environment. We claim that it is not possible to consider agency without thinking of structure (Holland, Skinner, Lachiotte Jr & Cain, 2001). This implies that we believe agency and structure cannot be separated from each other. Agency is implicated in structure and structure is involved in agency. Structure are not only constraining, but also enabling. Agency involves making use of historical given resources, their constraints and the contingency given in any social situation. Agency gives the agent an opportunity to act purposively or reflectively within complex historical situated interrelations.

Given knowledge in most educational situations is an important premise for teaching and learning in school. This fact has to be seen in relation to one of the most important findings in learning research the last 30 years, that robust conceptual understanding is dependent on prior student knowledge, and that the students' prior understanding needs to be explored in relation to the conceptual knowledge taught in schools (Brandsford et al., 2000). In order to achieve a deep conceptual

understanding, this paper will argue that students have to overcome the given knowledge to take part in productive interactions (see e.g.: Mercer and Wegerif, 1999; Stenning, Greeno, Hall, Sommerfeld & Wiebe, in press; Ludvigsen, Rasmussen and Solheim, 2001). The phrase 'productive interaction' is here used to mean that students become deeply engaged in solving tasks and problems where they develop new conceptual knowledge in a specific knowledge domain, or in project work. Productive interactions seem to have two basic features. The first is how students construct knowledge, which for them is new, and the second is how disciplinary knowledge – for example from mathematics or biology – is part of the knowledge construction. These two layers of knowledge construction have to be connected to the aims for the educational activity in a broader sense, which includes specific types of participation structures. This means that reproducing simple answers is not a productive interaction. Productive interaction is therefore a theoretical concept, which is important in designing the learning environment and is of vital importance in the empirical study of the actual learning processes. In the design effort shown here, productive interaction is an abstract principle, while in the empirical work, productive interaction is the end point of the analysis. Whether productive interaction occurs or not is defined by the analytic endeavour, where theoretical concepts are used. So there is no direct relationship between an abstract principle and the empirical analysis.

The aim of this paper is to explore how students' agencies are related to variations in openness and structure within technology-rich, student-centred learning environments. We approach this issue by studying two such environments designed to promote productive interactions: a 3D learning environment called Queen Maud Land,[2] and a multimedia-learning environment called LAVA-learning.[3] Three problem areas are raised to illuminate important aspects of the students' agencies:

- How do they understand the task and how are their goals evolving through the activities?
- How do they structure their activities in relation to the representations in the learning environments?
- How do the teachers get involved in the students' structuration of their work?

These questions can be seen as interrelated and the empirical analysis here will attempt to understand the relationship between agency, tasks and artefacts, as part of social practice. Interaction analysis will be used here as an analytical tool (Jordan and Henderson, 1995) and an attempt will be made to draw on these analyses to discuss how the presuppositions behind the designs are played out when students use representational systems and talk together. Four levels of analysis are integrated:

- The content level, which includes how different kinds of conceptual knowledge are developed in situ;

[2] Queen Maud Land is part of the Telenor R&D initiated project EduAction (http://www.telenor.no/fou/program/nomadiske/eduaction.shtml). Several papers and reports have been published during the project period. These are both design-oriented (Krange et al., 2000) and user-directed (Krange et al., 2002; Krange and Fjuk (in press).

[3] LAVA is a Norwegian acronym for 'delivery of video over ATM networks'. The Lava project is a multidisciplinary research project that focuses on the use of interactive multimedia for educational purposes (http://www.nr.no/lava/). Two book chapters were published during the project period (Ludvigsenet al., 2001; Ludvigsenet al., 2002).

- The interaction level, where students interact with each other and the representations inscribed;
- The participation structures, which implies how the students and the teacher position themselves in order to understand the task;
- The large-scale activities which entail how school activities are defined from the student perspective.

The paper will conclude by identifying problem areas related to further designs and the organization of tasks within such learning environments. As such, this paper is a contribution to both a theoretical discussion of variations between openness and structure in technology-rich, student-centred learning environments that aim to be productive, but it can also be considered as an empirical subscription to a more broad socio-cultural interpretation to students' agencies in such environments.

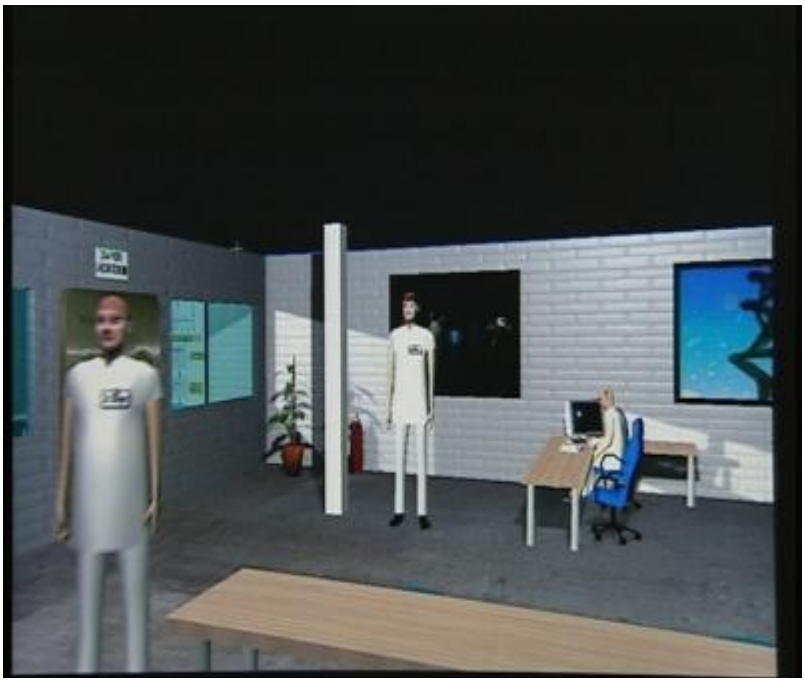
Designs of the learning environments

The two selected environments provide fruitful illustrations of how students' agencies are related to the degree of openness and structure of such environments. The design of Queen Maud Land can be characterised as being a highly structured, while the design of the LAVA-learning environment can be typified as open-ended. The two environments are not selected for the purposes of a comparison. Instead they function as different illustrations of technology-rich learning environments that have been designed to promote productive interactions. Furthermore, to provide a starting point for the theoretical and empirical discussion presented here on how elements of openness and structure relate to the students' understanding of the given task, how the students structure their activities in relation to the representations provided in the learning environments, and how the teachers guide the students' work.

Queen Maud Land is a three-dimensional (3D) learning environment[4] developed for the purpose of constructing a simulated learning environment for productive, collaborative activities. The 15-year-old students, together with their teacher, are geographically separated in such a way that their collaboration only takes place over networks and through real-time communication. The story that frames the students' activities is that they enter a secret laboratory at Queen Maud Land as researchers (avatars[5]), and that they are part of The Human Genome Project[6]. The students together with their teacher are aimed to solve different tasks related to DNA-problematic. These tasks are given when the students enter the learning environment. This implies that the students' agencies in Queen Maud Land take place within a highly structured learning environment where guidelines are clearly described. In this environment, students have to be co-located with their avatars in order to successfully solve the task.

[4] Three-dimensional (3D) learning environments "evoke a feeling of immersion, a perceptual and psychological sense of being in the digital environment presented to the sense" (McLellan, 1996: 457). This means that interactivity is of vital importance; seeing as it includes the feeling of touch and manipulation of artefacts, and that the participants' different viewpoints according to their position in space are attended. These support the students' awareness about their own and the others' activities in a setting were they are geographically separated.

[5] An avatar represents an agent in the learning environment. Avatars might be designed as humanoids, but they can also lack any resemblance to humans. In Queen Maud Land there are two kinds of avatars.



Picture 1: A distributed collaborative setting where students and teacher are gathered in Queen Maud Land.

The LAVA-learning environment is a net-based multimedia arena with a purpose-built tool and content for project-based learning. The environment has been developed to support project-based learning as defined in the Norwegian national curriculum. In addition, the co-located teacher hands out a print out; a step-by-step guide to project work developed to support the students' structuring of their work. The general theme of the project was 'Norway as a multicultural society' with an initial focus on food and culture and food and religion. The theoretical and normative foundations behind the designs are to create a multimedia learning environment that stimulates productive interactions in small group work. One of the main research objectives in the LAVA project is to study students' use of multiple resources. The task is given at the start of the project work when the whole class of students are gathered and are presented to the learning environment. The end product for students is expected to be a multimedia presentation.

In the macro world, shaped as a laboratory, the avatars look like scientists. In the micro world that represents a cell cosmos, the avatars have odd shapes adapted to suit this transparent gel universe.

[6] The researchers in The Human Genome Project aims to sequence the human DNA molecule. Link to the project: http://wwwornl.gov/hgmis/project/html.

Picture 2: A collaborative setting where students and teacher are gathered in front of the LAVA-learning environment.

Theoretical foundations

Socio-cultural approaches commonly understand that the relationship between agents and the artefacts is inseparable (Engestöm, 1987; Säljö, 2000; Vygotsky, 1978; Wertsch, 1998). This means that human activity is seen as mediated by different kinds of artefacts, where the output of the activity has to be understood by including human action and artefacts in the unit of analysis. Several socio-cultural researchers argue for multi-level analysis (Rogoff, 1990), but few have shown how these kinds of studies could be performed. The four following interrelated levels of description consider this further:

- A *content level* where the main focus is to highlight similarities and differences between how subjects are shaped. These bring together social and cultural guidance about how the subject is understood, such as its status and how it is presented. The relationship between procedural and conceptual knowledge is often considered differently in different knowledge domains.
- A *level* that discuss *the interactions between agents and artefacts* where the specific character of these interactions are the focus of analysis. A central element here is how the artefacts influence the agents' activities and visa versa. Also, how the social and cultural guiding are distinct present in the artefacts. This can be exemplified by the accumulated knowledge inscribed in the calculator (Säljö, 2000).
- A *participation structure level* that is considered to be the most important element of this interpretation. The third level is an abstraction where the two previous levels, in relation to the fourth level, are linked together. This makes it possible to study data at an interaction level, while also including more structural elements. The extended temporal dimension, which goes beyond a particular situation, seems to be particularly important. The identification of collaboration patterns among students is an example of such participation structures.

- A *social practice level* that focus on how participation structures are related to a broader set of long-term activities. This might be illustrated by how the students' interactions are influenced by task-solving structures within activity systems such as schools. Furthermore, how activities in schools relate to other activity systems where the students are engaged.

There have been several attempts to grasp social practice as multilevel phenomena. This paper will discuss three important efforts to organise for such multilevel analysis:

- The activity theoretical approach (Engeström, 1987);
- The synthesis of the culture historical activity theory (CHAT) and the language sciences (Baker et al, 1999);
- The situativity approach (Stenning et al., in press).

Within the activity theoretical approach the multi-level analysis is an explicitly formulated ambition.

Based on the activity theoretical approach, different types of participation structures can be categorized. Gallego and Cole (in press) have identified four participation structures: "(1) the teacher interacting with the whole class at once; (2) the teacher and students interacting in small groups; (3) one to one interaction between a teacher and single student and (4) student having no interaction with teachers or peers (seat work)." In addition, Gallego and Cole claim that it is important to emphasize that how tasks are understood is not trivial and that competing views sometimes exist between participants. This highlights a fifth participation structure: interaction between peers, where students interact with each other. These categories should not be considered exclusively, but rather as mixes of participation structures that form part of multiple learning trajectories. The participation structures described are part of activities that reach beyond the wall of a classroom, or a learning environment. This means that classrooms and learning environments are not homogeneous, but are rather characterized by diversity and hybridity. The dynamics in every learning activity are grounded in social and cultural diversity. Furthermore, the different activity systems or communities of practice, of which the students are part have different motives and goals, and this creates both discontinuities and continuities in the learning activities. Breakdowns or forms of tensions or disturbances can be understood as concrete events where the relationship between discontinuities and continuities becomes manifest in the data. Teacher intervention and negotiation between students might be indications of different forms of discontinuities. Here it is argued that the activity theory approach has its main emphasis on levels three and four as described above. This implies that proponents of activity theory characterize their analysis by a distinct focus towards collective aspects of activities, even though objects are the most important driving force in an activity system. The interactions between agents and artefacts as a semiotic process – and how these processes are related to collective changes – are de-emphasized.

The second effort of the multi-level analysis is the synthesis of the culture historical activity theory (CHAT) and the language sciences proposed by Baker et al. (1999). The main problem with this is how the aspect of time comes together in the two interpretations. According to the language science perspective it is the *moment-by-moment* interaction that is focused on, while the *long-term cycles* of activity fall within the scope of the CHAT interpretation. The combinations of these are not

sufficiently elaborated and explained in a coherent way. Based on the four levels outlined above, it could be argued that Baker et al. would benefit from using a concept such as participation structures to form a bridge between CHAT and their own language sciences approach.

The third effort of a multi-level analysis is the situativity approach (Stenning, Greeno, Hall, Sommerfeld & Wiebe (in press); Greeno and Hall, 1997). Their attempt is to combine analysis of social interaction in the mathematical domain at the semantic level, the interaction level and the discourse level, where structures of participation facilitate group reasoning. These levels are seen as integrated parts of how representational practices are co-ordinated in domain-specific inquiry.

To grasp the relationship between mathematical knowledge, social interaction and types of participation, Greeno and collaborators have developed concepts like problematizing, authorizing, and positioning. Problematizing implies an argument or a question, which the participants need to clarify in order to establish a common understanding or a disagreement. Authorizing imply that participants are positioned in the conversation, so that their voices are heard. Their utterances could be explanations or justifications or other types of speech. In the interaction where problematizing and authorizing takes place, both aspects are directed to achieve a better conceptual understanding of the problem at hand. However, it is an empirical question whether the students actually involve themselves in this kind of interaction and how these aspects eventually unfold during collaboration. Students position themselves towards the learning activity, the subject domain, and other students and teachers. The process of positioning depends on how activities in schools are structured and how the students view subjects as part of their activities. Problematizing, positioning and authorizing seem to be important aspects in creating productive interactions (Steening et al., in press). However, the problem within this approach is that ‘social practice’ as a concept is somewhat vague. This approach does not include basic premises where social complexity is understood as diversity, hybridist, and multi-voiced.

This discussion attempts to highlight that the concept of activity can offer opportunities in somewhat different directions. These directions are based on different positions within the socio-cultural field. Activity theory creates possibilities of understanding and analyzing the historical development of long cycles of activity systems (Engeström, 1987), and how more short-term situations and episodes are part of long cycles of activity. This provides a concept for the complexity of learning as mediated social activity. However, here it is argued that the activity theoretical interpretation is disposed to be structurally oriented. The CHAT–language science effort – which tries to bridge the understanding of long term activity and language oriented short term processes – tends to be problematic about the temporal aspect. The situativity approach has its main focus of attention directed towards semiotic processes. The concept of activity in this approach gives us opportunities to explore how students create specific kinds of learning trajectories, how students engage in specific domains, and participate in situations and communities (Greeno and Hall, 1997). This entails the combination of the four levels – content, interaction, particpation structure and social practice – and the use of the participation structure level is an crucial element that separates our interpretation from the others.

Knowledge production and productive interaction

In the last part of this theoretical discussion, a perspective will be presented that can provide an analytical grasp of how knowledge is produced. We will argue that Pickering's (1995) idea of "The Mangle of Practice", gives new possibilities of understanding knowledge production at different levels, ensuring a better understanding of knowledge given and knowledge produced.

By the idea of the 'mangle of practice' Pickering aims to understand how scientific work is achieved by machines, instruments, facts, theories and disciplined human activity, all intertwined in complex social relations. A key point for Pickering is that machines, instruments and artefacts perform certain actions and are part of the activities when research is performed. The machines and the instruments are designed to achieve advances in science and have to be seen as part of the mangle of practice. Humans and technology is a reciprocal relationship in the production of science and the development of knowledge.

In order to understand how agency and knowledge construction is distributed between tools, students and teachers, this paper will use Pickering's three concepts of *bridging, transcription and filling* (1995) for analysis. Bridging involves extending concepts or conceptual systems. This involves use of accepted methods or concepts. Transcriptions are connected with how to treat a new topic with regard to old and accepted concepts and methods. Filling is the process whereby agents give additional definitions in the new domain (Boaler and Greeno, 2000). The staring point for all three processes is a model that is given and historical accepted, by the research community. The process of transcription is performed by procedures, which is given by the knowledge domain. The researcher is not free to vary in the process of transcription:

> Bridging and filling are free moves, as I shall say. In contrast, transcription is where discipline asserts itself, where the disciplinary agency just discussed carries scientists along, where scientists become passive in the fact of their training and established procedures. Transcriptions, in this sense, are disciplined forced moves. Conceptual practice therefore has, in fact, the familiar form of a dance of agency, in which the partners alternately the classic human agent and disciplinary agency (here from Boaler & Greeno, 2000, p. 94; Pickering, 1995, p. 116).

Pickering's concepts of disciplined agency are understood as a relationship between free and forced moves, which may provide a great analytic potential to better understand how students work with given knowledge and how this is transformed to the socially accountable action in situ. Transcriptions as forced moves create a necessary condition for productive interactions. As forced moves, transcriptions create a necessary condition for productive interactions but, it can be argued, these only occur when transcriptions are combined with the free moves of bridging and filling. Productive interaction is understood as the given knowledge transformed through the actions played out in specific situations.

Pickering's idea of the 'mangle of practice' shows that given knowledge is constituted in a historical process, where the knowledge given and the knowledge produced becomes a cultural extension. Since Pickering's focus is directed towards knowledge production as disciplinary agency, it can be argued that the social complexity related to the fourth level of analysis is less emphasized. The three other levels comprise the historical dimension of a knowledge domain, and the forced moves (participation structure) combined with free moves (achievement in interaction).

Analytical tool and transcription method

To study the characteristics of openness and structure in learning environments, extracts of dialogues and the individuals' actions have been examined by using interaction analysis (Jordan and Henderson, 1995). The focus lies on how the students choose to work together and how they use the learning resources provided within the environment. Data gathered from video recordings of the students constitutes the basis for this study. It should be noted that the recordings were collected differently: in the 3D learning environment one of the networked clients acts as a recorder allowing the entire session in the learning environment to be played back during later analysis. The teacher's position as recorder provided an overview of all the activities in the 3D learning environment (Krange et al., 2002). In the multimedia environment the interactions between pupils, teachers and tools were filmed using a video camera. This information constitutes the fundamental empirical data in this analysis. Both approaches provide possibilities to focus on the temporal organisation of dialogues and actions, and on how the technical artefacts are used to operationalise certain actions. Also, to focus on the interweaving of the function of language use, the use of computer software, the practical solution of a task and the content. Another important aspect is that the experiences of the students become visible and documented in the "temporal orderliness and project ability of the events they construct" (Jordan and Henderson, 1995: 61). In addition to the temporal dimensions the 3D learning environment gives the possibility of studying socio-spatial aspects, ie, how students oriented themselves *within* the environment. This becomes especially important when the students move with their avatars in Queen Maud Land. Finally valuable aspects can be included while studying the participation structures as part of a broader set of long-term activities.

A transcription of the unfolding dialogue is presented below. Short pauses and overlaps are indicated in the text. Indications are also made of what the students are doing. The level of detail in both transcripts suits the depth of the analysis and creates a high level of transparency so the reader can easier follow the dialogue. Technical details that are usually given by linguists interested in the relationship between meanings and form are not given here. One of the aims of this transcript is to preserve the liveliness of the interaction: "Literal transcriptions of classroom talk which faithfully record all the words can be lifeless and can also be uninformative about some of the meanings being exchanged" (Edwards and Westgate, 1994:62). Both the Norwegian transcripts and the translated English versions are presented.

The students' agencies related to the degree of openness and structure of the learning environment

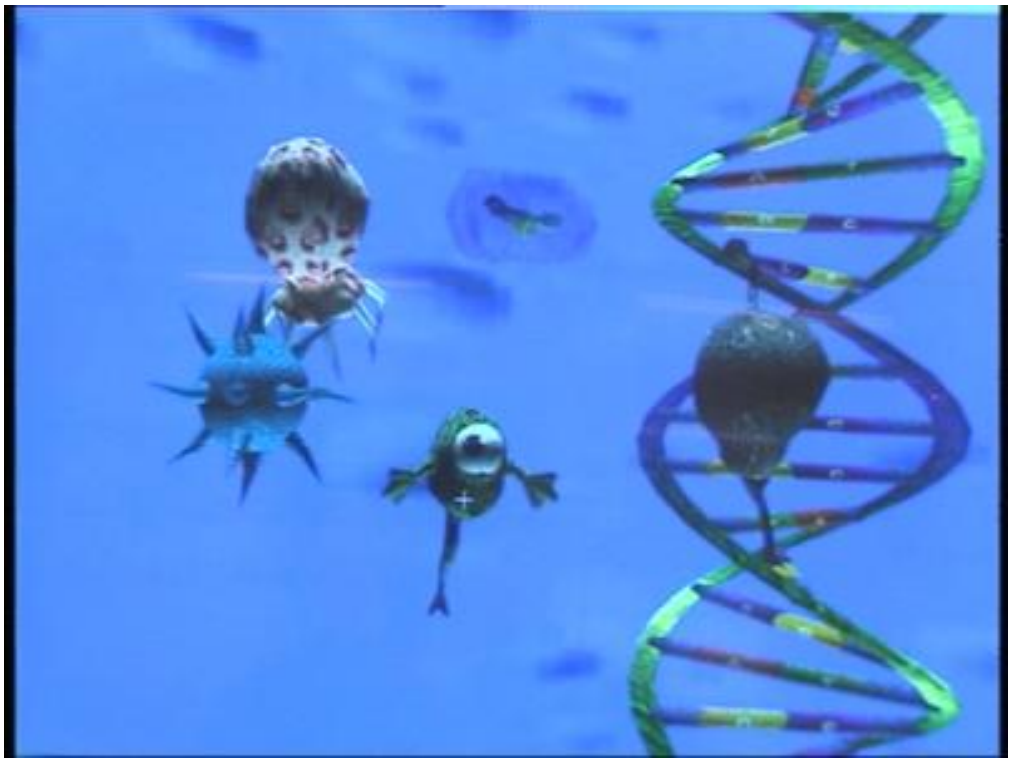
Two separate analyses illustrate how the students' process of understanding a given task constrains and enables in situations are related to the degree of openness and structure of the learning environment. The analyses are gathered from two separate design experiments (for elaboration see Brown, 1992). Dialogues are given first from Queen Maud Land and then from LAVA-learning. These analyses should be

understood as a contribution to the discussion of how students' agencies are related to the degree of openness and structure within learning environments.

Illustration one: Queen Maud Land[7]

To explore how the students' agencies are related to the degree of openness and structure of the 3D learning environment, the focus here lies on an extract gathered from a process where students are solving a task about how to sequence a DNA molecule. All the information needed to solve the tasks is given either in the 3D learning environment or on a website provided to support the students' activities. This latter learning resource consists of a main page, the missions (tasks), important vocabulary, a library with relevant links and a description of 3D navigation.

The task starts in what we have called macrocosm, a specialised laboratory or the so-called sequence lab. Here there is an entrance into what we have called microcosms were the participants, represented as odd avatars, are able to participate in activities at a cell level. The students have previously solved different tasks on what part of the DNA structure looks like (a gene), what its basic units are (pairs of bases) and how these are related (A and T, C and G). We enter into the data where, as we will argue, the students are about to understand how they are going to sequence the gene structure (read from the bottom to the top and along one of the sides of the gene structure) and find out how to close the task (compare the reading with three sequences they find at the web adjusted to their problem solving and decide which of these that are similar). Information about how to sequence is explicitly expressed in the given task.



Picture 3: Students and their teacher in microcosm about to sequence the gene structure.

[7] This data is from an upper secondary school, located in the suburbs of Oslo. The recording was made in January 2002.

The students have until now discussed what 'sequence' means and what kind of activities they have to realise to sequence the DNA molecule. In addition to the mission page, they have used the 'vocabulary' page at the web as learning resources. The sequence task was rather complex in the sense that it requires integration of the previous tasks as well as reasoning and negotiation. This implies that the students had to understand specific, foundational aspects of the knowledge domain to be able to solve the more advanced task. The whole dialogue takes about 22 minutes. Henry is the teacher, while the others are students.

1. Henry: Trykk slik at dere får opp oppdraget. Og der står det - les oppdraget … *(Alle studentene ser på weben.)*	1. Henry: Press so you reach the task. Read the task … *(All the students looks at the web.)*
2. Cornelia: Sekvenser DNA molekylet. Hvilke av de tre sekvensene A, B og C er den riktige? *(Cornelia leser fra weben.)*	2. Cornelia: Sequence the DNA molecule. Which of the three sequences A, B and C is the right one? *(Cornelia reads on the web.)*
3. Henry: Ja, ok. Og hva ser dere under spørsmålet.	3. Henry: Yes, ok. And what do you see below the question?
4. Pat: Alle de der forskjellige …	4. Pat: All the different …
5. Cornelia: Sekvens A, sekvens B, sekvens C …	5. Cornelia: Sequence A, sequence B, sequence C …
6. Fredric: Det er ikke så veldig vanskelig fordi du skal bare lese de der oppover og finner ut hvilken som er den riktige.	6. Fredric: It is not that difficult because you are just going to read upwards and find out which one is the right.
7. Pat: Å ja, da er det ikke så veldig vanskelig da. Da er det bare å begynne.	7. Pat: Oh yes, Then it is not so difficult then. Then it is just to start.
(51) *(Gruppa snakker litt videre.)*	(51) *(The group talks a bit further.)*
8. Pat: TAC TTT GTC TTG GA (...) *(Beveger seg rett oppover i 3D verden.)*	8. Pat: TAC TTT GTC TTG GA (...) *(Moves straight upwards in the 3D world.)*
(177)	(177)
(Cornelia skriver ned det Pat sier slik det står i oppgaveteksten og avklarer lesningen underveis der dette er uklart. Guttene småsnakker litt, mens læreren holder seg i bakgrunnen. Alle er i mikrokosmos.)	(Cornelia writes down what Pat says as asked to do in the task text and clarifies the reading where there are uncertainties. The boys are chatting, while the teacher keeps himself in the background. All are in microcosm.)
9. Pat: C og det var det hele.	9. Pat: C and that was all of it.
(242)	(242)
(Studentene oppdager at de har lest feil og de har en lengre diskusjon på hvordan de skal sekvensere DNA molekylet. Skal de lese ovenfra eller nedenfra, og på høyre eller venstre side av molekylet.)	(The students find out that they have read wrongly and they have a longer discussion about how to sequence the DNA molecule. Are they going to read from the top or the bottom, and at the right or left side of the molecule.)
10. Henry: Da begynner du nederst, Fredric.	10. Henry: You start at the bottom, Fredric.
11. Fredric: Greit, jeg er nederst.	11. Fredric: Fine, I am at the bottom.
12. Pat: Så da kan vi følge med om det er riktig, ok.	12. Pat: So then we can follow if it is right, ok?
13. Cornelia: Ja.	13. Cornelia: Yes.
14. Pat: Begynn Fredric.	14. Pat: Start Fredric.
15. Cornelia: Begynner vi helt oppe ved ATG eller CAA?	15. Cornelia: Are we starting at ATG or CAA?
16. Pat: ATG.	16. Pat: ATG.
17. Fredric: Begynner jeg på T eller begynner jeg på A.	17. Fredric: Do I start at T or do I start at A?
18. Cornelia: Du begynner …	18. Cornelia: You start …
19. Pat: A.	19. Pat: A.
20. Cornelia: Hvor er folk hen da?	20. Cornelia: Where are you then?
21. Pat: Vi er inn i den derre …	21. Pat: We are in that …
22. Fredric: Hvor forklarer vi hen?	22. Fredric: Where do we explain?
23. Mark: Vi bare leser der det står.	23. Mark: We just read where it is written.
24. Fredric: Der er Henry *(he he)*.	24. Fredric: There is Henry *(he he)*.
25. Mark: Kom igjen, fortell...	25. Mark: Come on, tell me ...
26. Fredric: Ok.	26. Fredric: Ok.
27. Mark: Ja.	27. Mark: Yes.
28. Fredric: T. *(Beveger seg fra side til side for å håndtere rotasjonene i DNA molekylet. De andre er*	28. Fredric: T. *(Moves himself from side to side to handle the rotation in the DNA molecule. The others are back at the web and make corrections while Fredric*

igjen på weben og korrigerer hvis han leser feil. Henry holder seg i bakgrunnen.) 29. Mark: Ja. 30. Fredric: G. 31. Mark: Riktig. (186) 32. Pat: Ja, helt riktig. Det er sekvens A. 33. Mark: Helt riktig. Ja, det er sekvens A. 34. Fredric: Er det sekvens A. 35. Pat og Mark: Ja. 36. Fredric: "Let's go outside a."	*reads. Henry keeps himself in the background.)* 29. Mark: Yes. 30. Fredric: G. 31. Mark: Right. (186) 32. Pat: Yes, that's right. It is sequence A. 33. Mark: That's right. Yes, it is sequence A. 34. Fredric: Is it sequence A. 35. Pat and Mark: Yes. 36. Fredric: "Let's go outside."

The extract shows three different interaction sequences. First (sentences 1–7), the students and their teacher work to understand the task. Second (sentences 8–9), they fail in solving the task. Third (sentences 10–36), they start over again and this time they succeed.

These interactions display both teacher (sentences 1, 3 and 10) and student intervention (sentence 8). There are three types of teacher intervention. First (in sentence 1), the teacher *closes a discussion* about what they are going to do by asking the students to read the task over again. Second (sentence 3), the teacher *gives direction* for further activities by following up his first comment. Third (sentence 10), the teacher offers Fredric a *concrete hint and ends the students' discussion about how to sequence the DNA molecule*. As for student intervention (sentence 8), Pat's action oriented profile is worth mentioning. At one point she does not wait for the other students to agree. She just acts. The discussions seem to be circular; they read the task, gather information, talk about it and then return to the task. Even though the task is clearly defined, they have to read and re-negotiate it until they have understood it properly. This implies that even though the task is clearly defined and constructed step-by-step, confusing and competing views exist among the participants. In the process of understanding, even detailed explained tasks are not trivial (Gallego and Cole, in press).

Another interesting aspect is the different strategies used while they are failing in the task (sentences 8–9), as opposed to when they are succeeding (sentences 10–36). While failing, Pat and Cornelia begin to collaborate. Pat is reading, while Cornelia, as requested by the task, is labelling the bases along the DNA molecule. This is not the best way to solve the task partly because the boys become passive, but also because the students only consider one learning resource at the time. All of them are, at least most of the time, located in the microcosm. In addition, it is obvious from the tape that Pat is not moving adequately through the 3D learning environment. She misses the difficulties that are inscribed in the rotated molecule while she moves straight upwards during reading. When the students begin to succeed, Fredric first of all clarifies which side of the molecule he is going to start sequencing from (sentence 17). Furthermore, he and the others choose to split up so that Fredric is the only one in the microcosm while the others are looking at the three sequences on the web to sort out which is the right one. Finally, Fredric, in opposition to Pat, manages to move adequately according to sequence the DNA molecule in the 3D learning environment, moving sideways to comply with the rotations in the molecule. In both situations Pat and Fredric are bridging by using the knowledge they have collaboratively constructed during the previous tasks (see Pickering, 1995). The teacher's repetition of the importance of closely reading the task and the students gradually understanding

of how to sequence is reminiscent of transcriptions. Meanwhile, it seems that Fredric is the only student able to perform filling activities by understanding which side of the molecule he is going to sequence from, and by combining the curriculum knowledge with the specific representations that are so characteristic to 3D learning environments. In the interaction Fredric develops a position where he moves between the task and the conceptual aspects of the task. This is necessary to make transparent the relationship between the task and the concepts. In other words the students are able to bring their newly constructed knowledge into new situations via their collaborative efforts, but it is only Fredric who manages to use this adequately in relation to the possibilities and constraints of the situation.

This implies that there are 'mangles of practices' in the students' efforts to solve the task. They carry out both free and forced moves, and it is in the combination of these that productive interactions occur. Here forced moves refer to the repeated process where the teacher prompts the students to go back to the text where the task is explained. The design of the environment also forces the students to move in specific ways. In this process of navigation they go through a process of transcription, which is a necessary condition for arriving at the bridging and filling process, where the understanding of how to 'sequence a DNA molecule' is performed. To do this the students need to be deeply involved in solving the task and thereby develop new conceptual knowledge related to DNA problems. They need to position themselves in relation to the disciplinary knowledge.

Further it seems that there are 'mangles' of participation structures shifting between student interactions, and student–teacher interactions. These two kinds of participation structures also seem to pull in different directions. Student interactions are dominated by problematizing where the students clarify and exchange their views. Student–teacher interactions are characterised by authorizing, where the teacher gives directional hints and gathers the students' focus during problem solving (Stenning et al., in press). This finding seems rather counter-intuitive because one could expect that a highly structured environment would create knowledge production, with less need for authorizing. This finding needs further explorations.

Based on these analyses, it is argued that forced moves performed in the transcription process provide the necessary condition for productive interaction, because the students need to appropriate the given knowledge to a certain degree. These conditions open up the possibilities for the bridging and filling processes as the free moves. It's in the interaction between these different kinds of moves that productive interaction occurs as part of students' practices.

Illustration two: Lava-learning[8]

The students' agencies are, in the LAVA-learning environment, related to an open-ended task in an open-ended environment. The children's assignment was to work together and make a multimedia presentation with initial focus on food and culture and food and religion. They were told to use the purpose-built software tool 'Slime', and the project's web pages about food, culture and religion, together with books,

[8] This data is from a lower secondary school located in the eastern part of Norway. The recording was made in April 2001.

CD-ROMs and the Internet. Over a period of three whole school days, the students (aged from 11 to 12) worked together, four in each group. The school has several small rooms for group work so most groups had a permanent base with an online computer. The students also had access to several online computers in the computer hall and to the adjacent library.

The 'Slime' tool enables integration of different data types in one multimedia presentation. Multimedia elements such as audio, film, text, pictures and web pages can be imported and then placed onto the canvas of the tool. The spatial placement can be done freely by placing the data-types as the user wishes. The data types are organised along a global timeline and are placed under user-defined scenes with different headlines.

The project's web pages consist of a home page on the Internet designed as a collage. Behind each picture the user can access different elements, like text, sound and film clips that relate to the theme of food, culture and religion. The web pages also contain articles and pictures from a Norwegian publisher, a list of relevant film clips from the Norwegian Broadcasting Corporation and a selected archive of text, pictures, film and audio clips from the National Library of Norway. The pupils also used books, pens and paper. Thus the pupils had access to, and used, multiple resources.

The following extract takes place after the whole class has looked at the project's web pages. The teacher has talked about how the groups should work together to create a multimedia presentation. The web pages were projected at a screen so that the pupils could look at the content while the teacher talked. After watching several film and audio clips, the pupils were asked to discuss what they had just seen and listened to. The children were then asked to join their groups and begin the collaborative work. The children were left to research the content, specifically developed for the project, to use as a starting point for the group work on problem statements. This extract is selected from the talk that took place as the pupils gathered around the computer to look at the web pages. Paul and Anna are standing behind Nancy and Greg who are sitting at the computer. John, the teacher, is also standing. He is looking through the project's content with the pupils, explaining what the films are about.

1. John: Her er det noe som heter ølbrygging. Hvordan man brygger øl og lignende- ehh margarinreklame. Bruk av fisk og grønnsaker, det er sånn gamle filmer fra fra gammelt av, litt sånn reklamefilmer (...) Brødbaking. Også den med de elevene på Bjølsen skole som forteller litt om om kulturen de kommer fra (...)	1. John: Here is one named beer brewery. How one brews' beer – ehh a margarine commercial. The use of fish and vegetables, they are old films from from years back, a bit like commercials (...) Bread baking. And the film about the pupils at Bjølsen secondary school who is is telling about their culture (...)
2. John: Nå skal ikke jeg styre dere veldig mye I dette her annet enn at dere kikker litt på bildene og websidene.	2. John: Now, I`m not going to control this a lot, besides that you take a look at the images and the web-pages.
3. Paul: Skal vi ikke begynne å jobbe liksom	3. Paul: Shouldn't we start working now then?
4. John: Ikke sånn konkret ennå Paul- nå starter vi først med at dere får kikke litt på det som er her- se på det dere synes er spennende også må dere etter hvert gjøre et valg	4. John: Ehhh (Smiles) not concretely yet Paul (...) we'll start with looking at what you have here. Look at what you find interesting and from there you'll have to start making a decision.
5. Paul: Skal vi velge ut fra det da?	5. Paul: Should we decide out of that then?
6. John: Ja ut fra at dere har sett på alt som er- nå skal dere på en måte sondere hele terrenget dere skal se på alt som finnes da har dere et litt bedre utgangspunkt I	6. John: Yes, if you have looked at everything – now you'll have to overlook the scenery – you'll have to look at all that's there – then you'll have a bit better starting

stede for å si (med "tullestemme") ja vi velger den som handler om ølbrygging (elevene ler litt)- så har vi ikke tenkt noe mer på hvorfor vi velger den- så mens dere nå ser på filmene og mens dere leser websidene så finner dere kanskje noe som dere finner er *ekstra* spennende som dere har lyst å jobbe litt mer med.	point. Instead of saying (makes a cartoon-like voice) yes we'll choose the one on beer brewery (the pupils laughing). Then we haven't really thought about why we're choosing it, so while you watch the videos and read the web pages you might get to something you find *especially* interesting that you would like to work on.
7. Paul: Men du- hadde det ikke vært bedre om for eksempel en satt her og en satt på datarommet (peker) eller liksom fordelt oss litt- for da kunne vi- sa kunne vi bare tatt å -si at Anna fant en her som hun ville ha- så kom vi andre og så på den og så kunne vi diskutere ut fra det.	7. Paul: But – wouldn't it be better if for example one sat here and one sat in the computer hall (pointing) in a way split up. Because then we could – we could only – let's say that Anna found she wanted to use – and then the others could look at it and discuss it.
(John svarere at det hadde vært fint, men så mange maskiner har vi ikke med dette utstyret) …….. (50)	(John answers that it sounds good, but there aren't enough computers with the right equipment) ……. (50)
8. Paul: Men sånn som den derre (peker). Si at plutselig jeg kommer med en film og den er fjorten minutter skal vi sitte å se på hele den?	8. Paul: But like this one (points). Say, that I found a film and it is fourteen minutes long, shall we then watch the whole thing?
9. John: Det vil ikke jeg si noe om egentlig Paul. Jeg skal ikke si at dere skal se alle filmene for da. Ehhh, for det første ville det ta veldig veldig lang tid hvis dere skulle se på absolutt alt. 10. Paul: Det var det jeg også mente.	9. John: I don't really want to make that decision Paul. I'm not saying that you should look through all those films because then. Ehhh, first of all it would take a long long time for you to watch absolutely every film. 10. Paul: That's what I meant.
11. John: Og for det andre så går det ann å hoppe litt i filmen (...) sånn som du gjorde nå i stad (…) Men dere må etter hvert som dere ser ting nå som dere synes er spennende så må dere snakke litt om det (...) i gruppa og si hvorfor dere synes at akkurat det var spennende (...). Og så argumentere du Paul med at jeg syns at dette er bra, jeg har lyst til å jobbe med dette fordi sånn og sånn og sånn. Også sier Nancy at ja det er vel og bra, men jeg så en annen film som jeg synes var veldig bra og det gjorde jeg fordi sånn og sånn og sånn. 12. Elevene: Mmmm (humrer litt)	11. John: And secondly it is possible to skip through the film (...) like you just did (…) But as you look at films that you find exiting you must talk a bit together about it (...) the whole group and tell each other why you find that film exciting (…) And then you Paul argue that I think this is one is good. I want to work with this because this and that and this. And then Nancy will say that yes that is nice but I looked at another film which I think was good and this because this and that and this. 12. Pupils: Mmmm (amusement sound from the children)

The sequence starts with the teacher giving a summary of the list of on-line film clips from the Norwegian Broadcasting Corporation available on the web pages. Then, (sentence 2) he says he will not "control this a lot". However, they should look at the images and the web pages. The talk (sentences 3–7) is a negotiation between Paul and the teacher. They are negotiating; what is it to do school work and how the pupils should conduct the task. Paul is trying to understand the task (sentence 5) and also how they should conduct the task using the recourses provided on the web pages. In (sentence 7) Paul puts forward a suggestion that is rejected by the teacher. The teacher answers that the suggestion sounds reasonable but that there aren't enough computers with the right software. Further, (sentences 9–12) they are talking about how to use the on-line film clips. The analysis begins by focusing on how the students' process of understanding the task is intertwined with the openness of the learning environment and the representations inscribed.[9] Then, an examination is made of how the teacher becomes involved in structuring the students work in this open-ended environment.

[9] The use of the term 'inscription' in this paper is inspired by Latour's work (1990). However, this will however not be elaborated upon further.

Firstly, this data provides an example of a negotiation process about how to work together, how to use what is available to solve the task, and how to define the task. As a result, the use of multiple resources becomes part of the task. The process of jointly understanding the task is linked to understanding how to work and how to collaborate. In the process of understanding how to work, Paul is looking for a common reference point, which can give him and the group a direction for their work. This is not given, so the students and the teacher need to create some kind of forced moves (sentence 5). The forced moves are directed to choose part of the content as a starting point. The teacher's answer attempts to create forced moves, and points to the method of doing project work. His instructions on how to use the representations inscribed in the environment also focus on the joint process of doing project work. The 'mangles of practices' are then represented by Paul and John's negotiation on how to use the representations inscribed and how the pupils should talk together.

In relation to the content level, this extract of talk does not contain anything about the theme of the project work; the talk revolves around the method of how to work together in this environment. It can be argued that understanding the task is equivalent to the process of seeking joint understanding on how to collaborate in this learning environment. Paul says (sentence 3): "Shouldn't we start working now then?" implying that looking at films, images and web pages is not work. Paul's question can also be looked at as talk about what schooling is and then illustrating a viewpoint on what pupils and teachers should do in this institutional context. Paul elaborates this further (sentences 7, 8 and 10) when he is talking about how the pupils' could divide the task and weather they all should look at a film clip that is fourteen minutes long. He suggests a more efficient way of working together. We interpret Paul's suggestion (sentences 7, 8 and 10) both as an expression about schools as a place where pupils solve tasks, and these are not tasks children choose themselves, therefore they should be solved in an efficient manner. And at the same time Paul is advocating a jigsaw model of collaboration (CTGV, 1997). On the other hand, the teacher, talks about collaboration as a joint process characterised by rational discussions (see e.g. Mercer, 1994). The teacher says (sentence 11) that the pupils should work together explaining each other why they prefer certain films as a starting point for the group work on problem statements. This way of designing for different participation structures (Gallego and Cole, in press) can be seen in relation to the attempt to design for productive interactions (Mercer, 1994). Gallego and Cole write that it is important to emphasize that how tasks are understood is not trivial and that competing views sometimes exist among participants. By problematizing (Stenning et al., in press) the work method, Paul raises a question that needs to be clarified in order to establish a common understanding or a disagreement and hence to better understand the problem at hand (Edwards and Mercer, 1987). In relation to the openness of the learning environment there are several utterances, which are indications of tensions or breakdowns (sentences 5 and 7). The two collaborative models expressed are linked to the openness of the learning environment because this openness leaves room for negotiation. The representations – together with the participation structure – play an important role in how Paul and John talk about collaboration and the task (Crook, 1999; Säljö, 1999). Their negotiation indicates, through problematizing and authorising how to use the multiple resources, how they position themselves and how they relate to the learning environment.

Secondly, the teacher is saying (sentence 2) that he is not going to control this "a lot". He is trying to organize the student's activities in relation to the representational system so the students take charge and through that develop an ownership of the content that they have actively selected. The teacher says (sentence 6) that the students need to have an overview of the scenery to get a better starting point and by doing this: "you might get to something that you find especially interesting that you would like to work on". Encouraging the students to take charge relates to child-centred learning and to finding about students understandings and how this is dependent on students' prior knowledge (Brandsford et al., 2000, Hakkarainen et al., 2001). It is argued that what students learn in the school contexts depends on the activity they are engaged in (Greeno and Goldman, 1998) and that students need to be closely engaged in their activities. It also relates to the endeavour of designing for different participation structures using new technology and thus constructing different opportunities for developing new conceptual knowledge.

Finally, based on these analyses it is argued that the lack of forced moves in this learning environment creates a situation where Paul, as part of his agency, seeks authorization in order to understand how to work collaboratively and through that create an understanding of the task. The two models of collaboration presented points to the aim of designing for productive group interaction. In order create productive group interaction, in this learning environment, the students need to talk together in order to create a common understanding. Conversely, it is possible to see that a jigsaw model of collaboration would only have the potential for productive group interaction when the students' meet face to face.

Conclusions and further comments

This article is a contribution to understanding the variations between openness and structure through students' agencies in technology-rich, student-centred learning environments. The aim has been to explore this by studying students' agencies in two different learning environments. Variations between openness and structure have been identified by analysing the students' agencies, where artefacts play an inseparable role in the activity. As a result attention has been drawn to how the relationship between openness and structure is not a fixed point. Drawing on four interrelated levels of description, this paper concludes by arguing that, in spite of the level of structure and the interaction achievement, the process of understanding a task is often complex and opaque.

At the content level, the talk in the LAVA-learning environment does not contain anything about the theme of the project work. The talk revolves around the process of understanding how to work together and, by that, seeking forced moves. It can be argued that understanding the task in this open-ended learning environment is equivalent to the process of seeking joint understanding on how to collaborate. Furthermore, the analysis of Queen Maud Land has shown that when the students needs to appropriate given knowledge, it is necessary for the students to perform a set of forced moves. The forced moves performed in the transcription process are a necessary condition for productive interactions, because the students need to appropriate the given knowledge. The conclusion of the analysis of interactions in

Queen Maud Land is that the students gradually understand the 'given' task. This implies that their goal is shaped as a part of clarifying the task. Their agencies are clearly related to the structure of the learning environment, and it is only when this relation is understood that they are able to solve the task. The data extracted from Queen Maud Land illustrates students' agency in a structured learning environment. Their process of understanding and being able to solve the task lies in the relation between the knowledge domain, which is given, and the conceptual knowledge developed in situ. Productive interaction occurs when forced moves are combined with the free moves in the environment.

The forced moves have to be achieved not only on the content level, but also at the interaction level. The relationship between the content, the interaction, creates different participation structures. One important point is that these participation structures are produced by the semiotic work done by the students and teacher in relation to the task. A specific participation structure can therefore be identified in the interaction between agents and artefacts. The conclusion of the analysis of the students' interactions in the LAVA-learning environment points toward the need of a joint negotiation about how to work in an open-ended learning environment. This implies that the students' goal shapes slowly as the joint negotiation proceeds. The students' agencies relate to the openness of the learning environment, the multiple resources, and the open-ended task. The students' therefore seek forced moves in the work method, it seems that they want the teachers to authorize these forced moves. As argued earlier, the process of understanding a task in collaborative group work relates to the process of gaining joint understanding on how to collaborate and how to use the representations inscribed in the learning environment. This finding relates to both learning environments. The process of gaining a joint understanding on conducting collaborative work mirror to a large extent the process of understanding the task in both environments. In spite of the differences relating to openness and structure – both in the way the task was set up and according to the representations inscribed in the two technology rich learning environments – the process of gaining joint understanding is still the main challenge in collaborative work. This process looks different in the two environments but this difference seems to relate to subject domain and not so much to the technology in use or general design. This finding brings us to support Gallego and Cole's (in press) claim that it is important to emphasise that how tasks are understood is not trivial and that competing views sometimes exist among participants.

In relation to different participation structures, it has been argued here through the analysis of two learning environments, that both students and teachers are involved in structuring students' work. Furthermore, teacher interventions are vitally importance even though activities in the learning environment are clearly expressed through design and that the knowledge domain is defined step-by-step (see Gallego and Cole, in press). Without the teacher's interventions the students would not be able to create free and forced moves (Hakkarainen et al., 2001). At one level it seems that the students in the most structured environment were most dependent on the teacher to authorize their understanding of the task. In the more open-ended environments the authorizing was mostly concerned towards the work processes. This finding was counter-intuitive for us, and needs further work.

The fourth level seems particularly apparent through our analysis of the LAVA-learning environment, where the understanding of task is part of an ongoing negotiation. The openness of the LAVA-environment turns the students' activities into seeking clarification on how to work. These kinds of breakdowns occur only in the open-ended environment, where the negotiation process indicates diversity on how schooling is perceived. The idea of efficiency, where a high degree of labour division is crucial, could be seen in contrast to the idea of talking to create a common knowledge, where a low division of labour is a condition for productive interactions. When the work format and the content are both turned into negotiations, the idea of schoolwork become essential. These kinds of discussions relate to how participants both inside and outside the school think about schooling. Schooling is seen here as a large-scale activity, as part of a diverse and complex society.

In the Queen Maud Land, the development in the Human Genome project is the 'mangle of practice' that provides the possibility for the design of this environment. The accumulated knowledge in which the Queen Maud Land the students now can take part, was discovered by advanced scientists only a few years ago. This also shows us how knowledge accumulates at a collective level of society, and that students are exposed to more and more demanding cognitive and social tasks. So Queen Maud Land as a learning environment is only possible as a historical development at the level of social practice.

At the theoretical and methodological level, the empirical analysis presented here is weak at the level of participation structure. No data has been chosen to provide a reasonable insight into the temporal aspects of the activities performed. However, the aim here has been to contribute to the theoretical discussion about multi-level analysis, and illustrate how such analysis might be performed.

As a conclusion it is argued that the kind of multi-level analysis tried out here provides us with a reasonable and promising account of how moment-by-moment interaction is constituted as part of larger-scale activities. This is a socio-cultural stance and a way of showing more clearly what is going on when agents interact with artefacts and what this means for our attempt to understand learning. These could be considered as part of the theoretical and methodological discussion of how and what students learn as participants in different kind of learning environments. Further theoretical and empirical work is needed to elaborate the notions of multiple level analyses.

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