

Papers, Screens and Genes

A Socio-Cultural Case Study of Group Work with Multiple Resources

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Abstract

Being familiar with scientific concepts is important both in the Norwegian curriculum, and for our understanding of ourselves in the world. Learning science has for long also proven to be hard for students, and particularly in the topic on genetics, the building blocks of life, do students struggle.

This socio-cultural case study investigates students work and meaning making in a lower secondary school science class, and the research question for the thesis are:

1. What characterizes group work in this multi-resource environment?
2. How do the students make sense of various representational forms?
3. How does the range of representational forms and resources challenge the class-room norms and rules?

By employing an embedded strategy, this study's primary analysis is founded in interaction analysis, whilst quantitative data from student's written products and pre- and post-test are used for enriching and contextualization. The data reported on in this thesis comes from a case study in the Ark&App project at the University of Oslo's Department of Education¹, and makes use of video-recorded interactions, interviews, pre- and post-test results and some of the students' written end-products.

Summed up, the main findings in this study are: Students are socialized into being students in schools, and changing the way in which they conduct their daily practices is not always without troubles. Removing the traditionally strong authority of the textbook, and allowing the students to freely inquire for information also removes the structures from the work. By lacking structures such as clear tasks, how to divide the labour and what representations and representational tools to use, students may easily lose track of the purpose of their activity. Without a clear object to direct their activity towards, the students in this study struggle to do fully collaborative work, and their meaning making processes with complex scientific concepts often stay procedural.

¹ <http://www.uv.uio.no/iped/forskning/prosjekter/ark-app/>

Preface

The last years and this project in particular have given me great many insights and experiences, of which many are not visible in this thesis.

First and foremost, I obviously want to thank my supervisor Jan Dolonen for patience, countless readings and activating me then the theory didn't.

Last spring, I was thrown straight in to the lion's den with my first day as an intern at Engagelab also being the first day of fieldwork for the case in the Ark&App project this study is based on. So thanks a lot to Anniken Furberg, Irina Engeness, and Jan for letting this measly master's student learning by doing what classroom research is, and not only carrying camera bags.

Thanks to the entire Ark&App project, being part of a big research project have been proper cool. Also thanks to the guys at Engagelab, it's because of my internship with you I ended up being here and writing this.

Thanks to Anders Kluge for reading and commenting on the thesis.

Thanks to all the guys and gals' in Studentorchesteret Børneblæs for on a weekly basis reminding me how nothing is serious. I only have one word for you; Generelt!

The masters' students in Forskningsparken naturally deserve a mention, thanks for making it easy to not just work.

Lots of gratitude goes to Espen and Fredrik for proofreading this thesis, and not having too much of an ironic distance to my qualitative research.

Of course I must thank my family. Thanks to dad for all the food at odd hours, and to Sindre for always wanting to talk about anything else than this.

Finally, I want to thank my mom. You never got to read this, but it's because of you and dad I'm here today!

Stian

Blindern, June 2015

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1 Introduction

It is increasingly commonplace that school practice today is a mish-mash of both planned and improvised use of resources for both information and learning (e.g. Bjørkeng, 2015; Furberg, Kluge, & Ludvigsen, 2013; Gustavsen & Bringedal, 2014; Gustavsen, 2014; Lund & Rasmussen, 2008; Tessem, 2014). More and more schools embrace the variety of opportunities presented by modern ICTs and equip their students with not only books, but also computers and tablets. These resources together invite to rather diverse forms of interaction both with and between the users. This wide variety in tools also enables teachers and students to vary the ways in which knowledge is both created and represented, Be it as for example in form of a movie, text, picture or audio-recording. When used together, multiple representations of knowledge offer different meanings and views, and contribute in their own distinct way to students meaning-making (Ainsworth & Newton, 2014; Phillips, Norris, & Macnab, 2010) It should be safe (albeit perhaps a bit naïve) to assume teachers choose and combine these resources in an effort to ease and better students learning practices.

This selection and use of representations and representational tools is particularly intriguing in the subject of natural science (no¹: *naturfag*), as science separates from most other school-subjects in that the ideas and concepts often are constructed purely theoretically, and thus in “the mind” (Kozulin, 1998; Taber, 2013; Vygotsky, 2012). It is thus no wonder students find natural science hard to learn, and often struggle with it (e.g. Eilam & Gilbert, 2014; Furberg, 2009a; Kindfield, 1991; Lewis, Leach, & Wood-Robinson, 2000b, 2010; Linn & Eylon, 2011). Natural science contains information that is often either too big or too small to see with the naked eye, for instance what our solar system look like or how cells divide (Eilam & Gilbert, 2014; Lewis et al., 2000b). This necessitates much of the scientific communication (ie. the teaching) to proceed without the students being able to see for themselves what they are talking and thinking about. Therefore, it is often both necessary and helpful to represent reality in other and more convenient ways than face-to-face. A representation could thus broadly be defined as “something re-presented or revealed in another manner, in a form that differs from that of the referent” (Russell, 2014, p. 1).

¹ no = Norwegian term

Representations are as the name implies our go at representing something in such a way that that those viewing it takes from it what we want them to. However, one can never guarantee how others interpret the world, and to highlight this ambiguity such embedded ideas are often not branded meanings, but rather *Meaning potentials* (Linell, 2009; Rommetveit, 2000). This potential refers to the situated aspects of human meaning making. accordingly, things do not have a concrete or lexical meaning, but meaning is made out of things in a given context. There are for example very different meanings to be taken from a swastika seen in a parade in Europe or on a temple in India.

Expanding on the concept of representations, using not only one but multiple representations, often in different forms, can be an efficient strategy to help teach advanced concepts

(Ainsworth, 1999;

Tabachneck, Leonardo, & Simon, 1994; van der Meij & de Jong, 2006). A good example of such use is by letting a particular representation explain and establish the foundations of another and more advanced one. This is for instance as shown in

Figure 1-1. Here statistical information is represented both as a table of numbers, and as curves in a graph.

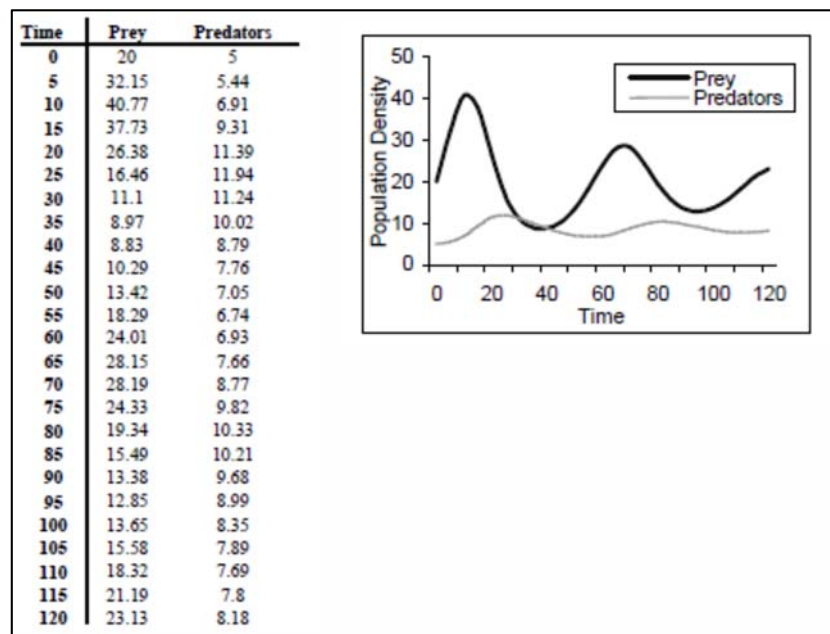


Figure 1-1 An example of multiple representations

(Ainsworth & VanLabeke, 2004, p. 4)

To see the unity multiple visual representations set out to create, such as the thermometer and the graph as mentioned above, the person interpreting them (the student) must understand the underlying concepts and, make a translation between these two different graphics.

Translating and understanding unities between different representations can often be a great cognitive load for the student (Miller, 1956; van der Meij & de Jong, 2006), which can be

problematic in a learning situation where one arguably should spend more time on the subject at hand, than on the visuals representing them. It has also been found that people inexperienced in the field often have trouble making these translations whilst those experienced in the field don't seem to have these same troubles (Kozma, 2003; Tabachneck et al., 1994). It is in other words fair to claim that good representations are not buy themselves quite enough to help students meaning-making with advanced scientific concepts, but it is also important how these representations are, or are not, understood. And unless such representations and their possible connection are immediately clear to the students, their job of interpreting and understanding these could become next to impossible (Linn, 2003). However, all the while it appears to be an established truth to the beneficial outcomes of using these diverse and multiple representations, little light is shed on students day-to-day task of wading through these (Furberg, 2009a; Roth, Pozzer-Ardenghi, & Han, 2005) And, as we have briefly touched upon, different representations, tools, and resources invite different users to different forms of use.

We have briefly touched upon the concepts of (multiple) representations and meaning potentials, some of the core “functions” in ICT-enhanced learning. As we then can surmise, these representations have to be seen and understood by the user. Just as reading books demand the reader being literate, using ICT in learning-situations demands the learner (and of course the teacher) to be literate in regards to these tools as well. It is perhaps then naturally to assume today's students have this Digital Literacy, as it is often labelled (Erstad, 2010; Eshet-Alkalai, 2004). However, a recent study finds 59% of students in Norway use digital resources weekly or more often to find relevant information (no: finne faglig informasjon). Yet, they also find that a quarter of these lack basic knowledge and skills in regards to participating in an increasingly digitized society (Ottestad, Throndsen, Hatlevik, & Rohatgi, 2013)

In what's been described as a mixed culture (no: Blandingskultur) (e.g. Rasmussen, Gilje, Ferguson, Ingulfsen, & Bakkene, 2015), teaching is no longer confined to using the traditional resources of schools (e.g. books, maps, calculators) but often embraces the many possibilities of ICTs. Underbuilding this, a recent study finds that 81% of teachers use textbooks as a primary resource augmented by digital (Gjerustad, Waagene, & Salvanes, 2015). Results from the latest ICILS survey in Norway (Ottestad et al., 2013) show that 84% of teachers would like

to use more ICTs in their work. These findings are also supported by another survey from Norway (Senter for IKT i Utdanningen, 2013), where it is found that 66% of teachers are encouraged by their school-administration to expand their use of ICTs. As these numbers show, we are truly heading towards a culture of mixing traditional and digital resources. All the while, this contemporary combination of representational tools, meaning potentials and the possible challenges of making meaning in such a culture warrants a thorough look into. The interplay of teachers, students and diverse representational forms seems to be becoming more and more a crucial part of schooling, and yet there are many questions both unasked, and unanswered (e.g. Furberg & Arnseth, 2008; Furberg et al., 2013).

1.1.1 Genetics

In science, the subject of genetics proves to be particularly hard (Furberg & Arnseth, 2008; Kindfield, 1994, 2008; Lewis, Leach, & Wood-Robinson, 2000a; Lewis et al., 2010; Tsui & Treagust, 2010). To highlight the complexity of this subject, I will give a swift description of the different parts and layers of cells taught during our intervention. There are two kinds of cells, animal- and plant-cells, these also have different parts, organelles. Further, and as is the focus of most of my empirical data, cells split in two different ways. In processes called mitosis² and meiosis³ (Hannisdal & Haugan, 2008). When cells split they copy and/or mix their genetic material (no: *arvestoff*) which is in its chromosome. This consists of DNA⁴. DNA again is put together of different combinations of four specific Bases gathered in pairs. Pairs which are sorted in triplets. Many of the scientific concepts also have many names, or are in other languages. Meiosis for instance, is also talked of as both reduction-division and sex-linked-division⁵ in the classes observed in this study.

In a qualitative study of students working with DNA replication, Furberg (Furberg, 2009a) argues students change their orientation from exploring to pragmatically solving the task at hand. Similarly, Krange and Ludvigsen (2008) argues that students often solve tasks procedurally except for where it is necessary to construct conceptual knowledge, such as when

² http://www.biology.arizona.edu/cell_bio/tutorials/cell_cycle/cells3.html

³ http://www.biology.arizona.edu/cell_bio/tutorials/meiosis/main.html

⁴ Deoxyribonucleic acid

⁵ In norwegian this is called *reduksjonsdeling* and *kjønnsdeling*

writing down answers. Learning scientific concepts is hard for many students, but it is also the key to understanding the foundations of our own being, as well as part of the curriculum. Thus, investigating not what is difficult for students, but what makes them do as they do when making meaning out of genetics could provide interesting insights

1.2 This projects relevance

At present, a rather large debate is alive in the Norwegian public discourse, between among others educators, academics, software creators and of course students, on how to approach education in the 21st century. Textbooks have been made interactive and available on the web, educational videos are freely available online, and students do indeed know how, and the limitations, to “google” something (Forte, 2015). All in all, one should expect students to do better today than before, but do they? Some proponents of more use of ICTs in education are talking loudly of how much schools today are lagging behind (Krokan, 2015), whilst some educational researchers are more cautious, and highlight the need for both more experience and empirical evidence for understanding how ICT changes classroom cultures and school as an institution (Blikstad-Balas, 2015; Dolonen & Kluge, 2014).

This study could contribute to this discourse, not by any form of generalizability, but as another empirically derived piece of the puzzle on how to adjust and adapt education for a contemporary and technologically advanced society whilst at the same time maintaining the focus on students deep and conceptual understanding of complex scientific concepts..

Thus, the research questions for this thesis are:

1. What characterizes group work in this multi-resource environment?
2. How do the students make sense of various representational forms?
3. How does the range of representational forms and resources challenge the classroom norms and rules?

1.3 Current study

This project came to fruition as a part of the larger Ark&App⁶ (literally: paper & app) project at Department of Education, University of Oslo. The Ark&App project is funded by the Norwegian Directorate for Education and Training (no: *Utdanningsdirektoratet*) and looks at how educational resources are used in the planning, conducting and evaluation of teaching in the school subjects English (as a foreign language), social science, mathematics and natural Science. These studies will eventually constitute of twelve reports from qualitative studies in schools, and two nation-wide surveys asking teachers, school leaders and school owners about their choices and practices with different educational resources. After all data is collected on the surveys and the individual cases, a synthesis report will be written, describing the overall findings of the project.

The current study is rooted in data gathered in the field-work for Ark&App's study in Natural science classrooms in a lower secondary-school (no: *Ungdomskole*) setting, and have already resulted in a finished report (Furberg, Dolonen, Engeness, & Jessen, 2015). Most of the twelve Cases in the Ark&App project have their own unique research-design and form of intervention, and this case was carried out on a fairly new-built lower secondary-school well versed in integrating technology in their teaching practice west of Oslo. We followed 74 students and one teacher for eleven Lessons. The analysis in our report

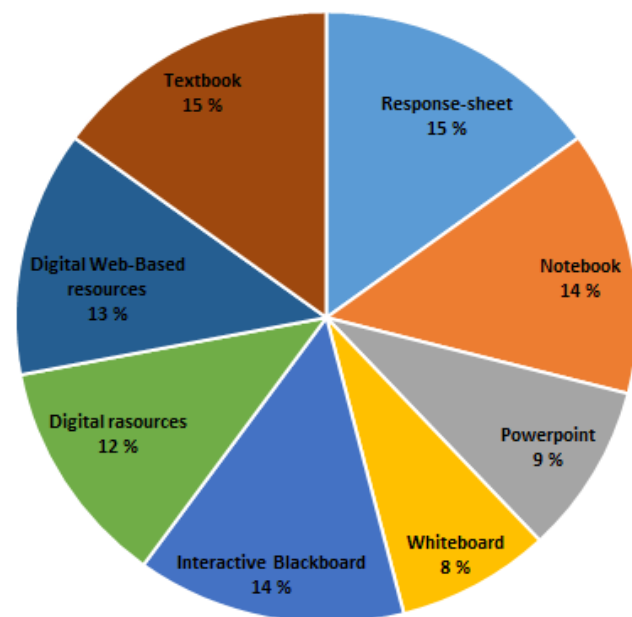


Figure 1-2 Students Use of Resources (percentage of time in use)

(Furberg et al., 2015) shows many resources in play, and a near 50/50 split between digital and analogue resources used by the students. The distribution of resources used by students may be seen in Figure 1-2, and nicely visualizes the mixed nature of this environment.

⁶ <http://www.uv.uio.no/iped/forskning/prosjekter/ark-app/>

1.4 The thesis' structure

This thesis has seven chapters. In chapter 2 I will present and discuss my epistemological standing a. Further I will present activity theory and how this both fits in and is applied in my study. In chapter 3 I review literature and research within the fields of visual representations, learning with multiple resources and science learning. Chapter 4 first presents the case of this study in detail before describing the types of data available. Then I present the analytical strategies, tools and processes I've employed, before reflecting upon this research' reliability. In chapter 5 I present the empirical data. Interactional data from video recordings are at the core of my analysis, but I also make use of student's written products, results from pre- and post-tests in addition to coded and quantified video recordings providing a descriptive view on the students group work as a whole. In chapter 6 I will first discuss moments from my data central to both research questions and reviewed literature. The final part of this chapter present my concluding remarks.

2 Theoretical perspective

This chapter seeks to establish the basic epistemological standing for the study.

First, I briefly argue for the necessity for a sociocultural point of view. Then I introduce activity theory and its evolution into the activity systems. finally, I present how this shifts into the thesis' analytical framework.

2.1 The need for a more holistic approach

As we shall see in in chapter 3, experimental studies commonly find a positive outcome for the use of visual representations in learning situations, while simultaneously acknowledging that students can find aspects of working with representations challenging. If proving some sort of measurable learning outcome were my goal, this study could have been based solely on results from the case study's (Furberg et al., 2015) pre- and post-tests, which could show us descriptively which questions the students answered correctly or not. However, we would still not be able to explain what contribute to the changes between the tests. To shed light on what is happening in this proverbial black box we must adopt a point of view that allows not only for analysis of test results but also opens up a more all-embracing interpretation of student test results, discourse and sense-making processes.

Linell (2009) draws a distinction between monological and dialogical perspectives on human cognition and meaning-making. Monological perspectives are often experimental studies from a cognitive or socio-cognitive tradition, highlighting individual actions as the prime catalyst for learning. By contrast, dialogical views on human cognition focus on the shared, contextual and interactional aspects of meaning-making. As an example let us look at how schools are today, here one does not merely receive and repeat facts but takes part in a process of making meaning out of various resources.

The students' task in several of the empirical examples in this thesis is to discuss and create an understanding of mitosis and meiosis, the two types of cell division, then writing their conclusions. In doing so, they are not simply to reiterate facts but must make sense of a variety of information sources and discern the differences among them. We cannot reduce the outcome of the students' sense-making processes to, as Suthers (2006) says, fit an *a priori* definition of learning, relying instead on a retrospective qualitative analysis of the students

and their interactions and sense-making processes. Similarly, Stahl, Law, Cress, and Ludvigsen (2014) argue that an analysis of learning should consider minimally not only the individual but also how individuals are influenced by community, society and culture. Therefore, we must have a situated approach to this analysis as our focus is on individuals together in a particular context. Therefore, nothing that those individuals say or do can be taken out of context. As Linell (2003, p. 221) puts it: “in producing a situated utterance, we respond to others and address ourselves to others, expecting and anticipating new responses from these others who thereby contribute to meaning making.”

2.1.1 A Brief history of sociocultural psychology

Sociocultural psychology stems from a group of Russian psychologists led by Lev S. Vygotsky in the 1920 and 1930s (Cole, 1996; Engeström & Miettinen, 1999; Kaptelinin & Nardi, 2006; Kozulin, 1998; Vygotsky, 1978, 2012; Wertsch, Del Río, & Alvarez, 1995; Wilson et al., 2003). Cole describes the starting point of sociocultural theory as “the assumption that the species-specific characteristic of human beings is their need and ability to inhabit an environment transformed by the activity of prior members of their species”(1995, p. 190).

Integral to this epistemological position is the assumption that humans interpret and filter or mediate our experiences of the world through both physical and psychological artefacts or tools (Cole, 1995; Kozulin, 1998; Vygotsky, 1978; Wertsch, 1991). Inherent in these artefacts is the social, cultural and historical experience of previous users and creators (Linell, 2009). It is the sociocultural-historical heritage of those before us that allows we contemporaries to do what we are able to do. A calculator is not only a machine but also a testament to its creators’ knowledge about mathematics, electronics and coding , combined with their active intention of creating that tool (Säljö, 2006, 2010). When one uses a calculator, one lets other persons’ cultural products mediate one’s perception of numbers. It becomes unnecessary to be able to solve these problems on one’s own, because others have computerised the process. As Cole argues in the quote above, we inhabit an environment transformed by those before us and manage to use their products for some parts of our own production. This is not to say that nothing genuinely new is possible, but rather to highlight that anything ostensibly new owes at least some debt to something or someone from an earlier day. It is notable that Vygotsky himself rarely used the term sociocultural; he and many of his contemporary and later

followers employ socio-historical, cultural historical, cultural historical activity theory (Wertsch et al., 1995) or cultural psychology (Cole, 1996). Based on how these different terms have been understood and the concept itself appropriated in the west, Wertsch et al. (1995) argue that the term sociocultural is the best of all the alternatives.

2.1.2 The mediating artefact

As seen above, mediation is the process of utilizing artefacts to filter or perceive the world. However, these artefacts aren't limited to physical objects. If instead of using a calculator for arithmetic, we have learned to do the same calculations mentally we can call this an intellectual artefact. This is not to say that when something is mediated, our entire perception

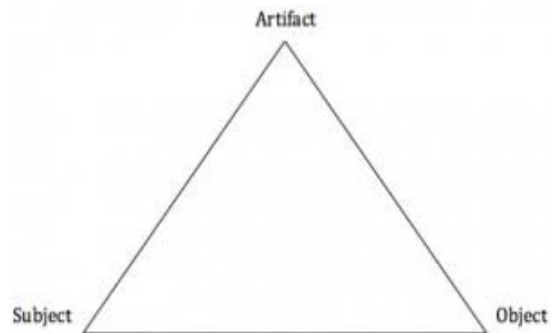


Figure 2-1 "The Mediating Triangle" (As popularized from Vygotsky, 1978)

is channelled through and by the artefact. As we see on the vertices of the triangle in Figure 2-1, there is also a connection between the subject and object along the base line of the triangle (Cole, 1996; Säljö, 2006; Vygotsky, 1978). Our experience is simply put direct and indirect at the same time. Just as the calculator was able to mediate our use of numbers, you still understand them as they are as well. In the words of Vygotsky (1978, p. 40), we use some secondary stimulus for solving the task at hand.

This mediation, or ability to use, psychological tools leads to what Vygotsky (1978) terms higher mental function, and are functions one is not born with, but acquires over the course of growing up in, and interaction with one's environment (Vygotsky, 1978, 2012). Or as described by Leontiev, mental processes "acquire a structure necessarily tied to the sociohistorically formed means and methods transmitted to them by others in the process of cooperative labor and social interaction" (1981, p. 56). In other words, what's termed *learning* is in a sociocultural tradition the appropriation of culturally and historically artefacts by social interaction. With respect to learning, another affiliated and important concept warrants attention, the *zone of proximal development*. This zone is conceived as the area outside one's own competences one are able to operate with the guidance of a more competent other (Kozulin, 1998; Leontiev, 1981; Rogoff, 1990; Vygotsky, 1978, 2012). For example, a student is frustrated and struggling when performing simple addition. But when a teacher guides the use

of strategies and tool the student is able to perform the addition. Following, this zone is ever-expanding and unique for both each person and situation (Vygotsky, 2012).

Accordingly, human development and learning is a social practice mediated by physical and psychological artefacts.

2.1.3 Psychological activity

As noted in this thesis' introduction, the goal of this study is not only to describe what one can see happening, but also to highlight how, and to some extent why the students interact the way they do with both their environment and one another. To achieve this, I cannot limit my study to just the measuring of stimulus and output, but rather design it to focus on the students' activity. As Kozulin puts it:

...human behaviour and mind should be considered in terms of purposive and culturally meaningful actions rather than in terms of adaptive biological reactions. Objects of human experience, and therefore objects of psychological experimentation, should be things, processes, and events that are culturally meaningful and not just abstract stimuli. Activity then takes the place of the hyphen in the formula S-R (stimuli – response), turning it into the formula subject-activity-object, where both subject and object are historically and socially specific (1998, p. 13).

Vygotsky (e.g. 2012) sought to critique the current behaviourist or associativist theories of learning in his period with the focus on this hyphen between the stimulus and response (Bakhurst, 2009; Säljö, 2006). Leontiev (1978) shares this criticism, and argues that associativists excludes the processes in which the connection between the subject and the objective world is made. As both stimulus and response is often clearly available to the eye, the truly interesting aspects of this process is what happens in-between these two, how connection between a subject and its object is mediated (Leontiev, 1978, 1981). This ability to activity is also what distinguishes living beings from the inanimate. To, as a subject, do something to or against another entity, an object (Kaptelinin & Nardi, 2006).

2.1.4 Leontievs Activity theory

An activity is an interaction between a subject and (directed against) an object. However, things do not happen by themselves and something must instigate the interaction. In other words, some sense of needs must motivate the activity towards the object (Leontiev, 1978, 1981). Be they biological or psychological (Kaptelinin & Nardi, 2006). It is only when the needs, and the object get connected that an activity can take form. In other words, activity cannot take place without some kind of object to direct It towards (Kaptelinin & Nardi, 2006; Leontiev, 1978, 1981). The lineage back to Vygotskys (1978) ideas of tool mediation becomes clear, we are many ways just reorienting and expanding our view of the triangle presented in Figure 2-1, above and instead of focusing on the tool-mediation focusing on the relation that is the subjects activity towards the object. As such the direction of an activity is given from its objective (Leontiev, 1978), we may simplify this notion by reversing it. Without a future target (object), we would not have something to need or want (motive) and any process or function (activity) would be pointless (Kaptelinin & Nardi, 2006; Leontiev, 1978, 1981). Further, an activity is not restricted to simple and/or short tasks, and may range from the menial to the complex (Leontiev, 1978, 1981).

2.1.4.1 The Structure of Activity

When analysing activities of increasing complexity, Leontiev (1978, 1981) proposes a three-tier hierarchical separation. The top level is the *activity* itself and as presented above this is driven by its object. This can for instance be finishing writing a historical book. Subordinate to writing this book is carrying our smaller *actions* needed to fulfil the activity; these are motivated by smaller and more concrete goals. Carrying on with the writing example this could typically be researching different pieces of literature needed for writing this book.

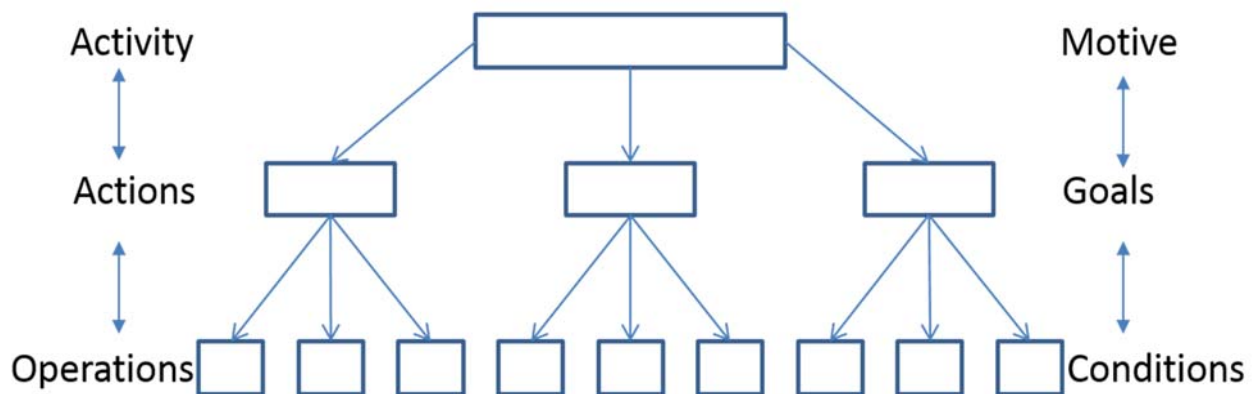


Figure 2-2 The Structure of Activity (Leontiev, 1978)

Secondary to this again are the *operations*. These routine-based tasks are often automatic, and we are oft able to carry these out without much deliberation at all. Going back to the book example, this is typically the process of typing the text itself. Operations are often what in conjunction with cultural and technical development becomes automated, and on par with Vygotskys (1978) notion of higher mental functioning, “turned into artefacts” which enables their use in the lower level of operations (Engeström & Miettinen, 1999; Kaptelinin & Nardi, 2006; Leontiev, 1978, 1981). It’s interesting to note that Leontiev submits humans have the ability to not always action directly against the object, but rather allows object and motiv to separate (Bakhurst, 2009; Leontiev, 1981). Following we may have an object that is getting food to survive, but our action does not focus directly on this, but rather on building housing for those hunting and gathering the food. Leontiev (1981) uses a similar example to highlighting humans dependency and relation to its social sphere.

2.1.5 Engeströms expanded activity system

Based on Leontievs work as partially presented above (1978, 1981), Engeström (1987) further developed the Activity Theory to more explicitly include the community. Best perhaps visualized as an expansion of the Mediating triangle, as seen in Figure 2-1. This expanded

model highlights not only the mutual relationship between the subject and object, but also adds the community as a third party and how its rules (and norms), and division of labour⁷ mediate the action with the subject or the object. Together these create a whole, and present what’s been termed an *Activity System*

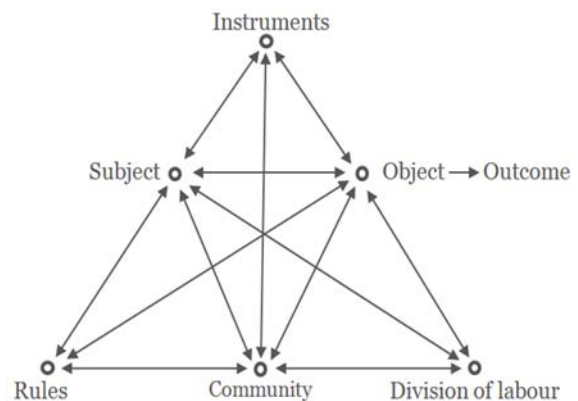


Figure 2-3 "The Activity System" (Engeström, 1987)

(Engeström, 1987). the activity system is used to visualise and point to contradictions or tensions between any of the nodes (Barab, Barnett, Yamagata-Lynch, Squire, & Keating, 2002; Engeström, 1987, 2000; Issroff & Scanlon, 2002). With this, each context or situation may be analysed with regards to this expanded model, shown in Figure 2-3. This allows us to see not

⁷ The division of labour may be both tacit or explicit(Kuutti, 1996)

only how activity is mediated through the use of artefacts, but also take into consideration how this activity constrained or aided in collaboration with the subject's community.

2.1.6 The Object of Activity

Before pursuing further with the concept of activity, one should clarify the object of activity. As we have seen above, there is not any activity possible without a object to direct it towards. Yet, Kaptelinin (2005) points to some important and easily overlooked distinctions and problems with respect to Leontievs (1978, 1981) and Engeströms (1987) activity theories. These approaches, as we have seen, differ from the outset with Engeströms inclusion of the community as an equal partner in the subject-object-community relationship. However, Leontiev himself may be read as to laying the foundations to understanding activity on a community-level, when suggesting multiple motives for an activity (Leontiev, 1978, 1981). This could, combined with his statement that the objective is the motive and vice versa. Kaptelinin (2005) notices the looming conundrums of multiple objects, and suggests instead a split between the motivation and activity.

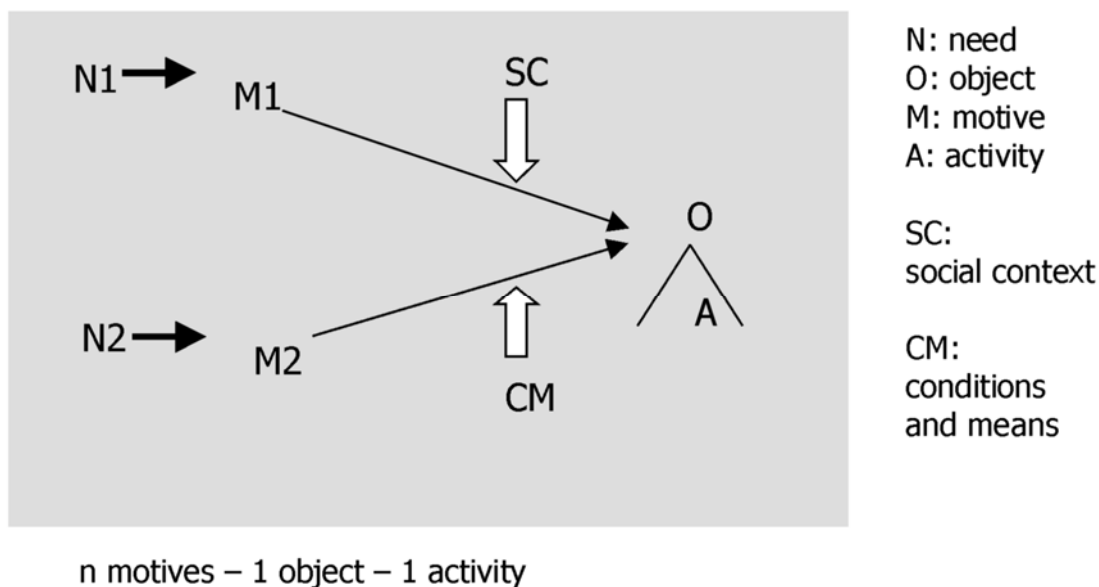


Figure 2-4 Kaptelinin's model of the negotiated object (Kaptelinin, 2005, p. 16)

As shown in Figure 2-4, above, Kaptelinin (2005) addresses how social context together with conditions and means guide the various motives of an activity to a common object. We see two different needs incite two motivations which are guided, or negotiated, by the social context and conditions; thus producing a singular object for the activity.

Leontiev was also adamant in that an activity's object cannot be limited to the biological, physical and physical properties of things (Kaptelinin & Nardi, 2006), it can in other words be some future state we want to be in, or a task a group wants to complete. Say for instance two students are working on a task together. Student 1 wants to just get the task done, whilst Student 2 wants to properly learn what the task's about. Through a negotiating-process their different motives are shaped and turned into a common object for the activity at hand. Engeström (1987, 2006) points to a very similar notion of contradictions within the system, and how these come to shape the object and outcome of the activity. However, in Engeström's (1987, 2006) view, the contradictions may occur in-between any of the part of the system. Though Kaptelinin (2005) may be read as agreeing more with Leontiev's (1978, 1981) than Engeström (1987, 2006) version of activity theory, his notion of the negotiated object, as recently presented, seems very much on par with Engeström's (1987, 2006) contradiction-driven activity system. An alterior version of the discussion outlined above could be that the two students split their task in smaller entities through a division of labour, these then become actions as talked of above, each solving parts of these. We may then view the students as directed towards different smaller goals leading to the same object.

2.1.7 The Double Activity systems

These systems, as seen in Figure 2-3. May also appear in tandem, trios etc. with other systems. The activity system does as we have seen regard the community as an important piece, yet there are still times when someone is partaking in the activity, but cannot be said to be part of the same activity

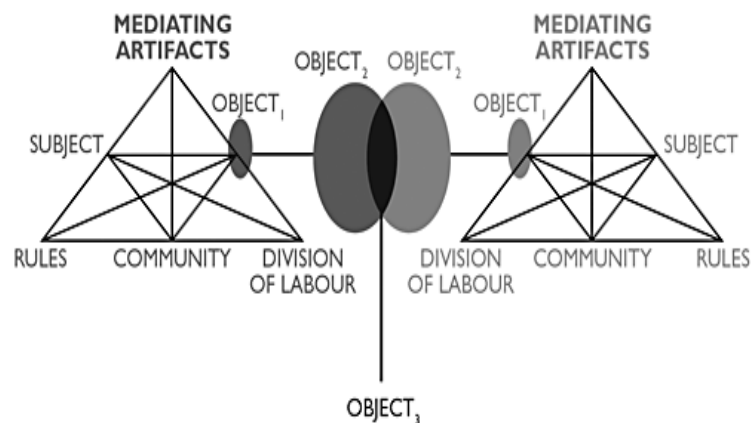


Figure 2-5 "The Double Activity System" (Engeström, 1987)

system. If for instance, we look at a teacher helping a group of students. They should at least partly share the object; for the students to understand what the teacher is explaining. Possibly, the teacher and his students will at the very least have rather different rules and divisions of labour impacting their activity towards the object. And as we can see of Figure 2-5. above, not

even the common object is absolutely similarly perceived by the teacher and students. This will, just as amongst the collaborators in one activity system, have to be negotiated and to some way agreed upon by the participants.

2.2 Activity theory as an analytical lens

As we then can surmise, this point of view, and my study, uses activity as *unit of analysis*, and as such allows us to further explore not only human beings or environments alone, but also their contextually situated interactions with their environment and themselves (Engeström & Miettinen, 1999; Kaptelinin & Nardi, 2006; Kaptelinin, 2005; Kuutti, 1996; Wertsch, 1991). Kuutti (1996) argues that activity theory may be used to analyse human practice on both the personal and social levels at once. With activity theory as an analytical lens we get a view straight into the core of the interactional sense-making practices, the students different and collective actions. Focusing on both individual and collective acts is important with respect to my sociocultural theoretical position which assumes that the human mind is social (Kaptelinin & Nardi, 2006). Thus, utilizing activity theory as a frame for the analysis allows not only a focus on the mediating artefacts between the subject and object but also how, when considering the community (with its rules and division of labour), it is object-directed activity unfolds. This enables a broad analysis of the situation as a whole, rather than a strict focus on the purely mediational aspects.

3 Group work & Multiple resources in science education

In this chapter I present relevant review literature with respect to answering my research questions. I will both expand upon already introduced concepts, visual representations, and various concepts of multi-resource learning, collaboration and group work. Before rounding this chapter off by presenting an overview of some contemporary approaches and views on science education.

3.1 Learning with multiple resources

Seen from a dialogical/sociocultural perspective words and symbols don't have a lexical meaning (Linell, 2009), and it is rather the outcome of a meaning making process that determines how things are perceived and understood. On the same note, Rommetveit (2003) argues it is impossible to capture a specific words entire repertory of meaning potentials. By employing different tools and symbols one then allows the users different potential meanings and uses of things. As such, utilizing diverse artefacts to help represent a phenomenon may allow the learners to draw meaning from different repertoires of potential meanings.

In Norway, the term mixed-culture (no: *Blandingskultur*) has been used to describe contemporary classrooms. Here, ICT integration into learning environments is considered to be an augmentation of the teachers more traditional practice. As such, to use ICTs is not a goal per se, rather it is designing an as good teaching-practice as possible with the help of all available and appropriate resources. The Ark&App project, which this study is part of, take the school from the outset to be a such mixed-culture (See appendix 1a in: Furberg et al., 2015). Another, and more prescriptive, approach to ICT integration in education is blended learning, which consists of face-to-face interaction and online teaching activities (Chan, Wilkinson, Graham, Borup, & Skeen, 2011; Drysdale, Graham, Spring, & Halverson, 2013; Graham, 2006; Hew & Cheung, 2014; Vanderlinden, 2014). Still, this approach is not fault-free, and based on their review, Hew & Cheun (2014, p. 5) highlights simply finding “the right blend”, to best utilize the strengths of both online and face-to-face approaches, as one of the biggest issues surrounding blended learning. Part of the argument for blended learning is also

the principle of multimedia learning (Clark & Mayer, 2008; Mayer, 2003; Moreno & Mayer, 2007), that we make separate cognitive representations of verbal and pictorial information, that these two representational systems have a limited capacity, and that one best learns when actively engaged in cognitive activity (Eilam, 2012; Mayer, 2003). Thus, by learning from both text and pictures one should be able to minimize bottlenecks in the cognitive system

In their review of 61 experimental or quasi-experimental studies, Smetana & Bell (2012) argue for a combination of computer simulations and traditional learning to the most effective instructional approach. They also highlight the teacher as having a critical role in guiding students to the most advantageous utilization of the simulations. Trygstad, Smith, Banilower, & Nelson (2013) in their study find that even though educators are freer with respect to choosing representational tools and resources, they still keep the traditional textbook on hand. These are often used as a structuring device when planning and executing their educational practices. In a survey of 935 Schools, Gjerustad et al.(2015) report that 81% of lower secondary schools in Norway mainly use printed textbooks, supplemented by some digital resources. Further, 16% mainly use digital resources whilst just 3% only use printed resources. it is as we can see only 3% of Norwegian schools that don't use digital resources. Interestingly, they (Gjerustad et al., 2015) also report that only 47% fully agree that the school network-connections have the capacity to the support the students use and activities. Also, a recent study from Norway (Senter for IKT i Utdanningen, 2013) find that teachers use a higher number of resources in their teaching than their students use for their own work.

3.2 Research on Visual representations

Visual representations are not “a thing”, it is by and large a top level denominator for a variety of different forms of presenting something. This includes simulations, animations, pictures, movies/videos, graphs, diagrams. As suggested in the introduction, a visual representation oft allows someone to see something differently than its original form. Representations are not only categorized as being multiple or not. Often the term multimodal representations is used

to describe representations that use different forms⁸. In the field of science education, visual representations are both particularly important and useful. This because many scientific concepts and systems not only are hard to physically see, but also have inner workings which demand close and often repeated scrutiny to understand. With all due respect to the historical realities of visualizing information in education, computer technology as a whole offer an unprecedented range of opportunities for educational use.

Research on the use of visual representations can easily be split into two distinct traditions (Furberg & Arnseth, 2008; Furberg et al., 2013). One is studying it from a cognitive orientation, often with an emphasis on testing hypothesized and measurable effects and factors of a particular set of representations. A second tradition is studying representations from a sociocultural standing, which focuses more on the meaning making aspects of interaction in-between the learners and the representations and tools at hand.

3.2.1 Quantitative Studies

Quantitative and experimental studies often cite cognitive load (Miller, 1956) as one of the more influential hindrances with respect to using multiple representations (Ainsworth, 2006; de Jong, 2010; van der Meij & de Jong, 2006). The cognitive load theory stipulates that the capacity of the working memory is limited, and of a task requires too much capacity, learning will be obstructed. In an experiment on 72 teenagers, De Jong & van der Meij (2006) finds that having to find relations between different (simpler) representations is more complex than understanding complex integrated representations. With respect to integrating representations, Renkl et al. (2013) cite several studies emphasizing that simple integrations of representations, such as sharing colour and being put into the same information boxes, just supports bridging the representations superficially and do not foster abstract or deep levels of understanding. These tendencies are also supported by Ainsworth (2006) whom cites several studies as finding students to treat multiple representations as individual, and struggle to integrate multi source information. Regarding notions of cognitive load, after an experiment of 4 different instructional designs with 48 college-students, Cook & Visser (2014) argues that

⁸ Russell (2014, p. 1) use the following definition for multimodal representations: *«the depiction or communication of an idea or ideas using more than a single expressive mode, either in synchrony or separately»*.

concepts like cognitive load theory is still dependent on a range of the individuals characteristics, such as previous knowledge, and that these should be accounted for.

The effects of previous knowledge is also underlined by Schwonke, Berthold, & Renkl (2009) who in two studies with total 46 university students also find positive results by simply explaining the functions of diagrams to students before they start using these. After two experiments in chemistry learning, Kozma & Russel (1997) also argues novices to superficially use representations, not being able to draw connections between different layers of the science, and not being able to put the pieces together. In an experiment with 357 eighth and ninth-grade students, ChanLin (2001) finds novices have the best learning outcome when using still graphics over animations, but finds no significant difference in for experienced learners. The difference in benefit of representations for novices and experienced learners is also a common denominator of, Superfine, Canty, & Marshalls (2009) short review. Other studies also find that when faced with dynamic representations, students believe they understand more than when using static representations (Kühl, Scheiter, Gerjets, & Gemballa, 2011). Lowe (2003) argues visualisations in fact may induce misconceptions in novices, as they often try to make meaning of the visualisations by matching them up with everyday concepts. Further along these lines Lowe (2003) also argues that novices are prone to believe they know more than they do.

3.2.2 Qualitative Studies

Whilst the quantitative studies highlight the measurable outcome of working with visualisations, few take account of the social and interactional aspects of the students sensemaking processes. From a more dialogical and/or sociocultural tradition, studies focus more on the (inter)action amongst people, artefacts and their environment. Such qualitative studies are smaller in scale, often encompassing participants in groups such as school classes. Whereas quantitative studies often point to measurable outcomes of using representations, qualitative studies offer valuable insights into what is happening when the students make sense of the representations together. Accordingly, these studies seek not only to uncover

what works or not but the students' practices when using these artefacts in their meaning making processes.

Furberg et al. (2013) Studied 20 upper secondary school students meaning making with the concepts of heat-transfer, and based on a micro level interaction analysis argue that representations have both constraining and complimentary functions, for example may picture-captions function as a limiter on the potential interpretations of the visualisations. Most interesting they find that in situations with rather similar representations (e.g. from the teacher, other students, books, visualisations) the students open up and “interpret, negotiate, and account for scientific versions of the scientific matter at hand”(Furberg et al., 2013, p. 59). Similar to this, Barab et al. (2002) in an Activity Theoretical analysis of a learning environment with students learning astronomy with the help of 3D animations, finds tensions between and within the different parts of an activity system to be fruitful, and suggest not attenuating all perceived tensions, for example between the teachers' instructions and students emergent agenda, arguing the learners act of balancing in this dynamic contributes to meaningful interplay. Kozma (2003) in a pilot study of chemistry students describes their observations and responses to specific features of representations to shape both their talk and thinking. He further argues novices lack competencies in using topic-specific representations and rely on surface features to shape discourse and shared construction of meaning. In a design study involving 4 students and a teacher, Krangle and Ludvigsen (2008) observe students construction of knowledge to be mostly procedurally oriented, and working towards solving the task at hand. As a result of they don't utilize all the information presented in available resources, sticking to what's needed to solve the task. Corresponding findings were reported in Furberg and Arnseth (2008) design experiment. after a Study of 50 secondary school students working with genetics they argue the in order to understand students meaning making processes it is important to consider the impact of institutional influences, such as time constraints and need for documentation. on these processes. Studies in school should thus be more naturalistic and take this into account.

From a sociocultural position it is important to also consider the cultural and historical aspects of school institutions. As such, meaning making in school-setting is not only constitutes solving a task, but also about finding out how to understand the task, the resources in use, and most importantly, the institutional expectations, values, and norms (Furberg & Arnseth, 2008; Furberg et al., 2013; Krange & Ludvigsen, 2008; Säljö, 2010). when considering these norms, it is interesting to remember that for instance until not long ago, talk amongst students in classrooms were discouraged (Mercer, 1995).

3.2.3 Summing up quantitative and qualitative studies

As we have seen, experimental research generally finds positive outcomes from using visuals in education. These findings are mirrored by many sensemaking studies, that when unpacking the students practices also find visualisations being an important contributing aspect of students processes (e.g. Furberg et al., 2013; Slavin, Lake, Hanley, & Thurston, 2014; Smetana & Bell, 2012) However, this does not mean one should trade teachers for technology. Successfully using visuals in education best succeeds when used as a part of a larger educational practice, they should not as it where, stand alone, but rather need support and guidance from a teacher(e.g. Chang & Linn, 2013; Krange & Ludvigsen, 2008; Lowe, 2004; Smetana & Bell, 2012). Further, when concluding their review of 61 studies, Smetana and Bell (2012) highlight the continuing need for both quantitative and qualitative studies into representations. As we have seen above, these two approaches don't exclude the other, but rather asks and answers different questions. The quantitative studies we have seen tend to focus on the measurable outcome of the various representations, whilst the sociocultural position is more attentive to the interactional aspects of using representations together.

3.3 Research on group work

Conversations and negotiating answers and understanding, in other words making sense together, necessitates understanding and justifying what one's position. Conversations are often a good fertilizer for reflection and meaning making (Barnes & Todd, 1995; Kozulin,

1998; Mercer, 1995), and is also sometimes presented as a social mode of thinking (Wegerif & Mercer, 1997). In the same vein, Stahl (Stahl, 2006) presents meaning as a something rising up through the groups negotiating of the individuals perspectives. Accordingly, collaboration turns the student from a passive recipient of information to a partaking in a learning activity of co-constructing a shared understanding.

With respect to collaboration or non-collaboration, it is worth highlighting some interesting aspects and findings. Firstly, working (and learning) in groups is not an equivalent of collaboration. It may as well indicate cooperation, a coordination of work focused on producing results then shared with the group (Stahl, 2006). Similarly, Panitz (1999) describes cooperation as a structure of interaction. Stahl (2006, p. 314) contrasts this to collaboration which in his words is “gradual construction and accumulation of increasingly refined and complex cognitive and linguistic artefacts”. Secondly, when considering productivity, White and Pea (2011) find groups in their stride towards efficiency sometimes leave (less performing) participants behind. Mercer (1995), when summing up experimental research on collaborative learning, highlights the distinction of being forced to or being allowed to collaborate an important factor with respect to the outcome a further potential pitfall is also presented by Stahl (2006) when students in a group chase down different paths, their meaning making is diverging until this becomes noticeable and the group must deal with their differences, either by negotiating a shared meaning, or by a breakdown in the ongoing meaning making processes.

Collaboration also opens up for students to function as tutors for each other, in that a more competent student may support less competent students along the lines of the concept of the zone of proximal development (Mercer, 1995; Rogoff, 1990; Slotta & Jorde, 2010; Wegerif & Mercer, 1997). White and Pea (2011) finds that students in groups not only negotiate the meaning of their topics, but also interpret and agree on what tools are relevant and how to efficiently complete the tasks given. Damstra (2014), in a qualitative study of bachelor students accentuates the importance of objective-orientedness, a shared and tangible outcome for group work, and that tasks complexity should be made to fit individual groups.

Pathak et al. (2011) finds students with more open structures of work perform better than those with tighter forms. One can perhaps suggest that along the lines of Kozma (2003), as presented above, the more proficient the participants in a group are the easier and better the collaborative tasks become. Put together, one might surmise that more proficient students with open task will do better?

However, more rigid systems for discourse have also proven effective. *Exploratory Talk* have been studied over time and in different continents (e.g. Mercer, Dawes, Wegerif, & Sams, 2004; Mercer, 1995; Rojas-Drummond & Mercer, 2003; Wegerif & Mercer, 1997) with positive results. Exploratory Talk is a system/concept developed with a goal of elevating students talk to a higher level. Firmly based on Vygotskys (1978, 2012) notion internalizing social and cultural tools, the higher mental functioning. This concept is built on three modes of talk (and thinking) (Mercer, 1995, p. 104). 1. Disputational talk, basically little cooperation and disagreements. 2. Cumulative talk, where students build on each other but also oft repeat one another. 3. Exploratory talk is when the participants in the dialogue engage in critically constructive discussion of each other ideas. Both meaning making and knowledge are here public and visible. Research on this concept (Mercer et al., 2004) have also shown that discursal rules may seem constraining, but when implemented it both regulates and equalizes social conditions in groups such as individuals dominance or subordination.

3.4 Inquiry

An often highlighted aspect of good science education is inquiry learning (Furberg, 2009b; Linn & Eylon, 2011; Scardamalia & Bereiter, 2006; Slavin et al., 2014; Suthers, 2003).

Synonymously, to stimulate to curiosity and desire of students to learn is also one of the tenets of *the learning poster* of the Norwegian curriculum, *Kunnskapsløftet* (Directorate for Education and Training, 2006). Inquiry learning stipulates people are curious and welcome new knowledge, thus leading to their inquiry. The concept have been described as adapting the scientific method to one's own learning processes (Kremer, Specht, Urhahne, & Mayer, 2013). The curiosity "about scientific events motivates children to explore, observe, connect, and question their ideas"(Linn & Eylon, 2011, p. 3) Even though use of inquiry-based learning, and learning environments, takes more time than learning situations where students

simply “absorb the information”(Linn & Eylon, 2011, p. 4), it is more effective with respect to students learning (Donnelly, Linn, & Ludvigsen, 2014). In addition to positive outcomes from inquiry learning, students even tend to believe such activities, with focuses on collaboration, personal initiative and uncertain outcomes, contribute to better learning than more traditional scholastic work (Linn & Eylon, 2011, p. 1).

In recent years the focus in education have turned from individual to collaborative inquiry (Scardamalia & Bereiter, 2006). This draws along the lines of the social meaning making processes highlighted in several sociocultural studies presented above (e.g. Barab et al., 2002; Furberg et al., 2013; Furberg & Ludvigsen, 2008; Krange & Ludvigsen, 2008; Mercer, 1995).

Concerning students work, Jiménez-Aleixandre, Rodriguez Bugallo, and Duschl (2000) based on a study of 9th class students in which students are given “problems” regarding genetics to discuss, submits a distinction between two types of student activity and discourse, “Doing Science”(were students mimic the scientific process by argumentation or scientific dialogue) and “Doing the lesson” (procedural operations such as answering a question or reading). With respect to this distinction, (Furberg & Arnseth, 2008) argues for the importance of considering both types of talk meaningful in the science education context. Talk when solving tasks, is not only about solving it, but also how to understand it, make use of resources, follow institutional norms. Jiménez-Aleixandre et al. also point to the teacher as having an important position in activities like this, creating a “climate of confidence” (2000, p. 782), supporting the students through uncertainty and argumentation such open ended tasks instil. That a teacher still is an important part in collaborative inquiry learning is also highlighted by (Kim & Hannafin, 2011), who find teachers are able to support students, with for instance problem solving and metacognitive processes, when they need it. Following they find that students with minimal prior knowledge are prone to be hampered from learning activities with minimal guidance. The same notion is argued by Kirschner, Sweller, and Clark (2010), whom in their review find little support for individually constructivist approaches, instead submitting the superiority of guided instruction. Kirschner et al’s arguments were however firmly criticized by Hmelo-Silver, Duncan, and Chinn (2007) and H. G. Schmidt, Loyens, Van Gog, and Paas (2007) among other things for seeing inquiry learning as a totally guidance-free activity. With

respect to digital learning environments, Furberg (2009b) draws attention to feature of prompting students to offer guidance underway as helpful tool in students inquiry learning.

3.5 Science Education

As it is just tersely talked of in the introduction, I will following expand upon and discuss some basic challenges with science education, and try to connect some, for the lack of better words, solutions to these with the three previous subchapters.

Vygotsky's (1978, 2012) distinguishes between peoples spontaneous and scientific concepts. We experience phenomena during our interaction in and with the world, and create naïve and spontaneous concepts of these. For example, a child that sees and thus believes the sun rotates around the earth. Scientific concepts on the other hand is derived through mediation. This are things we are (often) unable to experience face-to-face, and we thus need artefacts to help us experience these. Looking at a drawing of the solar system would then mediate our experience of the sun not revolving the earth, but the opposite. Further, scientific concepts are parts of system comprising other concepts and together creating a whole. When the students in this study is learning cell division. As such they also, for example, need to understand the concepts of a cell and of DNA. The concept of cell division by itself is not very useful. Accordingly, scientific concepts should be seen as part of a conceptual system (Vygotsky, 2012).

Science is as different from other traditional school subjects, and even though scientific knowledge is both rationally and logically derived, it is never absolute or certain (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Yet, often the most complex scientific concepts and ideas are simplified and, what Linn and Eylon (2011) describes as, transmitted by way of a single graphical representation. Such representations may take almost any representationable form, depending on what is best suited to communicate any given idea (Lemke, 2004). Still, students often struggle to obtain a conceptual or deep knowledge of complex scientific ideas because they fail to make a connection between the different representational forms and ideas. After an experiment with students first reading then explaining texts, Marton and Säljö (1976, 2005) described two levels of learning, surface-level and deep-level processing. Surface-level processing is when the learner is focused on the text itself, and is focused on being able to reproduce it. In deep-level processing, the students focus is on the normative content in the

learning material. In other words what meaning potential (Linell, 2009) the author may have put in the text.

Nearly two decades ago, science education in the US was described as being “*a mile wide and an inch deep*”(W. Schmidt, McKnight, & Raizen, 2002, p. 62), summarizing the superficial and yet broad focus of the subject. Similarly, a recent Norwegian Official Report (Kunnskapsdepartementet, 2014) pointed to challenges with respect to maintaining both breadth and depth in education. In a move for better science learning, research at the TELS Centre at UC Berkeley⁹ have produced great insights into science education(e.g. Linn, Davis, & Bell, 2004; Linn & Eylon, 2011; Quintana et al., 2004; Slotta & Linn, 2009). One of the products of this research is the Web-based Inquiry Science Environment¹⁰ (WISE), an online learning environment with modules for many topics in science. WISE is designed round the pedagogical thoughts of Knowledge Integration (KI)(Linn, Davis, & Eylon, 2004; Linn & Eylon, 2011). Knowledge Integration is a systemic theory of how good science education should be organized, and is founded on the results from the studies conducted at the TELS Centre over nearly three decades. (Linn, Davis, & Eylon, 2004; Linn & Eylon, 2011).

Knowledge Integrations consists of four steps:

1. Elicit previous knowledge
2. Add new ideas
3. Develop Criteria for sorting new and old
4. Sort and fit in the new and old information

First, the teacher readies students for learning new information by waking already known concepts and ideas to function as a foundation for the new knowledge to build on. Second, one adds new ideas to the students existing ones. Third, and very important, one must help the students to manage criteria to sort the old and new information by rooting new concepts and ideas in already existing experiences of the world and then expanding on these. Finally, one has to combine and sort the new and the old information, such as replacing naïve ideas with scientific facts. This then is seen as contributing parts towards an increasing interconnected web of knowledge. Much of these ideas harmonizes well with White and Peas

⁹ <http://telscenter.org/>

¹⁰ www.wise.berkeley.edu

(2011, p. 542) recommendation on how to view links between representations as “*emergent webs of relation to be continually drawn, reorganized, and re-established, and re-established through complex collaborative problem-solving activity.*”(White & Pea, 2011, p. 542).

Albeit developed within a cognitivist tradition, the general structure and principles of KI learning also fit well into the principles of the zone of proximal development (Vygotsky, 1978, 2012), and should in my view without problems be easily transferred to and utilized in studies from other epistemological positions.

3.6 In sum: The theoretical outset

So far this thesis has presented both the theoretical framework, and relevant previous literature presented. Several authors (e.g. Furberg & Arnseth, 2008a; Kozma, 2003; Krangle & Ludvigsen, 2008) points to the shortcomings amongst experimental studies (e.g. Kozma & Russell, 1997; van der Meij & de Jong, 2006) with respect to getting a deeper understanding of why students make meaning the way they do. Following this I have adopted a sociocultural standing for my study. In this tradition learning is not a thing one does to absorb new knowledge, but a product of a social process of making meaning from other students and representations potential meanings.

With respect to all this, the next chapter will present the case, data, and methodological strategies for analysing the data.

4 The Case, Data and Methods

In this chapter, I expand on the presentation of the case given in the introduction, and give a brief presentation of the Meiosis-programme on the viten.no web-site. Further on I present the fieldwork and the types of data collected, before outlining the selection of, and strategies for analysis of, the data.

4.1 Case-presentation

As shortly described in the introduction, the fieldwork for the case study (Yin, 2014) this thesis draws data from took place as part of the Ark&App project at the Department of Education, University of Oslo. The fieldwork for this case study was carried out on a relatively new lower secondary-school west of Oslo, Norway, well versed in both collaborative forms of work and integrating technology into their teaching practices. During eight sessions (two of these did not feature group-activity, and is thus not taken into account in this study. As such I will following refer to six group-sessions, totalling just under three hours), over five weeks we followed 74 students and one teacher. Our intervention may in many ways be considered minimal, as the teacher normally uses a wide palette of resources and tools as part of his everyday teaching-practices. During lessons, the class was divided in half, and every lessons was thus gone through twice. Our focus was on one of these to “half-classes”, The first class functioned as a dress-rehearsal before our observation-proper and allowed us to prepare for what could otherwise have been unforeseen events.

The students sit in the same groups of two dyads in all subjects (organized by the teachers, and changed three times a semester) in a big and open classroom with an interactive whiteboard, an AV-system and several (analogue) whiteboards.

This classroom may not be very typical in terms of its organization and technological opportunities. But, as this case-study’s aim is on student activities within multi-resource environments, statistical generalizability is not a goal.

The focal group was selected from among the three focal groups in the Ark&App case, the analytical reason for choosing this group is that they stayed more on task, had more productive discourse, and used the various resources more observable than the other two

groups. As such, I make no claim for the typicality or representability with respect to the entire corpus.

4.1.1 Cell division in “Viten.no “

The primary resource in the first three of my four episodes make use of an animation of sex-linked Cell division (no: *kjønnsdeling*) from *viten.no*. *Viten.no* was originally developed as a Norwegian version of the American WISE Learning environment (Jorde, Strømme, Sorborg, Erlie, & Mork, 2003; Mork & Jorde, 2005), and consists of 22 programs on several scientific topics, and have over two million monthly page views. *Viten.no* illustrates meiosis through seven chronological slides. The programme on the meiotic process and how this is visualized in seven slides is presented in Figure 4-1 and Figure 4-2. The slides are mostly static, and the animated aspects are the transitions from one slide to the next. On the left side is a text explaining the neighbouring circular graphic. The circular form is reminiscent of a cell, and inside it are different constelations of chromosomes. For simplicity, these representations show only one of the 23 pairs of chromosomes in the human body.

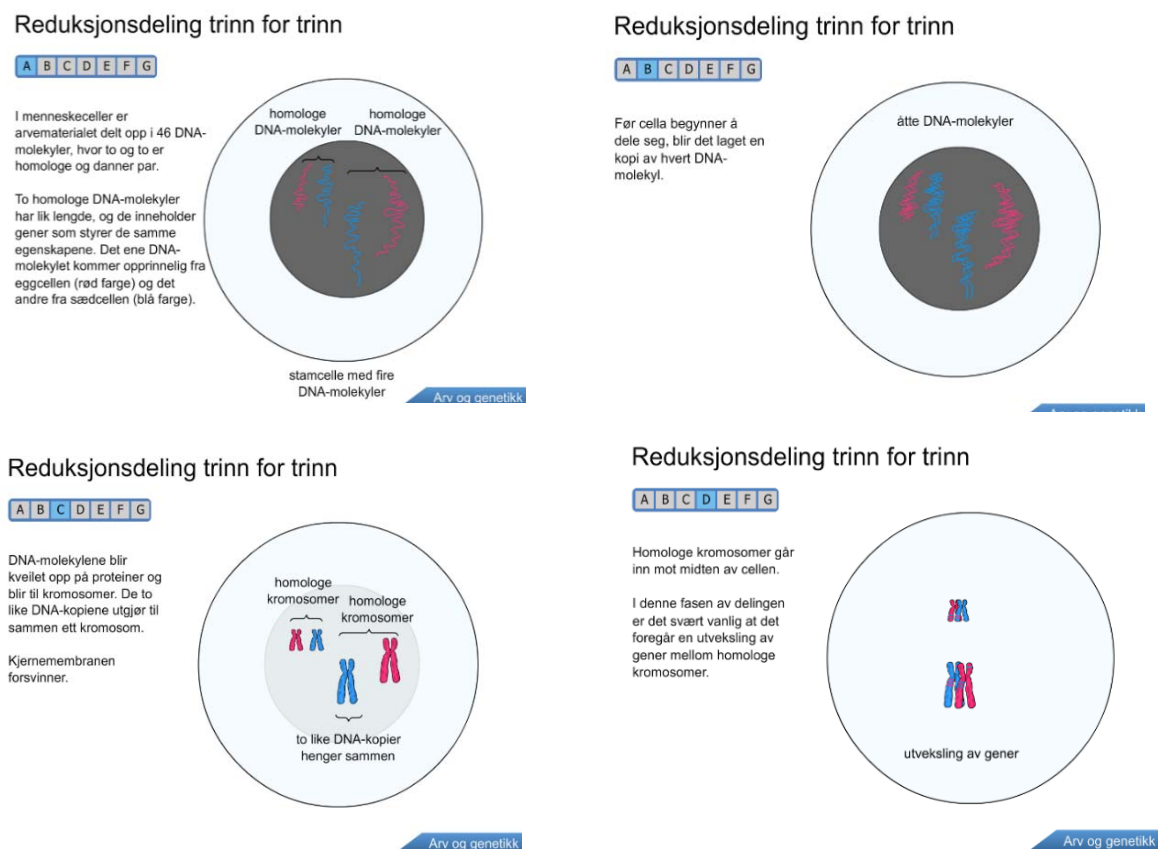
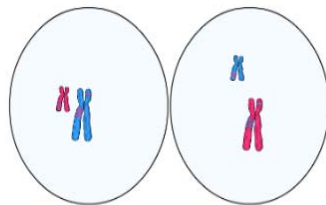


Figure 4-1 Viten Animations parts A,B,C,D

Reduksjonsdeling trinn for trinn

A B C D E F G

Ved første deling går homologe kromosomer til hver sin dattercelle.

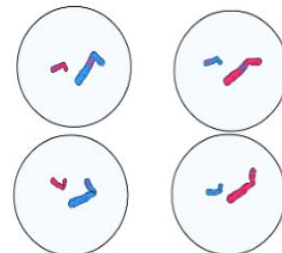


Reduksjonsdeling trinn for trinn

A B C D E F G

Ved andre deling går de to DNA-kopiene, som er kveilet til et kromosom, til hver sin dattercelle.

Kromosomene kveiler seg deretter ut igjen.



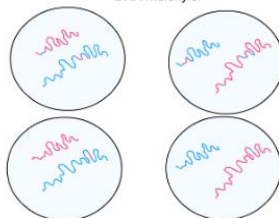
Arv og genetikk

Reduksjonsdeling trinn for trinn

A B C D E F G

Resultat:
Fire datterceller (enten sædceller eller eggceller) med halvparten så mange DNA-molekyler som morcellen. Alle cellene har forskjellig arvemateriale.

fire kjønnsceller med to DNA-molekyler



Arv og genetikk

Figure 4-2 Viten Animations parts E,F,G

4.2 Fieldwork and data collection

The data for this study was collected over 5 weeks in the spring of 2014 of which I participated in most aspects (the classroom studies, the interviews, and implementation of the pre- and post-test). The rationale for collecting these types of data owes to the overall design of the Ark&App project, which in addition to reports form the 12 unique case studies and the two surveys will produce a synthesis report. In order to facilitate synthesizing the individual studies, a set of same datatypes are produced in all of the cases. Accordingly, all cases collected pre- and post-tests, Semi-structured Interviews with teacher and focal student-groups, video

recordings, Structured field notes¹¹, reflective observational notes, and collected resources and products from the classrooms.

4.2.1 Descriptions of data

As shown in Table 1, Our case-study (Furberg et al., 2015) produced many different forms of data, I've sorted categorized these in two categories, *core data* and *contextual data*. The core data are the video recordings of the focal groups work as well as some of the written products of these sessions. The rest of the data collected during the case-study are used to contextualise the core data.

Types of Data	Description	Status
Video recordings	3 Hours of work with focal group.	Core Data
	6 Hours of work with 2 groups.	Contextualizing Data
	11 Hours of teacher / classroom-interaction.	Contextualizing data
	Semi-structured interviews with the three groups and the teacher.	Contextualizing data
Documents	4 filled out handouts from the “mitosis reasoning-task”.	Core Data
	Pre- and Post-test, 29 questions on the topic “Genes and heritage”.	Contextualizing data
	Handouts to students.	Contextualizing data
Structured fieldnotes; Reflection notes	Systematic notations of task, resources, form of work; Notes from all researchers taken down during and after each session.	Contextualizing data
Photos	Photos taken of resources, general interaction and work.	Contextualizing data

Table 1: The different types of data and their status

¹¹ These were also used to log students and teacher's actions and use of resources, and were the basis for the

The video recordings of the groups were mostly done by placing a camera on a tripod behind the students, and a putting microphone on their desk. A typical result of this setup is shown in Figure 4-3, below. The data collection also produced various documents. We collected the students' written products after each session, and the products from the "mitosis reasoning-task" are used in my analysis of three of the episodes presented later.

With respect to the pre- and post-test it is important to clarify some limitations. The pre- and post-tests were not designed or used to measure and generalize effects to a larger population. The test were instead tools used to highlight variation within the participating students or between different topical subjects. As such, the results from the pre- and post-test are only valid within the population that's being studied (Dolonen, 2014).

4.2.2 The Focal group

The focal group in my thesis consists of a pair of boys, Felix and James and a pair of girls, Eve and Tracy. Felix always work diligently, understands most subjects good and is very serious and on task. James seems more reactive in manner and rarely takes initiative to things. Eve is as Felix a good working student although she struggles a bit more than him. Tracy has by cause of a medical condition missed several classes, and is lagging a bit behind, something she herself is aware of. Tracy is not part of the session which the fourth episode is taken from. In Figure 4-3, one may get a sense of what this group and their environment look like. It is



Figure 4-3 The Group at work. (Clockwise from left: James, Felix, Eve and Tracy)

interesting to take note of the fact that the students not only have a wide range of resources at the ready, they also all use different ones and work individually.

4.3 Analytic approach

Both the empirical insights presented in the review and theoretical perspective above underpins the complexity of investigating these phenomena. This leads to a challenge; devising an analytic framework both able to describe the overall typicalities of the group, and at the same time allows for zooming in on, and analysing, the groups turn-by-turn interactions.

Therefore, the analytic strategy for this thesis can be described as a *concurrent embedded strategy* (Creswell, 2009, p. 214). In embedded research strategies one mixes methods, but let one particular have primacy. In this study, the primary data is the filmed interactions which will be analysed based on interaction analysis (Derry et al., 2010; Hutchby & Wooffitt, 1998; Jordan & Henderson, 1995). To enrich and contextualize these short interactional excerpts, I embed the students pre- and post-tests and written products, and additionally I quantitatively code and present the groups interaction with respect to forms collaboration and which resources they utilize. This embedding of more quantitative data provides insights into the groups work that the interaction analysis cannot do, and functions as a backdrop for parts of my discussion.

With working on the case-report for the Ark&App project (Furberg et al., 2015), I transcribed most of the video data verbatim in Norwegian. The episodes in this thesis were selected after viewing the recorded video, together with reading the transcripts, several times whilst taking notes of things interesting. This yielded several pages of unstructured notes that was wound down to four episodes in an iterative process going back and forth between the data and the notes. I re-transcribed the excerpts used in this thesis according to “Jefferson Conventions” (Hutchby & Wooffitt, 1998)¹², and translated these into English.

¹² Appendix 1, gives an overview of the basics conventions used

Using the coding of all video recorded from the focal group in addition to the analysis of interactions enables what Erickson calls seeing the data both “tree-wise” and “forest-wise” (2006, p. 185). I did this by coding the data in NVivo 10 (“NVivo qualitative data analysis software,” 2012) with respect to forms of work, and resources in use. It was thus necessary to operationalize practical, and distinguishable codes. As presented in the review chapter groups by themselves don’t just work as intended. Therefore, I found it useful to create three categories of work, collaboration, partial collaboration and individually. Collaboration is when the entire group is working together, partial collaboration is when parts of the group are working together, and lastly individually is when someone (or all) are working by themselves¹.

With respect to resources I’ve utilized eight codes. textbook, handouts, response forms², notebook, PC, mobile phone, tablet, and the teacher.

To best answer my research questions, the analysis is split into three sections.

The first, chapter 5.1, present and analyse the groups forms of work coded as presented above. Second, in chapter 5.2. I present and analyse three episodes (from the same session, and in close proximity to one another) highlighting three different faces of making sense of a visual representation.

Lastly, in chapter 5.2.5, I present and analyse a single episode from an earlier session highlighting how inquiry learning in school may be impacted by institutional aspects.

¹ Collaboration and individual/partial collaboration are mutually exclusive, whilst partial collaboration and individual work sometimes takes place at the same time. There is consequently sometimes overlap with these two codes

² These are handouts intended to write answers on. As these, when used, take the same role as the notebook It then follows that Handouts are considered to be on par with a textbook.

4.4 Reflections on research credibility

As I took part in the fieldwork, it is not possible to approach the data without any preconception. The danger of researcher-bias is present and should of course be accounted for¹(Derry et al., 2010; Jordan & Henderson, 1995). However, having been part of the fieldwork also affords a primary look view at the corpus of data before it was constrained and contained by the camera and its operator.

In quantitative research talking of a tests *reliability* points to a consistency or stability of responses (Creswell, 2009). Analogous, addressing validity in qualitative research isn't a single verification of data, but rather a process of using accepted validation strategies to document the accuracy of one's study (Creswell, 2007, p. 207). Further, Creswell (2007) highlights several validation strategies frequently utilized by qualitative researchers. Of these I comply with the following: 1. I participated in all aspects of the fieldwork, and thus spent a considerable amount of time *in situ* of our study. 2. Rich detailed descriptions of the situations surrounding my extracts from the interactional data are provided, affording the reader a glimpse of the broader setting. 3. An external reviewer have read through the data and its accompanying analysis. The reviewer is part of the Ark&App project, but have no connection to the case this thesis is based on. 4. I make use of several sources of data; Coded forms of work from video, filmed interactions, students written end-products from sessions as well as detailed field notes from each session contributed to by all attending researchers. Further I also bring up the results from the pre- and post-test to compare the focal groups progress with the rest of the class. The data my analyses draws from are also available in the thesis, allowing the readers to follow my analyses step-by-step and form their own opinion of the trustworthiness of my analytical choices and inferences. Further, these are presented as detailed transcripts based on a standardized system, the "Jefferson Conventions"²(Hutchby & Wooffitt, 1998)(These are available in Appendix 1).

In quantitative research *generalizability* refers to the possibility of transferring findings from a sample to the population. However, in qualitative research with non-randomized and few

¹ The results from the quantitative coding did in fact yield results contrary to my impressions after the fieldwork

cases in focus it is hard to talk of generalizability on the same terms. In sociocultural and dialogically oriented studies situatedness is fundamental, and as such a qualitative design can provide higher degree of ecological validity (Cole, 1996, 2004) as all meaning making processes are contextually dependant. Removing context would thus consequentially remove meaning and thus there would be no study.

4.5 Ethical considerations

As the students in our case were 15-16 years old (minors), the students needed written permission from their guardians before any filming could commence. Students not giving their permission were as such not filmed. The transcriptions were done with the students' real names, but these were anonymized before the analysis started. Additionally, the name and location of the school is also anonymized. Along these lines, illustrations in the thesis have also been treated as to make persons depicted free of many recognizable features. Files and documents related to the Case-study was stored on a secure server at the University, and scores from the pre- and post-test and identifying information is stored in separate documents requiring a decryption key to pair the two, thus demanding this unique key to access.

Before I started the work on my thesis I filed a notification request to The Norwegian Social Science Data Services (NSD), the privacy ombudsman for Norwegian educational and research institutions. NSD deemed my study to fit in with the Ark&App projects already approved permission¹.

¹ The project is registered with NSD as project number 33287 "Fra ARK til APP. Forskning om læremidler i skolen"

5 Empirical examples and analysis

This chapter presents the empirical data and my analyses of these. I've split this chapter into three parts. 5.1 presents the coded and quantified data of the focal group, and some inferences drawn from these. 5.2 is the largest part of this chapter, and contains three chronological episodes from the session with the reasoning-task, as well as of the written end products from this sessions and results from the pre- and post-test on the same topic. 5.3 presents one episode from a session where the students are confronted with contradicting information. First however, I present the coded video-data.

5.1 Typicalities of Group work

Of the six group-sessions, the two first where based around sorting information and answering questions based on the teachers' presentation at the start of the lecture. As can be seen in the table below, Figure 5-1, in sessions 1 and 2 the only resources used were papers handed out by the teacher. In session 3 (which my fourth excerpt is drawn from) the students were tasked with finding out how gender is inherited. Session 4 consists of two parts. First they fill out their own genetic wheel¹, and second they are searching for information about hereditary deceases. The latter part is mostly done individually. The two last group-sessions, 5

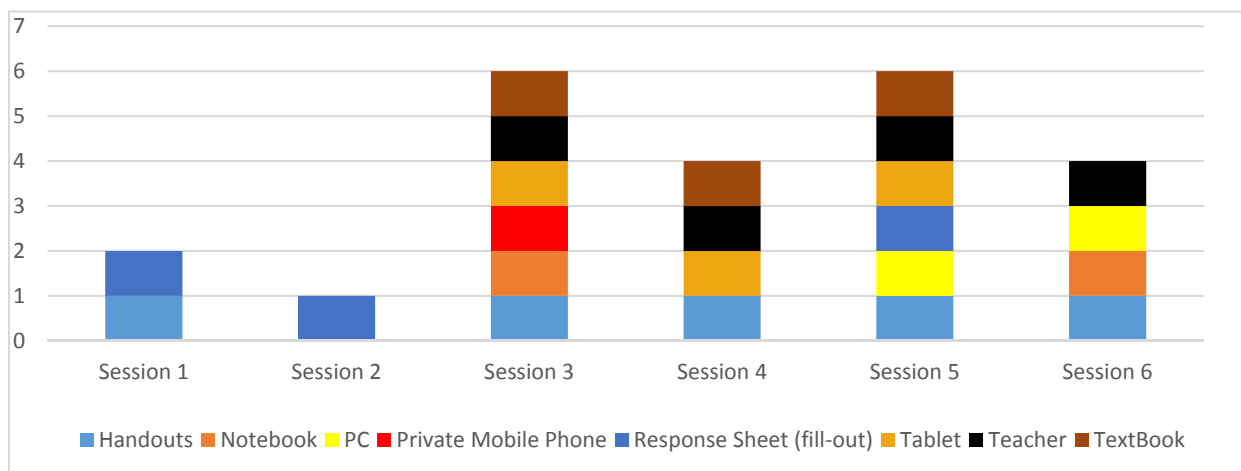


Figure 5-1 Resources Used per Session

¹A task were the students fill in how genes are physically manifested on themselves. For instance, whether you have blue or brown eyes, or whether your earlobes are attached or not. Working out from the centre of the wheel one finally gets a specific number or gene constellation. The students found it very amusing, particularly when finished and comparing their numbers.

and 6, constituted the largest part of our intervention with the reasoning-tasks (no: *resoneringsoppgave*). These tasks are about conceptual difficult subjects, the two types of cell division, and how gender-linked diseases are inherited (no: *Kjønnsbundet arv*). In sessions 3-6 the students are encouraged to themselves decide which resources or tools to use. The teacher has also provided the students with links to several educational websites with animations, texts, videos etc. Several times during these sessions, the teacher not only suggest the students use several these, but also highlights the educational value of seeing things presented differently. Regarding digital resources, our Case-rapport (Furberg et al., 2015) show the students spent time on not only visualisations but also more textually based representations of concepts of inquiry. We also noted the recurrence of some websites, such as: Viten.no, Wikipedia, SNL.no, Bioteknologinemda.no and SSB.no.

Further I've, based on the codes, correlated the student's resources with form of work, presented in the diagram below. The numbers represent minutes in use¹. This diagrams provide good insights into how varied this group in fact worked, and I briefly wish to draw attention to a few aspects.

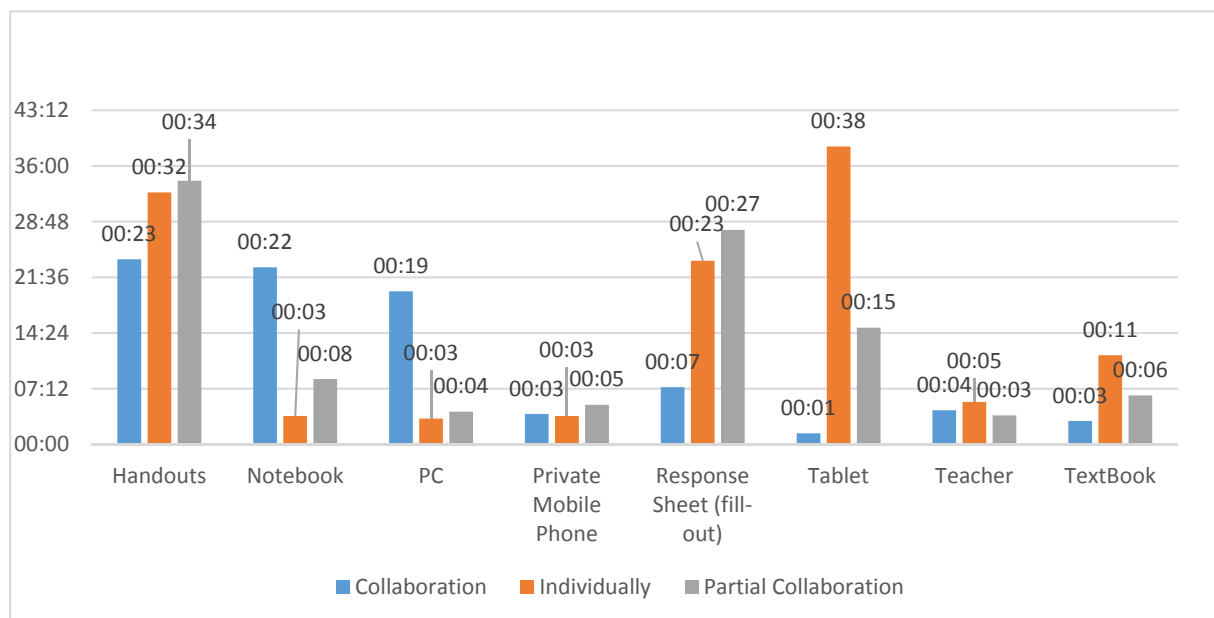


Figure 5-2 Resources and Forms of Work (minutes)

¹ As several resources and/or, forms of work took place at the same time, these numbers are not mutually exclusive.

Firstly, tablets were predominantly used individually. Rather the opposite was the use of the PC. This was mostly used as a resource for the entire group, Collaboratively. This may simply be because the group never had more than 1 PC, whilst they often had a tablet each. The tablets are also unable to run most animations used on educational web-sites¹. We thus see the students withdrawing from collaborative interaction when using tablets, this does not happen with the “shared” PC.

We also see how the notebooks, used by the students individually are mostly used when working collaboratively. They do in other words collaborate on their tasks, yet produce individual products.

Lastly, by simply comparing the numbers from the diagram, we see some connections between forms of work and resource the following way

- Notebooks and PC are mostly used collaboratively
- Tablet and Textbook are mostly used individually,
- Handout and Response form are nearly used the same individually and in partial collaboration²
- Teacher and Personal Mobile Phone are evenly distributed over all three categories of work, but these are also seldom used.

In total it is difficult, on the basis of these numbers to claim a specific form of work or resource as the typical one. However, this is still information of great value, knowing group-activity in fact is different collaborative and non-collaborative forms of work provides insight into how the students themselves shape their own practice. This macro-level also provides important and framing information with respect to my micro-level analysis of the students’ interactions.

¹ As these require Adobe Flash.

² it is worth remembering these two categories sometimes overlap

5.1.1 A lesson

The lessons often unfold along the same lines even though they last for either one or two hours. Normally the teacher starts with a short thematic introduction, checking and probing for previous knowledge on the subject at hand. This also aims at awakening a sense of curiosity for the topic. One good example of this is when the teacher asks the students to taste “PTC-paper”¹ he hands out then starts gradually stepping into the lectures “new information”. All this whilst almost seamlessly changing between monological and dialogical interaction with/towards the class. After the students are as-it-were warmed up, they are given tasks to be solved, most often in groups. To solve most of these tasks, the students are encouraged to freely choose selecting resources, including: PCs, tablets, textbooks, flyers, handouts, and even their personal mobile-phones. Whilst the students work, the teacher diligently walks around the classroom assisting the groups when needed, and if not answering questions for the students giving them new ones.

After ample time having passed with the task-solving, the class goes through the tasks together with room for discussion, clearing uncertainties up and for the teacher to make sure his normative informational goals are met. It is worth taking notice of that this structure is very similar to the knowledge Integration pattern presented in the review chapter. Sometimes however, they go over schedule and this summing step is dropped. Interestingly, even though the student rarely works individually, they almost always take individual notes. Something the teacher even stresses time and again. Considering that not only the spoken negotiation of scientific concepts is hard, but the written formulation is even harder (Kozulin, 1998), this individual responsibility seems somewhat out of touch with the overall social focus on almost every other aspect in this class.

¹ The PTC-paper is impregnated with PTC (phenylthiocarbamide). The ability to taste PTC is hereditary, and 7 in 10 persons taste a defined taste when the paper's put on the tongue. The rest won't taste anything. These are often used in genetics education in schools. (e.g. <http://www.fybikon.no/biologi/bioteknologi/genetikk/ptc-papir-pk-100-strimler>)

5.2 Episodes Part I

In this subchapter I will present and analyze the interactional data from three of the four interactional excerpts. Here the students work with conceptually difficult tasks regarding cell division. The three following excerpts are in sequence, and as indicated by the numbering, they come shortly after one another.

This group-session with the reasoning-tasks takes place in the last 40 minutes of a two hour lecture on DNA and Cell division. The teacher started this lecture by warming the students up the subject of heredity by making them do practical tasks, like folding hand and see which hand comes “on top”, warming the students to the idea of traits like that being genetically inheritable. Further he gradually expanded on the subject switching between lecturing and talking with the students. The teacher then introduced the concept of cell division and this takes two forms, Mitosis and Meiosis. After showing and explaining the two different animations on the subject at the viten.no, one of which I presented in chapter 4.1.1. The teacher then introduced the coming task, handing out papers with questions, links to useful websites such as the already used viten.no page, and forms to fill in and describe the different stages of the division-processes.

5.2.1 The task

The handout starts with the following introduction¹

“Cell division is the term of the process taking place when a cell splits into two new cells. Cell division has two forms, Mitosis (regular cell division) and meiosis (reduction-division. Mitosis needs take place for a body to grow, or to replace damaged cells. Meiosis is when gender-cells (Gamete²) is made. There are some similarities and some differences between the two division-processes. In these group-task, you will explain the two different forms ... Part of this task is to use different sources as foundation for your discussion and descriptions”

¹ See Appendix 3 for a copy of the handout

² This is the English term. There is no English corollary to the Norwegian “less academic” term “kjønnseller”

The tasks

- A. Describe Step-by-step the process of normal cell division (Mitosis)
- B. Describe Step-by-step the process of gender-division (Meiosis)
- C. Discuss and write down what you consider be the most important differences between the two processes

Below is a graphic of the two different types of cell division from the handout. Task A and B is to be written in the boxes between the graphics. Task C is to be written down on the backside of the handout after the discussion.



Figure 5-3 Two types of Cell Division

5.2.2 Episode I: Viewing Animation

in this first extract we are 8 minutes into the groups work on the reasoning-task, and they have just finished going hurriedly through the animations of Mitosis, and promptly ended it by saying “I got it”, enforcing their belief in understanding it. Felix, seems bored with the rest of the group’s efforts, and as may be seen to the upper right in Figure 5-4, he has withdrawn from the



Figure 5-4 Run-through of Mitosis

group, and already started answering the questions on his own. Now they are just about to start on the Meiosis process. Where we start, they have just moved the pc to allow James to fully see the screen, and opened the meiosis animation.

301 Eve Okay.. We Have..(1.0) ¹
302 Tracy Yes, We Have homological((reads from a description on part A og animation)).. I didn't [understand so much of].. It doesn't matter]
303 Eve [DNA, which means they are alike] ((points at the DNAmolecules on screen))
304 Tracy yes
305 Felix Not, That mean they are a pair
306 Eve Or. [They're paired then]
307 Tracy [mhm] They're homological too-
308 Eve But-
309 Tracy That heterogyle thing-
310 Felix Nah.. That haven't got anything to do with this
311 Tracy No, but that it is something else.. I didn't get the difference, [but we can take it some other time]
312 Eve [That's on gene.] (1.0) That's if it is big b og small b-
313 Tracy Ohh.. Okay.. (0.8)
314 Eve Recessive and dominant
315 Tracy [like tha::t]
316 Eve [And they split] ((goes to part B in animation)), right.. And become (0.5) ei[ght]
317 Tracy [copied]
318 Eve I mean they are copied, sorry.. (1.0) ((goes to part C))
319 Tracy and that's the [same thing]
320 Eve [and it becomes] cromosomes
321 Tracy mhm..
322 Eve ((Goes to part D))(0.5) and then they join [together]-
323 Tracy [together]-
324 Eve they kind of just borrow... borrow some parts
325 Tracy yea..
326 Eve (2.0) and then.. ((Goes to part E)) (1.0) ((While animation moves))
327 Tracy they are [dragged apart]
328 Eve [dragged apart], but then [they don't split]
329 Tracy [and they split].. Yes.. Look... look now.. [It's]-
330 Felix [It..] It's((part F in animation)) [now the split]
331 Eve [now they split] ((next move in animation)) (1.0) and we get [one more]
332 Tracy [But they] (0.4) Yea, Now i got it
333 Eve because they og ((goes back to part E)) thorough 2 [splits]
334 James [what's] up with that last animation being so damned long?

1 The transcriptions were done according to the "Jefferson Conventions"(Hutchby & Wooffitt, 1998) (see Appendix 1, Jefferson Conventions The Jefferson Conventions)

- 335 Tracy It's silly. Actually it should be now at the end there that they should like ((point to the screen))
 join together.. But then.. they must split once into two daughtercells, and they they must spli-
 drag them apart afterwards.. So they [become 4]
- 336 Eve [Okay]
- 337 Tracy Got it.
- 338 Eve And then.. Tada! ((Goas to part G, the last)).. (2.0) with (3.0) yeah..

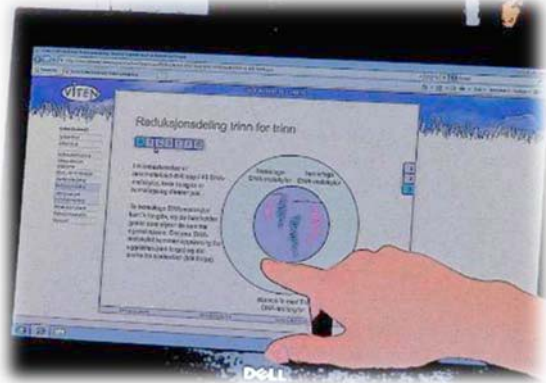


Figure 5-6 Viten.no Meiosis part A

We start in line 301 with Eve launching the animation-programme, Tracy is reading from the screen and stating she doesn't understand much, yet progresses. Eve takes little notice and is still talking about how they are the same when Felix interrupts I line 304, and says they 're a pair. To which Eve complies. Tracy (307), still seems to think they are homologous (a concept presented and used plenty when the class worked with

*Punnett Squares*²), but Felix further tells her off. Responding to this Tracy seems to contradict herself when in 311 answering no to Felix's statement, and at the same time saying it is something different, then that she didn't understand it but they could leave it for some other time. To this Eve in line 312 tries to clarify that it is when using big and small Bs (which they were doing when using the Punnett Squares. Tracy says okay, yet Eve continues her explanation in 314.

Eve narrates and goes further with the animation, we see the cell "split" in half., although Tracy corrects her and says it is "copied", not split (317-318). Eve concurs and goes to the next slide, C. Tracy says it is the same as the previous slide (319), Eve continues and says it then becomes chromosomes. They progress to the next slide which show the chromosomes mixing and say they join together, at the same time (322-321). Eve expands and says they now borrow parts from one another (a phrase used by the teacher earlier in the session). Further on the to the next slide, E. Whilst it is in motion both Eve and Tracy comments it being pulled apart (327-328), and try to

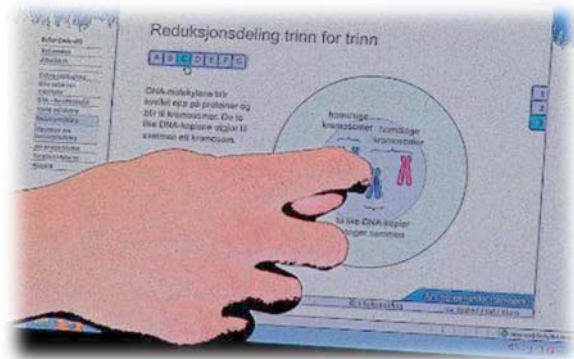


Figure 5-5 Copies, not a pair

² Punnett Squares are called "kryssningskjema" in Norwegian

predict what's coming next when they disagree by Eve saying it then won't split, and Tracy says it will. When Tracy tries to explain her position, and the animation moves into the next slide, Felix, for some time not part of the dialogue, in line 330 promptly says it is now they split. Eve (331) says the same and summarizes that we get one more (cell). Tracy (332) seems unsure, and hesitates a bit by saying "*but they..*" and then "*Yea.. how I got it*". Eve in line 333, goes back to slide E and show it splitting again, to which she says it is because it goes through two splits. In line 334, James, quiet until now, half-jokingly asks the point of the long animations, to which Tracy responds that it should be different and first split before being dragged apart yet again (335) (an explanation that is wrong). Eve seems to concur by saying okay as the animation concludes (336), and Tracy in a way answers herself by saying "*got it*". Finally, Eve opens the last slide lightly fanfaring it (337-338).

From this episode I identify three analytically interesting points. Firstly, the main mediating tool/artefact here is the animations from viten.no, which affords not only an animated step-by-step view of the meiotic process, but also controlling the speed at which the users progress it. In spite of this Tracy and Eve appears to rush through the program. If we consider their overall object for this entire task to answer the questions, we might look at their goal in this extract as being going through the animation. The talk is rapid, often providing a "play-by-play" comment to what they see on screen, and there are seldom pauses. This in my view corroborates the notion that their goal here is predominantly procedurally oriented to viewing the animation rather than focused on making sense of the underlying concepts. The two times Felix enters the conversation, Tracy and Eves goal looks to change to understanding him. However, this reverts back shortly after Felix leaves the conversation again. Twice, in line 311 and 335 we see Tracy claiming she gets it while she seemingly doesn't.

Second, Felix could be considered to be part of the community based on how he sits in the background until he by himself finds joins the conversation. James only says something once, but is in fact following the animations closely and have earlier in the session repeatedly asked for the group to collaborate. Therefore, I consider Felix to have a different object than the three others. As such he's part of the rest of the groups activity, and I label him part of the community. When he joins the conversation it is also on his own terms. As we can see in line 329, Tracy is about to test her hypothesis of what's happening next when Felix jumps in and explains.

Lastly, Tracy and Eve denotes the two splits differently. As we can see in lines 327-331 they speak of the cells as first splitting, and then being dragged apart. The animations are unable to correct this misconception. The (static) screenshots of the animations presented in chapter 4.1 does not show this, but the two splits are identically portrayed.

5.2.3 Episode II: Discussing Animation

In this second episode, we are 20 turns after the previous episode. The girls have been trying to explain the differences between mitosis and meiosis properly to one another without much success. Felix again steps in and tries to explain by way of the animation. It is still hard to get and he picks up the Textbook, Eureka 10 (Hannisdal & Haugan, 2008), which he has been silently reading in the background. It is interesting to take note of that even though the teacher has been encouraging the students, both before and during this task, to use different resources they stick with the viten.no programme. In spite of not making sense of it.

- 359 Felix Let me show you ((picks up the textbook)). I have a drawing here, so I
[can show you]
- 360 Eve [show me once more.. Heh]
- 361 Felix this is a drawing of all the chromosomes
- 362 Eve I was actually a bit behind
- 363 Felix ehh.. In normal cell division ((Mitosis), for example.. Eh.. Each of these two makes a copy of
itself(1.5), and then the next: (1.0) and then it goes ehh. Then the copy splits so you get 4, two of
each-
- 364 Tracy Yes, one original and [one copy]
- 365 Felix [-yea] (0.5)Then one each of these chromosomes goes to each cell. (1.0) So
in the end both cells have both of these two
- 366 Tracy mhm..
- 367 Eve yes:
- 368 Felix But in this ((Meiosis), it makes a copy of itself, and then the double, in other words two of these
to one cell and two of these to the other cell-
- 369 Tracy Yea. And [the it splits itself again after that]
- 370 Felix [And it splits itself again] so some cells of that and some cells of that. So One
cell can (1.0) It has (0.5) 23 chromosomes that could be random, so it could one of that and one
of that- ((points on karyogram¹ in the textbook, this is also shown in Figure 5-7))
- 371 Tracy Mhm?-
- 372 Felix and it is kind of random which they are (1.0)
- 373 Eve Yea, okey? (2.0)
- 374 Tracy yes-
- 375 Felix It's only from each.. From each chromosomepair you get one of the chromosomes (2.0)
- 376 Tracy Yes (1.5) How:::-

¹ A Karyogram is a picture of the different chromosomes put together

377 Eve Do we get on of these ((points on the screen)) is it one of these you're thinking of? (3.0) Like.. I'm still not getting it. I don't [know if it is only me whos-]

378 Felix [Go further back] now ((points at the screen))

379 Eve [drained or]

380 Felix [Go one more].. To C((directs the animation))

381 Eve Or just.. (1.5) Everyone keeps up until here ((talks about the slide in the animation))

382 Felix Yes.. Because.. What's important is that ((points)) think of it as a Chromosome

383 Eve Yea..

384 Felix because it is one chromosome only with one copy. So that's a chromosome and that's a chromosome.. And the two of them are chromosome-pair

385 Eve yes-

386 Felix which together make up.. If you go to D now- ((next slide in animation))

387 Eve But is that for instance a copy of that?

388 Felix [No]

389 Tracy [No]

390 Felix No: it is two blue ones here: but it is actually only one chromosome with two identical

391 Eve Yes ((0.5))

392 Felix It's so: (1.0) it is made a copy, that's this

393 Eve yea. And it is made a copy that that ((point so the chromosome))

394 Felix Yes:: and actually one blue, this((points)), and one red, this((points)) belongs together as a chromosome-pair

395 Tracy In a normal mitosis-thing?

396 Felix [yes]

397 Eve [Yea::] okey

398 Felix And now (0.5) so.. E ((directs to change slide)) (1.5)

399 Eve yea.. ((changes slide))

400 Felix So (1.0) To (0.5) to.. If this had been normal cell division, each had been given one part of that, one part of than one part of that and one part of that ((points repeatedly at different parts of a cells chromosomes))

401 Tracy mhm..

402 Eve yea.. ((changes slide))

403 Felix But instead, it gets two identical

404 Eve Yes okey.l. then i get what you mean

In line 359 we see Felix take control of the discussion, something Eve welcomes. Felix starts before Eve is done talking (360-362). When Felix starts to explain Mitosis in 363, he hesitates a bit as if he's perhaps a bit unsure of what to say. After explaining Tracy affirms what he been saying, although Felix has talked about a total of unique 4 cells. Tracy in 364 says “one and one” (totalling only two). Felix



Figure 5-7 Book and Screen

seems somewhat disagreeing with her response, yet continues on with how the cells then are copied (365). Both Eve and Tracy seem to understand this by saying “*mhm*” and “*yes*”. Felix then in 368 turns to talking about Meiosis, and Tracy builds on what he’s saying and continues with “*yes, and then it splits again after that*”(369). Felix continues his presentation without really acknowledging Tracy’s statement. Tracy follows up with “*mhm?*” sounding like she not really gets it. And Felix continues with “*it’s kind of random which they are*”(372). Eve seems to not exactly understanding by saying “*Okay?*” .. in a asking way after which there’s a two second pause before Tracy simply says “*Yes*”(373-374). Felix continues and in 376 Tracy asks “*How?*” and Eve continues (377) “*do we get these*” whilst pointing at the screen, indicating they both struggle with the same. Again, and talking over her, Felix tells Eve to go backwards in the animation, they move backwards until Eve says they keep to this point (378-381). Felix goes on comparing it to a chromosome (which they have talked extensively about in the latest classes). Eve indicates she follows by saying “*Yes*” (382-385). As they continue to the next slide she in line 387 interrupts Felix asking what she points at is a copy of another part of the animation (387). Felix answers no to this, and as does Tracy (388-389) (although she has given no indication of understanding this). Felix answers Eve in 390 and explains what in fact is copied into what. Eve then confirms her understanding by asking if “*that*” is the one making the copy. Felix confirms Eve’s understanding and further expands whilst pointing at the screen(392-394). Tracy then asks if this is “*in a normal Meiosis-thing*”, seemingly trying to confirm her belief. Felix concurs (395-396). Eve says “*yea::: okay*” and seems to get it all now, finally understanding the totality of the meiosis process. Felix in line 400 tells Eve to again change the slide and finishes up his explanation of meiosis. Tracy responds with a “*mhm..*” and Eve says she then understand what he means(401-404).

Analytically there are some interesting points to highlight. Firstly, we see the orientation of the work now less focused on doing a particular piece of work and more towards actually understanding the concepts. Tracy is out of the conversation for most of it, and the only times she says



Figure 5-8 Felix explaining to the group

something she's reaffirming what Felix said, although she doesn't seem to understand things. It is as if she's given up understanding the now more complex conversation between Eve and Felix. From line 370, there are more pauses in the conversation, this at the same point Eve is struggling with understanding.

Secondly the textbook, a new tool and representation in this extract, seems to only cloud the sensemaking processes. As both Tracy and Eve struggle with understanding the first representations, they don't benefit from the comparisons with another drawing. Also, perhaps clearer than in the first extract, Felix' explanations should also be considered a new representation for the group to fit into their sensemaking. This also in my view underbuilds Felix' position as a tool for the group. However, a tool that they don't control in the same manner as the Viten.no animations.

Third, Felix' object is still don't looks to be the same as the rest of the group. When Felix Joins the conversation, he has been reading the textbook to which he turns when explaining, the concepts to the rest of the group. Eve tries to make sense of his explanation and finally, in line 381, is able to break through and say where they struggle with making sense.

Fourth and final, even though the Teacher has told them to use any resources (tools) they want, they still stick with the one animation provided and the trusted old textbook. They are not able to create an understanding of the representations, but are perhaps to set in their ways to really go off the beaten track. This to me indicates that the rules and norms of the school are quite set in the students.

5.2.4 Episode III: Writing it down

This final extract comes some 54 turns after the last extract, and sees the girls in particular trying to negotiate an answer to write down. This episode serves a final glimpse into the groups sensemaking with respect to the cell-division task this session. As talked of in the theoretical sections of this thesis, formulating and writing information down is difficult, and demands a great deal of knowledge. Thus, this extract should give us good insights into the groups final act of making sense of the subject at hand.

458 Tracy The difference between mitosis and meiosis is mainly that (1.0) Ehh (1.0) Meiosis splits (1.0) twice? (1.5) Isn't it?

459 Eve [yea..]

460 Tracy [And then] (2.0) Yeah-

461 James hu?

462 Tracy Yea.. Because you said (mhm) meiosis was the one..

463 James (yeyeye)

464 Tracy last one, and then they split.. And in becomes 4 child-cells in the end and not two. So they split one more time

465 James so they split twice-

466 Eve that mit- but that's mitosis standing on a line and splitting [and]

467 Tracy [Like that] ((points to the screen))

468 Eve and gets dragged out at once

469 Tracy mhm..

470 Eve while..

471 Tracy to those single DNA, What's it called? Like that

472 James It says on the slide ((Of the animation))

473 Eve each side of the cell? ((reads narration from the screen))

474 Tracy It's on F ((slide F in the animation)), Yes.. DNA molecules was what I thought it was called

475 Eve DNA molecule (1.0) Like (1.0) They go on a line and splits, but in meiosis it (1.5) it is the same outset but they (1.0) go together and then they mix that (1.0)

476 Tracy Genetic material

477 Eve genetic material go they in a way mix up a little (5.0) and then both go to the sides (2.0)

478 Tracy yea..

479 Eve they're (kindof) dragged apart, but the entire (0.5) Entire chromosome goes to one side-

480 Tracy and then they split to DNA molecules

481 Eve and then, when they've gotten to that cell they split again

482 Tracy to DNA molecules::

483 Eve Yes,[I don't know how to (1.5) Write this]e

484 Tracy [and then it becomes 4 Child-cells. I don't know how to write].. Yes. Me either (2.0) Can't formulate it.. (mumbles something) (3.0)

485 Eve mainly that-

486 Tracy I'll write splits (2.0)

487 Eve I'll write Mitoses first.. (4.0) Mitose:: (4.0) splits (1.0) once.. ((Reads what she writes))

488 Tracy (3.0) But it is meiosis that splits once more..

489 Eve yes, they split once

490 Tracy ahh..

491 Eve (ehh) (2.0)

492 Tracy while (1.0)

493 Eve Once (1.5) Comma. And then half the chromosome

We start with Tracy vocalizing her understanding of the difference between mitosis and meiosis. Eve affirms this understanding, and Tracy goes on in 460, when James askingly says “*Hu?*” indicating he isn’t following. Tracy justifies her explanation by referring to what they have talked about earlier, and James seems okay with this (461-



Figure 5-9 Felix working on his own.
The rest of the group looks the screen

463). Tracy talks about the last step in the division-process. Out of which James gets “*they split twice*” (465). Following, Eve says it is mitosis that’s on a line and gets split. Tracy jumps in and points to the screen (showing just this), Eve continues with the chromosomes now being dragged apart (466-468). Tracy seems unsure and responds with “*mhm*” and Eve starts continuing in line 470 when Tracy says “*to those single DNA*” (471). Building on Eve’s statement in line 468. Tracy then asks what it is called, to which James says it is written in the slide describing what they’re talking about (472). Eve reads of the screen before progressing in the animation to the slide James just mentioned. In 474, Tracy says it is on slide F, and once the slide comes up confirms it is called DNA-molecules. Eve builds on this, starting to explain further, albeit with several short pauses seemingly trying to understand what she’s talking of. Her utterance ends with a question when she can’t remember the word genetic material², luckily Tracy can, and she continues (475-477). Tracy looks to be agreeing and Eve furthers on, struggling to explain the chromosome splitting, and moving the way it does in the animation (478-479). Without stopping to clarify, Tracy moves on saying this split into DNA molecules. Eve continues, by saying they again split, a sentence Tracy Completes with “*to DNA molecules*”. (480-482). Eve says she still don’t know how to write this. And Tracy continues her last utterance before catching Eves troubles. Troubles she’s also having (483-484). In line 485 Eve carefully tries to start explaining, Tracy starts writing, saying she will write splits. Eve responds in 487 by saying she will start with mitoses. And after reading aloud what she writes, Tracy asks if she’s wrong about this being mitosis (488). Eve states it is meiosis that splits once more, something that Tracy seemingly accepts (489-490). Eve again

² *Arvemateriale* in Norwegian

seems unsure about what to write. In the last two lines, 492 and 493, we see both girls reading aloud what they write down

First I here wish to draw attention to how the group is working. For the first time we see James properly taking part in the conversations. Felix on the other hand is absent. This again signifies he's not part of the activity. However, when he's not taking part, the rest of the group seems rather aligned with respect to the object, writing the answers. This object is now no

longer in the future, and is also the goal they are working on at the moment. Where before the object was distant, it is now close and looks to have a shaping effect on their activity as they now are delving into understanding and explaining the concept. This,

secondly, additionally shows this is still very complex and hard to make sense of. We see the Tracy and Eve

in lines 479, 480, 481 talking of a total of three splits (there are only two) in the cells without picking up on this gaffe themselves. This indicates they in fact are far from a conceptual and overreaching understanding. However, for the first time we now see them utilizing more of the affordances of the viten.no programme, such as going back and forth.

The hesitant nature of the last 10 lines to me underbuilds their uncertainty on the topic. By not being part of the conversation, Felix is also not shaping the direction in which the group work. That genetics is conceptually complex and hard to learn is on par with the literature presented in the review (e.g. Furberg & Arnseth, 2008; Krangle & Ludvigsen, 2008; Lewis et al., 2000b)

Third, still struggling they still don't look for other (better) explanations.

Fourth. As talked of in the review, formulating written texts is very different than speaking it. Thus, it is not surprising the group's unable to write something down, when they can even speak about it. Also possibly contributing to these writing-troubles is that they are writing individual answers. Even if they come to a collective agreement/understanding, they must still

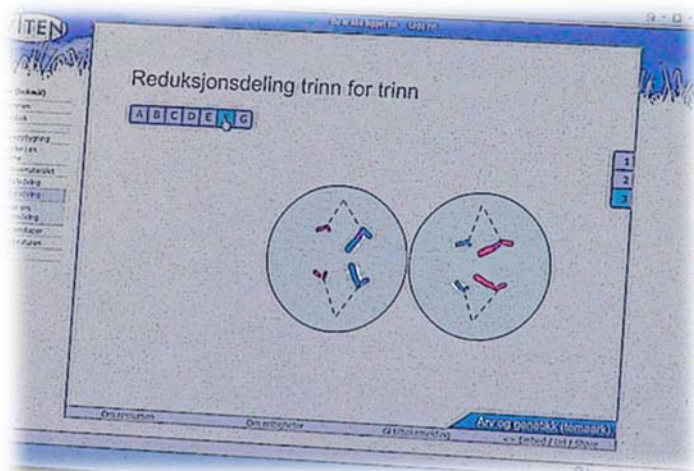


Figure 5-10 Chromosomes being "Pulled Apart"

formulate their own texts. As can be seen from the last 10 lines, Tracy and Eve looks to seek accept for every word they write down. Indicating they are very unsure of the actual facts.

5.2.5 Written responses, The Pre- & Post-tests

As presented in chapter 5.2 the task from the three first episodes were on a handout. The first page a presentation of a task, and the last two pages a response-form (available in Appendix 3, response form). Considering the students' written products of the interactional trajectory of episodes I through III is affords us a look on their final outcome of their meaning making processes. Lastly, I also present selected results from the pre- and Post-test given to the students as a part of the Ark&App study (Furberg et al., 2015).

5.2.5.1 End products from episodes I, II, & III

This additional data is interesting, and both underbuilds and contradicts analytical inferences made earlier.

Tracy has written down the two explanations, task A and B, more or less similar, and made no written explanation on the differences, task C.

Eve have written the most thorough explanation in the group and it is mostly faultless.

However, she still makes a distinction between the cells being dragged and pulled apart.

Felix, have contrary to what one might infer from the extracts above not even written as much as Eve. His description of the two different processes are mostly correct, yet his written explanation if the specific differences is only two sentences long.

Lastly, James have barely written anything, just two sentences on the differences, task B, rather than writing the explanations on the processes, task A and B.

From this I wish to highlight two aspects. Even though Felix gives an impression of being ahead of the other, he still has not completed his tasks. Eve, as the only one in the group, have written extensive answers on all three questions. One reason for Felix not having written much on the differences could be that task C ask for the students to discuss. Felix withdrew from the group when they started properly discussing the differences. Eve is as such the one with the best answer to the tasks given by the teacher. .

5.2.5.2 Pre- and Post-tests

The statistical information presented in this paragraph is drawn from the case-report (Furberg et al., 2015). With respect to the pre- and post-tests, which were for the entire topic of genetics and heritage, the class as a whole did very good. A Paired T-test (Howitt & Cramer, 2011) showed a significant difference between pre- and post-test, and the effect size Cohen's d (Cohen, 1992) were calculated to = 1,84, indicating a large increase in performance from pre- to post-test. However, two questions stand out with barely 20% correct answers in the post-test, those on the subject of cell division. With respect to the pre-test, none of the students on the group answered correctly on the questions regarding cell division. This however, is not that strange, as cell division is a new topic for the students. On the Post-test, Eve and James filled in the parts of the meiotic process correctly, Tracy did not write anything in these questions, and Felix was not in attendance when the test was given. We may as such infer even though the class as a whole showed large increases in performance on this topic, around 80% still struggle with cell division after having worked with it. We also see that our group aren't the only ones finding this hard.

As presented in chapter 4.2.1 these results shows the variance between the students and the different topical subjects, and should not be taken as being generalizable outside of this environment.

5.3 Episodes Part II

The task the students are working on in this excerpt is to find out how gender is inherited. When starting to work on this Eve asks the teacher how they are supposed to find this out. To which he replies: *“use Ipads, Textbook, mobile phones, and do searches.”*

This session the group consists of Eve, James and Felix. By being only three, the dynamics are radically different than seen in the above 3 episodes.

5.3.1 Episode IV: It's Simplified

This session, the group are working on describing how gender is inherited. After getting an introduction, per usual, by the teacher. In addition to their textbook, they have been given handout from «The Norwegian Biotechnology Advisory Board» and a Tablet and several useful links to web pages for researching this phenomenon.

The current section is taken from the midst of working, and the students have just found that contrary to their previous impression it is not born as many girls as boys. A fact not mentioned in the textbook or other «normal» resources, but found on «*Statistics Norway's*» website. The teacher comes by and is confronted with these facts by the students

- 174 James According to this table, it is always a bit higher chance of it being a boy all the way(1.0)
- 175 Eve so the chance of getting a boy is a bit bigger all the way (1.5)
- 176 Theacher the possibility of getting a boy (1.0)
- 177 James It's 51 (point) something everytime
- 178 Eve Statistisk sentralbyrå ((Statistics Norway))
- 179 Theacher (4.0) the probability of it being a boy is constant? it is higher all the way?
- 180 Eve (1.0) but (1.0)
- 181 Theacher Why?
- 182 James But here ((refers to the Punnet square they have drawn)) it's-
- 183 Eve Well, that is really simplified-
- 184 Theacher yes, that one's simplified-
- 185 James Well, it isn't here.. Its really simplified..
- 186 Theacher There's something that modifies it, or? It to some extent changed, yes.. Whe should- (1.0)
Are you able to find out more on this?-
- 187 Eve Yea
- 188 Theacher what causes it?
- 189 Eve [We could Try]
- 190 Theacher [Many are curious of this], many have heard of this. But many of those have heard its girls
(0.8) that more girls live on in any case-
- 191 Eve but?-
- 192 Theacher But here It said boys didn't it?
- 193 James Yes..
- 194 Theacher 51% Boys was it?
- 195 Eve Not that live on-
- 196 James [Only that-]
- 197 Theacher [No, that's how many] born, wasn't it?
- 198 James That's born-
- 199 Eve Yes..
- 200 Theacher So it's
- 201 Eve But girls live longer
- 202 Theacher There's probably some sort of discrepancy here
- 203 Eve though, It could be other stuff as well
- 204 Theacher Yea.. It could have something to do with those.. Things like that ((Teacher leaves the
group))
- 205 Eve Social heritage
- 206 Felix Okay (1.0) I think the reason for it not being 50% is that theres'e a difference between it
being X or Y Chromosome in the Sperm (1.0) they don't quite know yet. But they think
there's something to do with them swimming faster than others.. A little..
- 207 Eve ahh
- 208 Felix Because they have different chromosomes and that makes them bahaving a little
different. They think that's the reason for it not being exactly 50%
- 209 Eve Yea.. That's a really good explanation. That's alright

210	Felix	mhm..
211	Eve	It is.. (2.0) May I have a look at that ((Takes an extra and moreadvanced handout Felix have been given)) (1.0) What was this about? (15.0) It doesn't say anything about it here? (uhh) (5.0) thanks (1.0)

We start with James in line 174 explaining to Teacher what he sees on the web-page. Eve affirms this view by repeating what he said. Teacher Says this a third time, almost sounding like a question. James Answer in 177 by referring to the specific statistics. Eve further attest this by saying it is from Statistics Norway. Teacher than ask whether this is both constant and for every child born, as if trying to get them to solve this. Eve is without a clue and simply says “*but*”. Teacher completes this utterance in line 181 with “*why*”. James points to the Punnett Square in line 182, but before he reaches to ask Eve, and subsequently Teachers and even James says it is simplified (183-185). Teacher muses a bit around this before asking if they are able to look deeper into it? Eve confirms this, and Teacher adds “*what causes it?*”, to which Eve says they could try (186-189). In Line 190 Teacher gives some justification for the group to do this, that other have heard it is the other way around. Eve simply answers as if expecting a “*but?*” coming (191)? Then Teacher counters with what info they have just given him, something James agrees with. In 195 Eve, and later James, clarifies they’re not talking of those that live on, but number of children born (195-200). Teacher keeps probing for more information. Eve follows with “*but girls live longer*” in line 201. Teacher sums it up with being “*some sort of discrepancy here*”. Eve expands and submits it could be other aspects as well. In line 204 Teacher reaffirms that it could have with other things to do, and without answering any of their questions leaves them be. As Teacher leaves Eve suggests “*Social heritage*” as a contributing factor. In line 206, Felix Suddenly enters the conversation by reading out an answer he’s found inline. He seems a bit unsure, but summarizes the information, That Y Chromosomes swims faster, to which Eve simply replies “*Ahh*” and lets Felix continue in 208. In line 209 Eve Say’s it is a good explanation, Felix simply replies “*mhm*”. In line 211 Eve reassures Felix she wasn’t being humorous, and borrow an extra handout he had, she finds no explanations on this.

This episode is particularly interesting as it offers a glimpse into students' inquiry in a mixed culture. As opposed to the three previous episodes, the problem at the heart of this meaning making process is that the representations they use are simplified, and they come to realize it. Above we saw the students struggle with a very

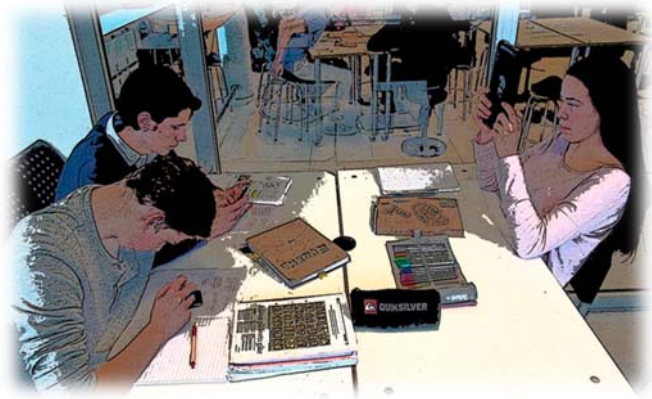


Figure 5-11 Everyone using a mobile device

complex process, and barely managing to speak of it. Here we see them move beyond the typical representation of this and beginning to discuss more advanced than the representations invite to. However, they do very little to in fact question the explanation they get in this episode. But the last 10 minutes of the session sees the group working with this, everyone utilizing a tablet or mobile phone. Eventually they gather enough information and start discussing how the probability of getting a boy changes with the number of children one already have given birth to. it is all in all a very interesting how finding this little simplification of a representations actually invites moving way beyond

The students have many times drawn the Punnett squares, and are very used to this representation of heredity. However, when the new information comes up, this challenges their existing ideas. However, as opposed to what we have seen in the previous three episode, now the students move out of the institutional norms and rules we have seen constraining them to not move “outwards” with respect to finding resources and tools.

When Teacher arrives, the group starts confirming their understanding with him, as if still not fully trusting their sources. Teacher confirms their findings, and encourages them to look even further. This to me is the teacher supporting the students inquiry. In Activity theoretical terms the teacher is interesting, in the same way as Felix I see him as being both community and tool. But differently from Felix, Teacher tries to support the students inquiry instead of giving them the answers. Instances like this are hard to imagine happening in a traditional textbook-driven school reality.

6 Discussion and concluding remarks

Learning genetics is hard and complicated (e.g. Furberg & Arnseth, 2008; Kindfield, 1994; Lewis et al., 2000b). During the four episodes we have seen several examples of how students work not only with different resources and representations, but also with each other in a group. In this chapter I will again draw attention to this study's research questions and seek to answer these, with respect to both the empirical data and literature provided, through a discussion.

6.1 What characterizes group work in this multi-resource environment?

There are many aspects and considerations to take into account when characterizing this group work. To answer this question as thoroughly as possible, I wish to highlight four topics.

6.1.1 Activity theoretical considerations

Considering the group, from the three first episodes, in activity theoretical terms one should perhaps believe they at least in part share the same object. However, in our case the group was put together by the teacher, and as such the constitution of the group itself is a rule enforced upon them. I would further consider Tracy, Eve and James to constitute the subjects, those in an activity towards the object. The object and outcome is fulfilling the task, describing and discussing the similarities and differences of mitosis and meiosis. Division of labour is contributed to both the explicit description in the task, and the tacit and traditional norms of the school regarding work. The tools are resources at hand, PC, book, handouts. The community is the rest of the class, the teacher, and additionally, Felix. James is mostly a bystander and has very little to do in these episodes. But as he is partaking in the task following what the girls do I still consider him part of the subject

6.1.2 The object of activity?

Central to the three first episodes are the groups concrete outcome, to fill in and explain the handout. As an extension of this, Eve, Tracy and James agree on an objective that is viewing the animations to be able to fill in the handout. In line with Kaptelinins (2005) negotiating of

the object, the trio adjusts their motives and thus ends up with a shared object and as a result have a direction for their activity. The activity is then broken down to several actions and goals. In the first episode, the group looks more oriented towards the immediate goal of completing the viten.no programme, than their (at the moment) more distant object – Completing the task. Further, when Felix jumps into the conversation, he changes the balance of the entire activity system. This however reverts after this immediate problem have been solved. In episode II and III, as they get closer to the object and outcome, the group looks to focus more on understanding so they can write their answers rather than simply rushing through.

I make of this that Eve, Tracy and James' are procedurally oriented (Furberg & Arnseth, 2008; Krangle & Ludvigsen, 2008), and as such their focus' for the most part are connected to completing individual actions and not the activity as a whole. Following, gaining a deep conceptual understanding (Krangle & Ludvigsen, 2008) is not of immediate concern. Opposite to this is Felix' orientation, he withdraws from the group seeking more conceptual knowledge from the textbook. However, Eve, Tracy and James' orientation changes towards understanding the underlying concept in Episode III, where they are working on what is to be the outcome itself. This further shows the benefit of what Damgård (2014) presents as a tangible outcome, to have something concrete and within reach to work towards. However, procedural work is still important and creates a foundation for the conceptual work (Furberg & Arnseth, 2008). It would have been interesting to see the group have 20 minutes extra to work to let them finish their procedural work thoroughly, before moving on to the more conceptually complex discussions.

6.1.3 Many resources in play

If trying to describe anything as typical drawing from the data presented in this study, it is variation. As shown in Figure 5-1 the resources in use per session is varying a lot, from a single handout, to desks full of handouts, books, PCs, tablets and phones. From Figure 5-2 we also see that the forms of work vary in what we may perceive as a continuum from individual to collaborative. Some of the sessions had a lot of movement, with the students constantly going in and out of collaboration, whilst other session had the student working relatively stable in one form. One big difference stands out with respect to episodes I-III and IV. In the three first, in which the group are working at the top of their capabilities there is very little

inquiry present. Here the group, as we have seen, are more focused on coming to grips with the topic. In episode IV on the other hand the topic is different, and not fully as complex. Here we see the students follow their inquiry and utilizing all available resources to understand the complex properties of the topic. White & Pea (2011) argues that students make their own selection of resources from those available to them, picking what works the best for their goal at the moment. From the first three episodes I argue we can observe the students seek efficiency and staying procedurally on the task. Except for Felix, who is working more conceptually and going back to the textbook. Perhaps this had been different had the students for example been aware of static animation being easier to understand than dynamic for less proficient students (e.g. ChanLin, 2001; Kozma & Russell, 1997; Superfine et al., 2009), and thus having some criteria for doing this selection. Regarding the difference in conceptual complexity, we also see the group act differently from episode I-III and IV. When the representations they use and concepts they are working with are understood, they quickly start searching expanding their horizon as in episode IV. On the opposite end, we see the hardships of understanding both the representations and concepts of cell division being hard, and the students focus more on understanding this, than looking elsewhere.

6.1.4 Various forms of collaboration

Even though the groups constitution and forms of work are rather varied, there are several recurring tendencies. Firstly, Eve is a primary actor in every episode and also the only one taking part in every episode. Secondly, Felix is or tries to stay outside the group.

White and Pea (2011) argues that groups, in an effort to be effective, can leave people behind. In this this data, it is the opposite way around. By not being part of the group, Felix stays the most effective. Rather opposite to this is the way Eve acts, asking the others to start.

Interestingly, when asked what they feel they learned the most of, all four mentioned the overall structure. Felix described it this way: “The combination of teacher teaching it first, and then we’ll get more understanding out of it by talking to the others on the group afterwards”.

However, the group do not abide to these words when working. This could be because the groups in the class are set by the teachers, and thus a rule forced upon the students. it should therefore not be seen as contradictory that students state they enjoy collaborating and at the same time not participating.

Even though I argue that Felix is not fully a part of the group, he stills has an important

function for it. As we can see twice in episode I, Felix jumps into the conversation clearing up misconceptions and errors. As soon as he has done this he withdraws, not taking part in the groups meaning making process. In episode II where Felix explains the group the meiotic process he functions more as a tutor than a fellow student. Felix is without taking part in it still contributing to the group's, and in particular Eve's meaning making processes. I interpret his role to be that of as a more competent other, guiding the group to expand their zone of proximal development (Vygotsky, 1978, 2012).

6.1.5 Summing up research question 1

Group work is not just the group working together all the time, but should be seen as forms of work and organization somewhere on a continuum between full collaboration and no collaboration. Contributing to this movement along the continuum is the direction of the group. If the groups object is in clear sight, the group work somewhat productively on their given tasks. However, as we see in all four episodes, the students make their own selection of both resources and forms of work. Felix is more efficient by beading the book on his own, whilst the rest of the group try to understand the viten.no programme.

6.2 How do the students make sense of various representational forms?

6.2.1 The potential meanings in representations

Every artefact has a potential meaning and a potential use. Thus, within artefacts made for school, such as the viten.no programme and the textbook, the creators have intended for the students to come away with a specific piece of knowledge after interaction with a specific artefact. Digital environments such as viten.no is created with programmes consisting of many representations, one of which we have seen the students work with in episodes I-III. The program on Meiosis consists of still graphics, animated graphics and text. All these offer different potential meanings (Linell, 2009; Rommetveit, 2000) to the learner.

We see Eve, Tracy and James in particular, keep to surface features on describing just what they see, and not what is happening conceptually (Kozma, 2003). This also resonates with the

ideas of deep and surface learning (e.g. Linn & Eylon, 2011; Marton & Säljö, 1976, 2005). When the girls differentiate between pulled and dragged apart this could very well be them not seeing the underlying concepts, but just keeping on the surface. Had the students understood the underlying concepts of the representations, they should have had no problem translating between the symbols that are symbolizing them. The proponents of multimedia learning argue that humans are differently processing, and benefiting from the mix of, graphical and textual information (Clark & Mayer, 2008; Moreno & Mayer, 2007). Yet, we do not see the students picking up all the potential meanings from either the text or the visuals in viten.no. When the students go through the programme they read aloud from this text, but do not pick up on the underlying concept. To me this indicates the students do not see the text as part of the representation, but as a simple narration and utilize it as another resource (Krange & Ludvigsen, 2008). This text denotes the two splits as first and second division, yet the students keeps saying they are dragged apart and split. To reinforce that both the text and the visualisations are connected, they are even boxed in together (e.g. Ainsworth, 2006; Renkl et al., 2013). Yet, in episode III James have to tell Eve and Tracy that what they are asking for is in the text next to the graphic.

While Eve, Tracy and James are trying to make meaning of the animated viten.no programme, Felix, uses the book. We can also see that opposed to experts, the students struggle moving between connected representations(Kozma, 2003). So when in Episode II Felix explains mitosis whilst moving between representations in the book and on the screen, it is perhaps the rest of the group found it difficult to move between resources and representations (Ainsworth, 2006). When Eve starts asking questions to Felix in episode II, these are mostly concerning what the parts of the representations are and little about the concepts. To me this indicates the students not having problems with the concepts of cell division, but understanding the representations.

As shown, even though the students use different sources, and representations. They are rarely able to discuss these deeply or conceptually (Furberg & Arnseth, 2008; Krange & Ludvigsen, 2008). I argue that in order to understand what hinders the groups understanding of these representations we must also grant attention to the social plane of the students meaning making.

6.2.2 The social nature of making meaning

From the sociocultural position, one assumes human meaning making not to take place intrapersonal but rather interpersonal. The idea of students collaborating on understanding tasks and concepts are thus founded on the same assumption (e.g. Damstra, 2014; Mercer, 1995; Stahl, 2006; White & Pea, 2011). Even though the students create their own end products, most task work is a social activity. Yet, producing and formulating something written is a more complex task, and demand both factual and topical knowledge and an explicit and conscious language (Furberg et al., 2013; Kozulin, 1998; Vygotsky, 2012). Producing a written account of the concepts together, forces the students to agree on a conceptual and advanced explanation. When they, as shown in episode three, each write their own accounts of this we never see them discussing and fully agreeing on a particular and shared form of understanding of the concept.

In group-session two of this case-study the students' only resource was a single sheet of paper where they as a group discussed what traits are inherited and what is influenced from the environment. Here all four participated equally and the task even spurred advanced discussions. Barab (2002) argues tensions within an activity system can be productive, but in this study the rules and structure enforced on the group by giving them just a single handout is what keep them all collaborating. They really have no alternative.

We also see the way their talk is rarely changing. If considering this to the concept of explorative talk (e.g. Mercer et al., 2004; Mercer, 1995) it is noticeable that the group rarely talk exploratorily, finessing and expanding on each other's arguments. Most of their talk is by these terms cumulative, building on each other but also with much repetition and confirmations. We see this particularly well in episodes II and III when Tracy often repeats what Eve or Felix are saying. Analogous to the example in the paragraph above, I argue that had the group had a more rigid structure (Mercer, 1995), the group would possibly not have been able to not collaborate.

However, there is easily perceived a slight miss-match with both focusing on collaborative work and meaning making and at the same time enforcing everyone to make different products. In fact, this could in activity theoretical terms be seen as everyone in the group working towards their own outcome. Considering the (shared) object leads to the outcome, one would expect productive collaborative object oriented activity to occur when they all are

creating a shared outcome (Damstra, 2014). In Episodes I-III the tasks, tools and structure allow Felix to mostly withdraw from the group. Yet, what little he does together with the group is still enough to guide Eve in her zone of proximal development (Vygotsky, 1978, 2012). Also, as we saw in chapter 5.2.5, Eve was interestingly the one with the best answers on this task.

We also see the group spending much time on understanding the animations, instead of the underlying concept. From the Get-go Tracy is mixing up information, when she tries to tie the term homological genes (no: homologue gener) (line 302 in Episode I) together with what she has learned in an earlier lesson. In Episode II, Felix spends most of his time explaining what is on the screen and not the underlying concepts, this looks to get Eve back on track but also keeps much of the discussion on the procedural, focused with understanding the animations, and not in the conceptual plane with the group discussing the underlying meaning of the representations (Krange & Ludvigsen, 2008).

6.2.3 Main findings from question 2

I argue that the students do not pick up on the meaning potential embedded in the representations. The group not picking up these, further inhibits them from discussing deeply, and their discussion stays procedural and cumulative for the most part. Yet, the major gains in the students understanding comes aided by each other, and not just the different representations. They do in other words make sense of the representations socially. But this collaborative meaning making loses its momentum as Felix, the most proficient, withdraws from the group and Eve, Tracy and James are stuck mostly trying to understand the animation in front of them

6.3 How does the range of representational forms and resources challenge the class-room norms?

This, the last of my research questions, warrants a more philosophical rather than empirically driven answer. The school, or more to the point, the concept of educating people in an organized fashion is as a practise almost as old as humanity. A lot have changed since our forefathers painted animals on caves in the south of France, yet many parts of the jigsaw puzzle that makes a school are still the same.

6.3.1 Depth vs. Breadth

The Norwegian curriculum to the importance of being familiar with important scientific principles in order to successfully take part in society as an adult, and the importance of being curious (Directorate for Education and Training, 2006). Looking at the way the lessons go about, most are based around the same general pattern, with much likeness to Knowledge Integration (e.g. Linn & Eylon, 2011). The teacher usually has a small lecture eliciting previous knowledge and awakening some curiosity for the topic. Then the students are often set free to by themselves add new information, before the teacher finally sums tings up at the end and sort away possible misinterpretations with the whole class. After Episode IV however, the students keep working for about 10 minutes until the teacher abruptly stops them, as they have run out of time. Thus losing the opportunity to do a plenary session, and sorting and adjusting the students' new knowledge.

Simply put, learning complex concepts takes time (e.g. Donnelly et al., 2014; Linn & Eylon, 2011), and more time is not always available. This is exemplified in the task of episodes I-III, which specifically ask for the group to discuss the differences of the mitotic and meiotic processes. This never happens, and the group mostly spend the session understanding and formulating the descriptions of the two processes, task A and B. Had there been more time available it would have been interesting to see if they had ended up with a more exploratory (Mercer, 1995) and conceptual discussion. Although Eve writes a good explanation on the differences, task C, she is the only one in the group doing this and in fact sits writing for 30 seconds after they are called back to a plenary session.

6.3.2 Students are socialized into the institution

Even though the students explicitly and often are given a free choice with regards to which resources and tools they use, we still see them using traditional ones. In line with White and Pea (2011), the students by themselves chose what to use and what not to use, and even though the teacher frequently highlighted the importance of seeing things represented differently, and suggested several alternative links to investigate, the students rarely went off the beaten track. When inquiring freely on the web the, students mostly use the same sites (snl.no, Wikipedia, Viten.no, bioteknologinemda.no and ssb.no). Still, the students did highlight that information on these sites often is more trustworthy than other more unknown sites (Forte, 2015) in the interview.

With respect to traditions and norms, we see the group spend nearly half their time in non-collaboration. Schools have as we have seen historically not been very collaborative (Mercer, 1995; Säljö, 2010). When the students are working freely, they still do not elevate their talk to a conceptual level. As the traditional forms of work are such a strong influence on the students practice, perhaps they could have benefitted from more structured forms of collaborative work (Mercer, 1995) and clearer targets and goals (Damgård, 2014). Using White and Peas (2011) terminology, this group is distributed by design, and the participants have little to say about this. However, as we have already seen, the students have different ways to cope with this. Felix withdraws from most collaboration, James tries to be involved (although not very insistently). Eve tries diligently to do as told, whilst Tracy mostly does what Eve does, if she is able to keep up. In activity theoretical terms this distributed design then is a set of rules, norms and labour division forced upon the group, thus impacting their entire activity system.

Variation is not synonymous with digital. As we may infer from the quantified video data presented in chapter 5.1, much of the time in the group is spent with paper resources. This is of course not a negative, and for instance using textbook for structuring the education is common among educators (Trygstad et al., 2013). Given the complexities of the topic (e.g. Furberg & Arnseth, 2008; Smith & Kindfield, 1999) it is of little wonder that the teacher may want to control what sources the students use, to perhaps help them from getting too lost. Of interest is then episode IV, which shows the students finding and accepting two different

versions of the same phenomenon, and then inquiring about and finding quite conceptually advanced explanations.

A further point I wish to make is that paper based resources always are functional. We noticed several times during our fieldwork that the schools' internet connection broke down, the regularity of which also the teacher and the students mentioned in the interviews. Thus, the teacher often has a contingency-plan without internet. Interestingly, the students in these cases used their own mobile phones, often with a student sharing his or her interconnection with others.

6.3.3 Inquiry science learning

Jiménez-Aleixandre et al. (2000) argues students work can be seen as doing science or doing the lesson. In episodes I-III, the students are doing “the lesson”, and are focused towards completing the task. As we can see, “doing school” also entails discussing the representations they use and how to write things down, and as such a part of creating their understanding. (Furberg & Arnseth, 2008; Krangle & Ludvigsen, 2008). Further, in episode IV, we see the students confronted with two contradicting ideas. With free reigns and little task procedures to do, they still act uncertain on how to proceed. After talking with the teacher and him assuring the students of correctness of their suspicions, they start searching for information and do science (Jiménez-Aleixandre et al., 2000) to clear up this contradiction. The students at the end of the sessions, not shown in the transcript, have gotten very deep into the facts, and their discussion is conceptually advanced. As such this episode also shows us how dissonances and differences between representations may contribute to the inquiry process (Furberg & Arnseth, 2008; Smetana & Bell, 2012). But, as we also may draw from episodes I-III, the students conceptually oriented work starts when they understand enough of the concepts to actually being able to discuss them. However, when they reach this point there is not much time left, and as presented above Eve is the only one writing up her answers properly and correctly. So even the students are working as scientist, this work is often limited by available time.

Even though this inquiry group work is meant to be without boundaries, the institutional aspects of the school also bring with it its own set of limitations. The students still have very clear task they must answer in a correct manner, nor is the way they are (supposed to be) organized free for the to decide. But perhaps most important in my view is the aspect of time. Scientific inquiry takes time (Donnelly et al., 2014; Linn & Eylon, 2011), and as long as everything is on a tight schedule the students do not get the time to inquire as they perhaps need. It is when the students can find the time and are curious enough to look elsewhere that they do just that. This is perhaps the big difference between episodes I-III and IV. In episode IV the students understand the concept and representations they are working with and have no troubles looking elsewhere for information. In episodes I-III the students are doing their best to understand the viten.no programme, and this procedural work (Furberg & Arnseth, 2008; Krangle & Ludvigsen, 2008) takes primacy over looking for other explanations.

6.4 Concluding remarks

Through the last chapter I have aimed at answering these by means of a discussion of both the study's empirical findings and the presented literature. Drawing on this discussion, I wish to make some concluding remarks.

The School as an institution have a long cultural and historical heritage. Schools have existed for approximately 5000 years (Säljö, 2010), the printed book has been around for over 5 centuries, whilst most schools and private households only have had an Internet connection a mere 20 years ago. The speed at which the society utilizes increasingly more advanced ICTs is both changing and astonishing, and it is of course by no means surprising that schools are trying to not only catch up, but also utilize the technology to its fullest extent to better it is practices. As said by Säljö (2010, p. 56) "New technology is no longer new; it is a taken-for-granted way of interacting with the world".

This thesis has shown aspects of how a classroom today grapples with melting together the old and the new in what is described as a mixed culture. Very few classrooms abide only to the textbook, opening up for not only more but also different forms of representing knowledge.

Most research in both experimental and qualitative traditions point to benefits with respect to learning from using different forms of representing the worlds' complexities (e.g. Ainsworth, 2006; Furberg et al., 2013; Linn & Eylon, 2011).

Yet, as our understanding of the world is made whilst interacting with it, no meanings can be conceived as lexical or concrete. It follows that everyone as such takes different meanings from both the physical and psychological artefacts they encounter and use. It is through the collaborative negotiations of these meanings the students are supposed to create a conceptual and deep understanding. Although the students are put in groups to aid them in this processes, their discussions rarely get off the ground to a more conceptually advanced level. When this does happen though, the students often are able to extend their zone of proximal development and reach further. But, this is also inhibited by several aspects. Even though the students enjoy full freedom with respect to finding and selecting resources for use, they stay with one throughout the entirety of three of the episodes presented. Still when having trouble understanding what it is representing the students don't look for alternate explanations.

Group work in this culture is characterized by variation in both resources in use and in collaborative forms. The groups are an institutional demand on the students, but the way in which the group works is not regulated. A lack of structure that allows one of the students to stays outside the group for large parts of the work. Further, by producing their own unique products, sharing a common object of activity is complicated and this focus on individual products could even invite to individual work.

Providing some structures for students processes looks beneficial both based on the reviewed literature and the empirical findings. However, structure is not tantamount to strict rules, and could also be provided by some of the following: 1. Well described tasks, making it clear for the students what to do. 2. Structure for division of labour, by implementing models like the jigsaw-model or turn-the-table (Furberg et al., 2013). 3. Tools for representation that open up for discussions. 4. Ground-rules for talking together (Mercer, 1995; Wegerif, 1996), and finally. 5. The aspect of time (Dolonen & Ludvigsen, 2012). As mentioned, the group work in

the second session spurred great collaborative work as the teachers' selection of available tools gave the group no real alternatives.

A recurring aspect constraining the students work in the sessions reported on in this thesis is the limited amount of time available. Learning complex concepts is hard and takes time, yet we several times see the students having to stop their work as the lesson is over. Do the students need broad but superficial, or more selective but deeper conceptual knowledge? As long as the goals of the curriculum are for the students to inquire and understand scientific concepts, not just be able to reiterate stand-alone facts, the school practice should make that possible by allowing the students enough time to understand what they are supposed to. And perhaps more important for the students, tested on in their exams.

It is not the representations or their form that really challenge the classroom norms, it is in fact the teacher, the students and the tasks they are given. By instructing students to reach outwards, the teacher makes them break their ties to traditions and norms. Norms the students perhaps even are more bound to than the teacher. The students are socialized into school-institution, and changing their way of acting in this context does not happen by itself. As shown in episode IV, the students see things are not adding up, but it takes time and guidance from the teacher to make them understand this is ok.

It seems it is perhaps the tensions that can properly explain this argument. The tensions between breadth and depth, tensions between individual and collaborative work, tension between having much to do and little time, tension between conceptual and procedural work, and tensions between free inquiry and structure. In the midst of these, we find the teachers and students trying to both understand the complex concepts, and get a good grade on the exam

The schools' institutional history, the teacher, the resources and the students all contribute to and shape their own unique learning situations. This case study has shown that students not always pick up the meaning potential of these situations as a whole. When four students, with different previous knowledge and interests are to use multiple resources to together create a conceptually complex understanding there are great many potential meanings in play.

Firstly, the students must understand what the representations are depicting, then what they make of it before negotiating this understanding in relation to the task between one another.

When this process takes place without enough structural support, we see the students lose sight the institutionally give purpose of their activity, and drift of track. Students together are more than able to conduct advanced scientific inquiry with many resources, given enough structural support and clear objects to direct their activity towards.

7 References

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8 Appendix

8.1 Appendix 1, Jefferson Conventions

The Jefferson Conventions (Hutchby & Wooffitt, 1998, p. vi)

	(.)	Just noticeable pause
	(.3), (2.6)	Examples of timed pauses
A: B:	word [word [word	Square brackets aligned across adjacent lines denote the start of overlapping talk. Some transcribers also use “]” brackets to show where the overlap stops
	wo(h)rd	(h) is a try at showing that the word has “laughter” bubbling within it
	wor-	A dash shows a sharp cut-off
	wo:rd	Colons show that the speaker has stretched the preceding sound.
	(words)	A guess at what might have been said if unclear
	()	Unclear talk.
A: B:	word= =word	The equals sign shows that there is no discernible pause between two speakers’ turns or, if put between two sounds within a single speaker’s turn, shows that they run together
	((sniff))	Transcriber’s effort at representing something hard, or impossible, to write phonetically

8.2 Appendix 2, Handout with tasks

Resonneringsoppgave om mitose og meiose:

Celledeling betegner prosessen som skjer når en celle deler seg til to nye celler. Celledelingen finnes i to former; *mitose* (vanlig celledeling) og *meiose* (reduksjonsdeling). Mitose må til for at en kropp skal vokse, eller for å erstatte celler som er blitt ødelagt. Meiose foregår når kjønnsceller dannes. Det er noen likheter og noen forskjeller mellom de to celledelingsprosessene. I denne gruppeoppgaven skal dere redegjøre for de to ulike formene for celledeling.

Oppgaveformulering:

Ta utgangspunkt i oversikten over de to celledelingsprosessene som står på arket dere har fått utdelt.

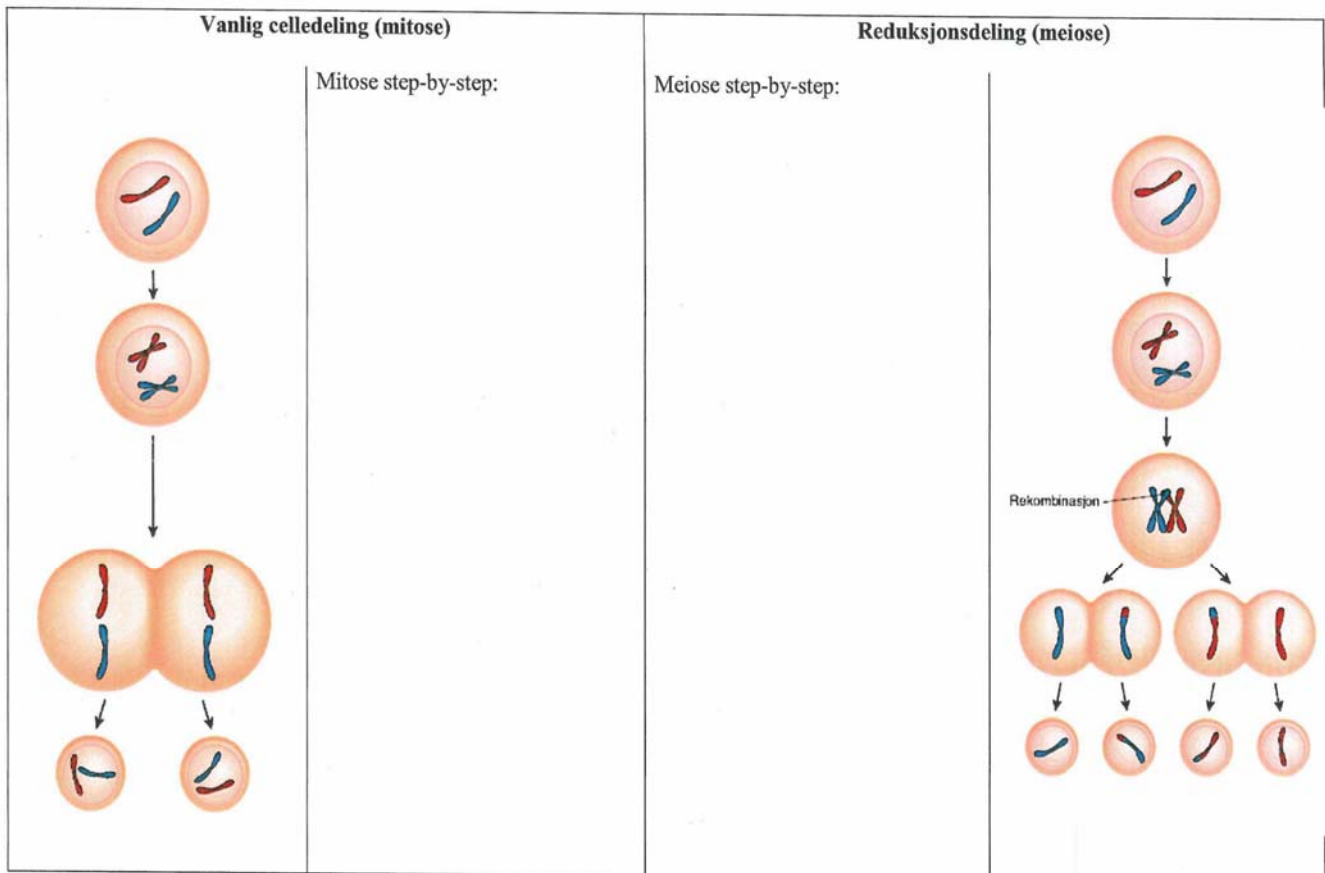
- a) Beskriv trinnvis hvordan vanlig celledeling (mitose) foregår.*
- b) Beskriv trinnvis hvordan reduksjonsdeling (meiose) foregår.*
- c) Diskuter og skriv ned hva dere mener er de viktigste forskjellene mellom de to prosessene.*

En del av oppgaven er å bruke ulike kilder som grunnlag for drøftingen og beskrivelsene deres. Bruk følgende kilder:

- **Lærebøker:**
 - Eureka s. 8-11
 - Faktaark «Arv og genetikk» fra Bioteknologinemnda. Se nedenfor for nettvversjonen

- **Nettbaserte kilder:**
 - Tellus:
 - <http://lokus123.lokus.no/static/flashEmbedder.jsp?contentItemId=37702931&selectedLanguageId=1&title=Celledeling>
 - Viten.no:
 - <http://www.viten.no/vitenprogram/vis.html?prgid=uuid%3A42241581-B892-15A9-626C-00000A2341CD&tid=1717509&grp=>
 - <http://www.viten.no/vitenprogram/vis.html?prgid=uuid%3A42241581-B892-15A9-626C-00000A2341CD&tid=1717564&grp=>
 - Forskning.no:
 - http://intern.forskning.no/arnfinn/kromozoomflash/kromozoom_nonpop.html
 - Bioteknologinemnda:
 - <http://www.bion.no/temaer/arv-og-genetikk/for-skoler/>

8.3 Appendix 3, response form



Beskrivelse av de viktigste forskjellene mellom meiose og mitose basert på en vurdering av de ulike kildene dere fikk oppgitt: