Research in Science & Technological Education

ISSN: 0263-5143 (Print) 1470-1138 (Online) Journal homepage: https://www.tandfonline.com/loi/crst20

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To cite this article: Irina Engeness (2019): Teacher facilitating of group learning in science with digital technology and insights into students' agency in learning to learn, Research in Science & Technological Education, DOI: 10.1080/02635143.2019.1576604

To link to this article: https://doi.org/10.1080/02635143.2019.1576604

Published online: 12 Feb 2019.

RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
https://doi.org/10.1080/02635143.2019.1576604

Teacher facilitating of group learning in science with digital technology and insights into students' agency in learning to learn

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ABSTRACT

The study provides an insight into how teachers may facilitate students' group learning in science with digital technology, which was examined when Norwegian lower secondary school students engaged in learning concepts of mitosis and meiosis. Quantitative and qualitative analyses of the teacher's assistance draw on Galperin's conceptualisation of learning.

Findings reveal patterns in the teacher's guidance: the teacher fulfilled the *orienting, executive* and *controlling functions* while assisting students in identifying the key features of mitosis and meiosis and solving the compare and contrast task. The teacher relied on and interplayed with the available mediational resources: compare and contrast task, digital animations, and collaborating peers. However, it was the compare and contrast task that demonstrated an approach to study scientific concepts which may have contributed to the development of learners' understanding about to engage in learning in science. By adopting such an approach, learning activity has the potential to not only help students to achieve learning outcomes but it acquires a functional significance, becoming *a tool* in the learning process aimed at the development of students' as learners. The digital animations, in turn, demonstrated scientific processes that were otherwise invisible for students and triggered group discussions. The study, therefore, raises questions about the need for practitioners' awareness of the type of support the technology and other resources provide to assist both conceptual learning and enhancing students' agency in learning to learn.

KEYWORDS

Teacher facilitating of group learning in science with digital technology; agency in learning to learn; Galperin; cultural historical theory

1. Introduction

This study examines teacher facilitating of students' group learning in science with digital technology and provides an insight into how teacher-student interactions and other resources may contribute to enhancing students' agency in learning to learn. Research has reported that teachers' guidance has considerable effect on the flow of students' learning activities, performance success and learning outcomes (Lazonder and Harmsen 2016). Despite important findings that teachers' support in a simulation environment should

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be directed toward interpretative, experimental, and reflective perspectives to invite discovery learning to enhance students' conceptual understanding (Reid, Zhang, and Chen 2003), there has been a growing interest in an approach to learning and teaching that goes beyond the acquisition of knowledge and skills, but is aimed at bringing about changes that will help students to thrive forward as learners and enhance their agency in learning to learn (Claxton 2013). The rationale for the growing focus on agency in education is that schools are struggling to prepare students for their adult lives (Mäkitalo 2016; Rajala, Martin, and Kumpulainen 2016). Psychological traditions conceptualise agency as a self-regulatory capacity of an individual (Clarke et al. 2016) while unpacking Vygotsky's dialectical approach to learning takes us straight to the agency of the learner, the demands in practices and how students interpret and respond to those demands to propel themselves forward, as they engage in and with the knowledge practices of the field (Edwards 2017). Therefore, from a cultural-historical perspective (Vygotsky 1986; Galperin 2002), agency in learning to learn implies students' understanding about how to engage in the learning activities and go about learning in specific subject areas and across them. In science education, among such approaches aimed to enhance students' agency in learning to learn is teaching through involving learners in a dialogue with their peers and the teacher to support student engagement in the practices of Science as they learn scientific concepts (Clarke et al. 2016). Clarke and colleagues show that all students enact agency in classroom discussions, but differences lie in the extent to which students perceive that they can enact agency. One of the ways of potentially enacting students' agency in learning to learn is by embracing the pedagogical potential of new technology. Selwyn argues (Selwyn 2011) that technology has the potential to contribute fruitfully to the education of 21st-century learners. However, research on how teachers can facilitate conceptual learning in digital environments and enhance students' agency in learning to learn is still relatively scarce. This study addresses this gap by i) examining teacher facilitating of group learning in Science with digital technology and ii) reflecting on how the guidance provided by the teacher may enhance students' agency in learning to learn. The following research questions are addressed:

RQ1: How did the teacher facilitate students' group learning with digital technology in Science?

RQ2: What are the implications of the teacher actions for enhancing students' agency in learning to learn?

2. Facilitating students' learning to enhance their agency in learning to learn

Research indicates that teaching and assessment focusing on learning of factual knowledge does not prepare for long-life learning and the main goal of today's schooling should be to support students in learning how to go about learning (Smith et al. 2016). In literature learning to learn is also defined as metacognition: knowledge and awareness about one's own cognition in general (Pintrich 2002; Schraw, Crippen, and Hartley 2006), which, together with motivational beliefs and cognitive strategies, constitute self-regulated learning (Winne 1997; Winne and Perry 2000).

Acknowledging its importance in the development of learners, research has explored ways to improve metacognition and enhance learning to learn through classroom instruction (Baird and White 1996; Beeth 1998; Gunstone and Mitchell 1998; Mason 1994). For example, in science education six strategic areas have been outlined to improve students' metacognitive thinking: (a) inquiry-based learning, (b) collaborative support, (c) strategy instruction to improve problem solving and critical thinking, (d) strategies for helping students construct mental models and to experience conceptual change, (e) the use of technology, and (f) the impact of student and teacher beliefs (Schraw, Crippen, and Hartley 2006). Schraw and colleagues also suggest that focusing on the transition from dependent to autonomous learner is of tremendous importance, to prepare students as life-long learners.

Zimmerman's work (Zimmerman 2002, 2008) has taken a broader perspective, outlining strategies such as goal setting, strategy use, and self-evaluation. In doing so, he has emphasised that mastery of these strategies is social in nature and can be learned from instruction and modelling by parents, teachers, and coaches. Like Zimmerman, Claxton recognises the social origins of self-regulation, and, then offers a cultural-historical-inspired approach. In his work on learning strategies, he emphasises the need for teachers to create an epistemic culture to expand learners capacity to learn (Claxton 2007). In sum, Claxton argues that this epistemic culture may help young people to be willing to be stretched and challenged with the aim of becoming powerful and effective real-life learners of the 21st century who possess the generic capacity to learn.

While recognising the importance of Claxton's analyses, Edwards (2015) has turned her attention to how teachers might support the growing agentic control of the learner as she or he takes themselves forward as self-regulated learners to become increasingly competent users of their knowledge. Edwards' argument is that in order to enable the exercise of that agency, teachers need to orchestrate tasks which allow familiarity with and competent use of the powerful concepts encountered in the curriculum. In this respect, a model of task sequencing based on Vygotskian notions of learning has been suggested (Figure 1).

4 Demonstration of grasp of key concepts and ways of enquiring	1 Introduction of key concepts and modelling of ways of engaging with key concepts
3 More open tasks which enable learners to apply key concepts and ways of enquiring	2 Tightly structured tasks which demand engagement with key concepts and ways of enquiring

Figure 1. A model of task sequencing to promote learning.

From Edwards, A. (2015). "Designing Tasks Which Engage Learners with Knowledge." In *Designing Tasks in Secondary Education: Enhancing Subject Understanding and Student Engagement*, edited by I. Thompson, 13–27. New York, NY: Routledge.

Quadrants 1 and 4 are where knowledge is displayed: by the teacher or more expert learners in quadrant 1 as they model and instruct; and by the students in quadrant 4 when they display their knowledge in some form of summative assessment (Edwards 2015). In quadrant 2, the students start to become competent in the use of the key concepts at stake; while in quadrant 3 they begin to use them in problem-solving activities, which require them to make decisions about the best approaches to take. It is in quadrant three that metacognition and self-regulation are crucial and where the teachers' efforts at creating a potentiating epistemic culture (Claxton 2007) are important. This model of task sequencing presents a way of structuring classroom conditions that may promote learning and develop students' increasing control over the subject matter while also developing as learners.

Students' engagement in focused, reasoned and sustained dialogues in learning with computers has implications for educational practice. In addition, using of strategies (Schraw, Crippen, and Hartley 2006; Wiliam 2006; Zimmerman 2002, 2008) and specifically designed activities to enhance students' agency in learning to learn (Clarke et al. 2016; Edwards 2015; James and McCormick 2009) places a particular emphasis on the role of the teacher as a designer and facilitator of such learning practices.

The significance of teacher facilitating of students' learning regarding the development of students' understanding of the nature of learning emerged in a thinking skills programme in science education, which found transfer effects in other subject areas three years later after the end of the project (Adey and Shayer 1993). In respond to these findings, Wegerif and Mercer (1996) have combined and transformed the notion of 'higher order thinking' and 'critical thinking' into a more sociocultural conception of the development of educational rationality as one of the guided induction into a community of discursive practices by identifying practices which support 'higher order thinking skills'. Such practices include exploratory talk as explicit reasoning through talk, where participants offer reasons for assertions and expect reasons from others (Wegerif and Mercer 1996).

Appropriate assessment practices may also enhance students' capacity to take control over own learning (Black et al. 2006; James and McCormick 2009). The findings of the Learning How to Learn Project with 40 schools, over 1000 teachers and 4000 students using survey, observation and interview methods revealed three dimensions of teachers' classroom assessment practices: i) promoting learning autonomy; ii) making learning explicit and iii) performance orientation. However, the findings showed that the majority of teachers participated in the project struggled with 'promoting learning autonomy' of students in their classes (James and McCormick 2009; James et al. 2007). This outcome might be explained by the fact that many teachers lack sufficient tools for implementing learning to learn approach as an integral part of their lessons and when crossing the borders of their own field of expertise in approaching learning to learn as a generalised way of instructing learners (Veenman, Kok, and Blöte 2005; Veenman, Van Hout-Wolters, and Afflerbach 2006).

However, the role of the teacher in students' group learning with computers, remains an area requiring more exploration (Greiffenhagen 2012; Urhahne et al. 2010; Van Leeuwen et al. 2013). The early study of Wegerif and Mercer (1996) emphasised the role of the teacher in facilitating learning with computers by encouraging exploratory talk with students and creating symmetrical nature of the teacher-student relationship in modelling and coaching exploratory talk. A later study of Hakkarainen, Lipponen, and Järvelä (2002), in turn, investigated the types of teachers' interventions in students' group learning with computers that were most effective with regard to students' conceptual understanding (Hakkarainen, Lipponen, and Järvelä 2002). Their findings indicated that indirect interventions, such as prompting questions and encouraging learners to retrieve subject-related information were more beneficial for students than direct interventions including descriptive explanations or prompting fact-based responses. Urhahne and colleagues argue that for successful implementation of computer-supported projects, the teacher has to (1) envision the lesson, (2) enable collaboration, (3) encourage students, (4) ensure learning, and (5) evaluate achievement (Urhahne et al. 2010). Another study (Strømme and Furberg 2015) addressed a different dimension of the teacher's role in computer-supported collaborative learning (CSCL) and showed that in technology-driven classrooms teachers may wish to create a balance between answering requests for information and supporting students in utilising each other's knowledge and understanding; balancing support at individual or group level; and directing students' attention to coexisting conceptual perspectives.

Overall, teacher facilitating of students' learning in technology-driven classrooms in science is still an under-researched area and the studies have mainly examined the types of teacher-student interactions that are beneficial for the development of productive discourse, and enhancing learners' conceptual understanding. These findings indicate that there is a need to examine the role of the teacher in technology-driven classrooms more closely, by exploring what teachers do when facilitating students' learning in science with computers and how teacher's actions may enhance both the development of learners' conceptual understanding and their agency in learning to learn. This study addresses this issue by examining the content of the teacher interventions in group learning in science.

3. Cultural-historical perspective on learning

A cultural-historical perspective has been chosen to examine the teacher facilitating of students' group learning in science. This perspective considers learning as a social and culturally situated process in which co-participants jointly construct interpretations of their context (Edwards 2005; Vygotsky 1980; Wertsch 1991).

In particular, the lens of cultural-historical perspective allows an examination of how tools, which may be social and linguistic as well as material artefacts, operate as meditational means, which carry the meanings that are of value in a culture. This approach, therefore, recognises that learning involves a continuous process of connecting individual sense making with the public meanings that are valued in cultures. These cultures include curricula such as genetics.

According to Vygotsky, the acquisition of cultural tools, such as language, signs, and concepts, constitutes the main content of the child's learning. Particular attention Vygotsky paid to the process of the development of concepts with children as determined and framed by the collaborative social activity with an adult who creates the zone of proximal development of a child (Vygotsky 1978).

In the analysis of the development of conceptual understanding, Vygotsky introduced the categories of spontaneous and scientific concepts (Vygotsky 1986). The categorisation was based on the way learners make sense: a child makes sense of spontaneous concepts during every day practical activities with an adult in a non-systemic way, usually by trial and error. In this way, a child is unable to separate essential from unessential features of concepts. In school, on the contrary, a child finds the conditions where systemic learning of concepts, for example, definitions, is highlighted by the teacher introducing essential features of key concepts in lessons. Vygotsky considered that understanding of the concepts' essential features makes learning in school different from everyday learning. The benefits of such a 'top-down' method of learning Vygotsky saw in a growing ability of a child to operate with the concepts and apply them in various contexts and, in doing so, a child's agency in learning to learn is being enhanced. In addition, Vygotsky put particular emphasis on the role of instruction as the major facilitator of school learning and 'provider' of cultural tools. In Vygotsky's view, the quality of instruction is crucial in terms of the effects it produces on child's learning (Stetsenko and Arievitch 2002).

However, Vygotsky himself did not specify how the specific content of instruction is related to learning, and in particular, how qualities of the tools acquired by the child affect learning and may enhance child's agency in learning to learn. A cultural-historical scholar Galperin has greatly extended Vygotsky's arguments about the leading role of instruction in the child's development by specifying the kind of instruction that can play such a role (Stetsenko and Arievitch 2002).

Specifically, Galperin's research strategy was to analyse how new mental processes emerge in the context of meaningful, goal-oriented activities of teaching and learning (Haenen 2001). Galperin explained that the transfer of the original external socially meaningful activity into a new psychological function happens through a series of six dialectically evolving phases: (1) *motivation*, (2) *orientation*, (3) *materialised action*, (4) *communicated thinking*, (5) *dialogical thinking*, and (6) *acting mentally* (Galperin 2002).

In the initial *motivational phase*, a learner's attitude and relation to the learning outcomes that have to be achieved is formed. In the second *orientation phase*, Galperin identified three types of orientation: (i) incomplete, where mediational means and the essential features of the target concepts are identified by learners through multiple trial and errors; (ii) complete, where learners are informed about all the mediational means that encapsulate the essential features of the target concept; (iii) complete, but being constructed by learners following a general approach of identifying the essential features of the target concept. In the third phase of a *materialised action* learners interact with material or materialised objects, and over time become less dependent on the material support they give and more aware of the meanings they carry. Speech becomes the main guiding tool in the fourth phase of *communicated thinking*. The fifth phase, *dialogical thinking*, establishes a dialogue of a learner with him or herself so that the action is being transformed mentally. In the final phase of *acting mentally*, an action is performed by means of mental images and meanings that help a learner to deal with similar or differing situations on the basis of previous experience.

These phases of the learning activity can inform teachers and researchers about the complexity involved in learners' move from, for example, orientation to the ability of learners to operate with scientific concepts in various situations to learners' growing understanding about how to engage in learning in science and they lie at the core of the discussions about teacher actions that follow.

4. Method

4.1. Participants and setting

Seventy-six Year 10 students from two classes, a teacher and three researchers participated in the project. The students studied the topic Genes and Inheritance for the period of 12 school hours over the course of four weeks. The class was divided into groups of four to five students that worked together during the whole project. Every science lesson contained a combination of whole class activities, individual work, and group activities. Previously to the lesson when the cell division was introduced, the teacher had covered the following subtopics: structure of cells, genetic and environmental variation, genes and chromosomes and genetic diseases. The subtopic genetic engineering summarised the whole project. The teaching sequence over the four weeks is presented in Table 1.

A group task was designed by the researchers together with the teacher and integrated into the teaching flow on 12.03 (see Table 1). This task focused on building students' conceptual understanding of normal and sex cells division (mitosis and meiosis correspondingly) and the students' ability to grasp the meaning of factual scientific information in a compare and contrast exercise. The assignment contained two distinctive steps:

Step 1: The students were to give detailed descriptions of each of the stages of mitosis and meiosis. The diagrams of both of the processes were provided in the task sheet. The students were advised to use various digital resources located at Viten.no,[1] Tellus,[2] Forskning.no,[3] Bioteknologinemda.[4] In addition to the variety of digital resources, they could also use their Science textbook *Eureka!* (Hannisdal and Haugan 2008).

Step 2: The students were to compare and contrast the stages of mitosis and meiosis and outline the main differences and similarities between these two processes.

The teacher, in his late thirties, had taught science for 11 years and has a Master's degree. He worked together with the research team and therefore he was able to include the task designed by the researchers in his planned lessons. During group activities, the teacher circulated among the groups providing various types of support. The researchers did not intervene in the teaching. Ethnographic notes described the class observations were taken by the researchers.

4.2. Viten.no environment

Despite the variety of digital resources which were offered the students, Viten.no occupied the central place in this study. It is an Internet-based digital resource developed at the Science Centre at the University of Oslo (Jorde 2003), containing sequences of programs on topics included in Norwegian secondary Science curriculum. The programs contain textual information, illustrations, interactive tasks, and animations/simulations. In the present study, students were advised to use the program 'Cells'[5] which contains animations that progressively show the stages of mitosis and meiosis. Each stage is supplied with the textual information on the screen. Figure 2 shows the interface of the animation representing the first stage of mitosis.

Table 1. Teaching sequence over four weeks.

Date	Duration, min	Topic	Activities	Learning resources	Technology used
26.02	120	Structure of Cells	Recap of previous knowledge Educational documentary Group work: structures of cells and their functions	Newton Documentary Task sheet Textbook Viten.no	Interactive whiteboard PC IPAD
03.03	60	Environmental and genetic variation	Teacher introduction Group work: types of variation	Power Point Task sheet Viten.no	Interactive whiteboard
06.03	120	Genes and chromosomes	Teacher introduction on genes, chromosomes, genotype and phenotype Group tasks on the structure of chromosomes and Punnet Square	Power Point Viten.no Textbook Copied articles from other resources	Interactive whiteboard PC IPAD
10.03	60	Genetic diseases	Teacher introduction on genetic diseases Group task on genetic variation and genetic diseases	Power Point Viten.no Internet resources Textbooks	Interactive whiteboard PC IPAD
12.03	120	Cell division	Teacher introduction on mitosis and meiosis Group task on mitosis and meiosis	Power Point Viten.no Task sheet Textbooks	Interactive whiteboard PC IPAD
17.03	60	Revision	Revision of mitosis and meiosis and Punnet Square Group task on dominant and recessive genes	Power Point Viten.no Task sheet	Interactive whiteboard PC IPAD
20.03	120	Genetic engineering and summary of the project	Whole class teaching and group activities	Power Point Viten.no Copied pages from other textbooks	Interactive whiteboard IPAD

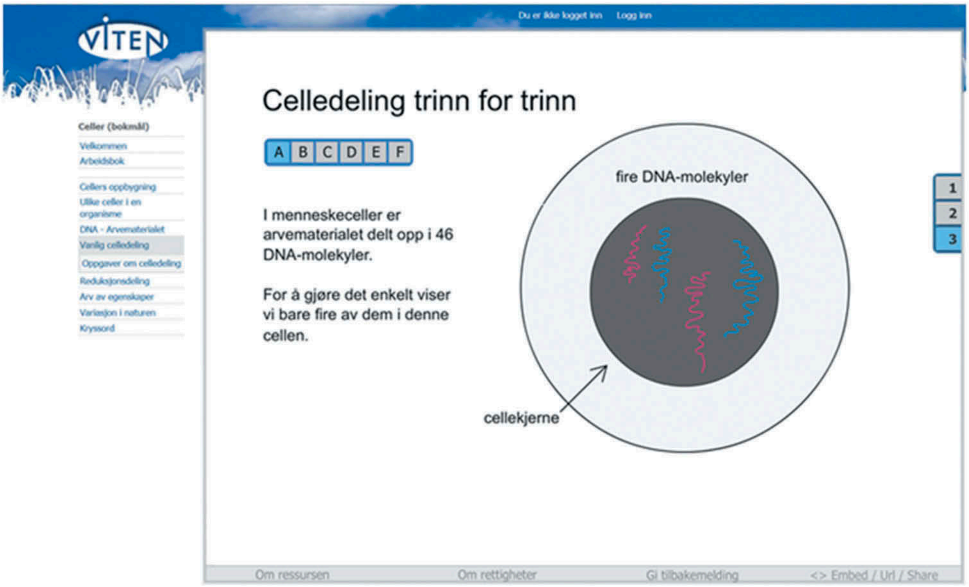

Figure 2. The interface of Viten.no/cells/mitosis.

Table 2. Time of the video recordings of the target groups and the teacher.

Group/Teacher	Time, min
Group 1	174
Group 2	180
Group 3	174
Group 4	84
Group 5	84
Teacher (whole class teaching and group interventions)	678
Total	1374

4.3. Data and analysis

Five target groups of four students, selected by the teacher because they were verbally active, were videotaped at different times during the project. Another camera followed the teacher for the whole time. 1374 minutes of transcribed video recordings constitute the data material of this study. Field notes taken during class observations were used to contextualise the data collected (Derry et al. 2010). A summary of the length of the video recordings is presented in Table 2.

Mixed methods (Creswell 2012) were applied to analyse the data. The *one-way ANOVA test* (Field 2013) was used to examine differences between the number of teacher interventions in different phases of the learning process (calculated by the research team during classroom observations).

To examine teacher facilitating students' engagement with the task, teacher-student interactions were analysed qualitatively. Detailed analysis of interactions of students working on the task on mitosis and meiosis were undertaken along with the analysis of teacher's interventions in these groups. Initially, 18 episodes which represent teacher-student interactions in the observed groups were analysed. Thereafter, a so-called 'story' (Derry et al. 2010) emerged through the analysed extracts, which determined the final selection of the extracts chosen to represent patterns in teacher-student interactions. Hence, the selected extracts represent a narrative structure of the story the study is intended to convey.

Three extracts of teacher-student interactions in these groups are presented in this study. These extracts represent patterns in teacher-student interactions in the observed groups at different times in the learning process. The qualitative analysis explored the nature of the teacher interventions in the groups.

The initial analytical procedure employed was interaction analysis, where interactions between interlocutors are analysed sequentially (Jordan and Henderson 1995). The primary unit of analysis was sequences and turns in sequences of student-student and student-teacher interactions rather than isolated utterances, and the analytical descriptions were oriented toward the interactional achievements of the participants. This approach, therefore, focused on how meaning was created within the exchanges of utterances (Mercer 2010). The description of the setting precedes each interaction sequence (Geertz 1973), which provided situational details for the chosen extracts.

The interaction analysis was performed in three steps (Linell 1998; Roschelle 1992): first, the teacher-student interactions were described by referring to the numbered lines of interactions; second, the interactions were analysed from the perspective of the research questions and finally, the emergent findings were outlined. Once the interaction analysis was completed, the interactions were examined through the analytic lens offered by Galperin's dialectically linked pedagogic phases and the types of orientation, to begin to unpack how the teacher interventions and other meditational means supported students at different times of the learning process. The video recordings were transcribed according to the Jeffersonian transcription notations (Atkinson and Heritage 1999). See Appendix A for the description of the transcript notations. The discourse was conducted in Norwegian; the material presented in the study was translated by the research team.

5. Findings

5.1. Quantitative analysis of the teacher interventions

The analysis starts by examining teacher facilitating of the learning process in the five observed groups. Table 3 presents the average number of teacher interventions in different phases (Galperin 2002) in the learning process.

The data points out the differences in the teacher facilitating students' learning between the phases of the learning process. The *one-way ANOVA test* (Field, 2013)

Table 3. Number of teacher interventions in the five observed groups.

Galperin's pedagogical phases	Group 1	Group 2	Group 3	Group 4	Group 5	Mean (M)
Orientation	4	2	4	2	3	M = 3.00 SD = 1.00
Communicated thinking	2	2	3	2	2	M = 2.20 SD = 0.45
Dialogical thinking	1	1	1	1	1	M = 1.00 SD = 0.00
One-way ANOVA test			p = 0.001			

shows significant statistical difference[6] between the numbers of teacher interventions in different phases in the five groups: the teacher provided significantly more support in the phases of orientation and the communicated thinking than in the phase of dialogical thinking. These findings indicate the need to examine the nature of the teacher interventions in the observed groups qualitatively.

5.2. Qualitative analysis of teacher-student interactions

In the extracts that follow the students are studying the topic Genes and Inheritance. They have already been introduced to the scientific concepts of DNA, genes, chromosomes, bases, amino acids, proteins, phenotype, and genotype. The teacher has just finished his whole class explanation of the processes of mitosis and meiosis. The students are sitting around the tables in the groups of four and working on the task (see Section 4.1) assigned by the teacher.

1.	Rita:	We do not understand the diagrams. What is this? ((*pointing at the mitosis diagram in the task sheet*))
2.	Teacher:	What do you think it can be?
3.	Rita:	I have no idea. It looks like-
4.	Teacher:	Look at what we began with in the class, you should have written it in your exercise book.
5.	Rita:	Here ((*pointing at the diagram in her exercise book*)) are copied DNA strands which are getting together into a chromosome, right?
6.	Teacher:	Where does this copying happen in this diagram ((*pointing at the diagram in the task sheet*))?
7.	Elisabeth:	Here ((*pointing at the cells in the diagram in the task sheet*))
8.	Teacher:	That is right. This is the simplified version of the process.
9.	Elisabeth:	So, they divide here and become like these ((*pointing at the chromosomes in the diagram of meiosis in the task sheet*))?
10.	Teacher:	Yes, we define them as single chromosomes.
11.	Rita:	Do the DNA strands have to come together to form a single chromosome? And do they copy to form a homo- Is it homogen-?
12.	Teacher:	Yes, the chromosomes are homologue.
13.	Rita:	These are homologue ((*pointing at the chromosomes in the diagram of meiosis in the task sheet*)).
14.	Teacher:	Yes, the genes in these chromosomes carry information about the same feature, but they can be different.
15.	Elisabeth:	They have blue and red stripes ((*pointing at the chromosomes in the diagram of meiosis in the task sheet*)).
16.	Teacher:	Yes, Viten explains the process in a different way with the different number of stages. The process can be presented in various ways, check out Viten if it helps you to understand.
17.	Rita:	OK.

5.2.1. Analysis of teacher-student interactions in group 4: the beginning of the learning process

Extract 1 presents the teacher intervention right at the beginning of the group work: the students are in so-called orientation phase (Galperin 2002). We start when the teacher approaches the group while circulating in the class.

Extract 1.

Having looked through the diagrams in the task sheet, the students sound confused (line 1) and the teacher suggests to compare the diagrams the students made in their exercise books during the whole class explanation session with the diagrams in the task sheet (lines 2, 6). The students follow the advice given by the teacher and once they have expressed their understandings (lines 12, 13 and 15), the teacher offers them to turn to the digital animations for more explanatory details (line 16).

At the beginning of the learning process, the teacher assists the students in their sense making and appropriation of the mediational tools (diagrams in the task sheet). By assisting learners' comparison of the diagrams in the task sheet with the ones the students made during whole class explanation session, the teacher facilitates the development of the learners' understanding of the processes depicted on the diagrams in the task sheet. Having received the confirmation of students' conceptual grasp, the teacher introduces another mediational tool that may contribute to further development of students' conceptual understanding – digital animations at Viten.no.

In Extract 1, in the orientation phase, the teacher takes the role of setting up the learning process and revealing the potential of the available mediational resources (diagrams in the task sheet) for the needs of the learners. The teacher acts as an orienting guide helping students to make sense of and identify the potential of the available mediational resources. Such guidance is of particular importance in the orientation phase as it creates a basis for the establishment and presence of the material mediational tools – the compare and contrast task and the digital animations to assist students' learning.

1.	Henrik:	They are beginning to exchange genes here ((*pointing at the chromosomes in Viten animation*)). Now they are going to divide.
2.	Andreas:	This one and this one, they are similar ((*pointing at the chromosomes in different cells in Viten animation*)).
3.	Teacher:	Do you understand what happens here?
4.	Rita:	They have jumped over two stages.
5.	Henrik:	Now they are going to divide, it's quite simple.
6.	Teacher:	Yes, you can see the similarity ((*refers to the chromosomes in different cells in Viten animation*)).
7.	Andreas:	Now they are dividing. They are similar, right ((*pointing at the chromosomes in Viten animation*))? Two single chromosomes in each cell.
8.	Teacher:	Can you click here ((*pointing at the first stage of Viten animation*))? They start with four chromosomes. But in reality how many chromosomes are there in a cell?
9.	Andreas:	Twenty four, no, twenty-three.
10.	Teacher:	Pairs? Which means forty-six single chromosomes.
11.	Andreas:	It's just simplified here ((*refers to Viten animation*)).
12.	Teacher:	Exactly, the animation shows a simplified process.
13.	Henrik:	Otherwise, it would have been too many chromosomes.
14.	Teacher:	And it would have been difficult to understand ((*leaving the group*)).

5.2.2. Analysis of teacher-student interactions in group 4: the students are engaged with digital representations

The events in Extract 2 chronologically follow the events in Extract 1. The students in group 4 are making sense of the animations at Viten.no: the learners are in the phase of communicated thinking (Galperin 2002) when the teacher approaches the group.

Extract 2.

While the students are making sense of the stages of meiosis (lines 1–5), the teacher confirms their understandings and introduces the process of recombination (line 6). Having received a confirmation of students' conceptual grasp of meiosis, the teacher draws the learners' attention to the initial number of chromosomes in the animation, which might prompt the learners that meiosis in human cells involves a greater number of chromosomes than the animation presents (lines 8, 10 and 14). In doing so, the teacher helps the learners to shape their understating of the process of meiosis and at the same time, to build a connection between the steps of the animation and the real process happening in human cells.

In the phase of communicated thinking by interacting with the digital animations and the collaborating peers, the teacher assists the development of students' conceptual understanding of meiosis and draws learners' attention to the simplifications embedded in the digital animation. In doing so, the teacher provides support and facilitates the learning process while helping the students to move forward in their learning.

5.2.3. Analysis of teacher-student interactions in group 3: the students are writing their answers in the task sheet

In Extract 3 the students of group 3 are in the middle of writing the differences between mitosis and meiosis in their answer sheets: the learners are in the phase of dialogical thinking (Galperin 2002). The teacher approaches the group and asks the following:

Extract 3.

1.	Teacher:	Are you in the middle of describing the differences?
2.	Helene:	Yes, this is a difficult phenomenon.
3.	Teacher:	Yes, and if you compare these two processes – what happens with the chromosomes?
4.	Helene:	Well, I think the main point is that they divide one extra time in meiosis.
5.	Teacher:	Yes.
6.	Chris:	This makes DNA to copy the same number of times as in mitosis, but the cell divides four times. There will be 46 chromosomes in two cells as they divide an extra time. So, each chromosome doubles copies itself once but divides twice, therefore there will be 23 chromosomes in each cell.
7.	Teacher:	Yes, it looks quite easy, what happens here ((*points at the diagram of mitosis in the task sheet*))? How many chromosomes are there?
8.	Helene:	Twenty-two? Twenty-six? No, twenty-three?
9.	Teacher:	Twenty three (.) pairs?
10.	Helene:	Yes.
12.	Teacher:	Are these daughter cells similar to those ((*points at the mother cells in the task sheet*))? Are there twenty-three pairs too ((*points at the daughter cells in meiosis*))?
13.	Helene:	Here, we've got twenty-three pairs, right ((*points at the mother cell in meiosis*)). And here we've got twenty-three pairs divided by two, haven't we ((*points at the daughter cells in meiosis*))?
14.	Teacher:	Here are forty-six single chromosomes.
15.	Mira:	And there will be twenty-three single chromosomes.
16.	Helene:	Twenty-three in each of them, right ((*points at the daughter cells in meiosis in the task sheet*))?
17.	Teacher:	Half of the number that was at the beginning.
18.	Mira:	Because they divide an extra time.
19.	Teacher:	So, this is the difference. And this is an important difference. The number of the chromosomes reduces by half. Here the daughter cells are identical to their mother cell ((*points at the diagram of mitosis*)), but what about those cells comparing to this one ((*points at the daughter cells and the mother cell in meiosis*))? [...]
20.	Mira:	Do they have different chromosomes?
21.	Teacher:	This too. The chromosomes are also different. This is an important difference between these two processes of cell division. Look at these two processes, what about the number of cells produced?

The teacher joins in when the students are in the middle of writing their answers in the task sheets. Having received a detailed description of the stages of meiosis from

Chris, he poses the question that requires comparing (line 3) and by in engaging in comparing of the number of chromosomes in the mother and daughter cells in mitosis and meiosis the teacher may enhance scientific thinking in the group. The teacher relies on various mediational tools, he refers to the diagrams in the task sheet to support his questions and make them visual, and he creates a pattern in his sentence by pointing out the number of chromosomes in the cells in mitosis (line 12) that prompts the students with the right answer (lines 13–18). The pattern makes teacher's thinking accessible to the learners: the students use the pattern and come up with the right answer.

In the phase of dialogical thinking, the teacher helps the learners to structure and organise their knowledge and to complete the compare and contrast task by identifying the essential features of mitosis and meiosis. Such guidance on the part of the teacher might evoke learners' reflections about how well their understandings match the publicly accepted scientific understandings of meiosis and mitosis required for learners to develop their conceptual grasp and to complete the compare and contrast task.

6. Discussion

The analyses performed in this study focused on examining teacher guidance when facilitating students' engagement in the compare and contrast task in the science class and addressed the following research questions: *How did the teacher facilitate students' group learning with digital technology in Science?* And *what are the implications of the teacher actions for enhancing students' agency in learning to learn?*

The patterns of the teacher assistance are presented in Table 4.

First, the analyses of teacher-student interactions revealed the patterns in teacher facilitating of the learning process. These patterns make visible that the teacher: i) set up the learning process and revealed the potential of the available mediational tools for students' needs in the orientation phase; ii) by interplaying with digital animations and collaborating peers, assisted the development of students' conceptual understanding in the phase of communicated thinking; and iii) structured and organised students' knowledge and brought learners' attention to the essential features of the target concepts in the phase of dialogical thinking. The quantitative analysis showed that the teacher provided substantially more assistance in the phases of orientation and communicated thinking than in the dialogical thinking. This might potentially indicate that learners require more guidance at the beginning and the middle of the learning process rather than in its final phase. Indeed, in the orientation phase, the learners required detailed

Table 4. Patterns of teacher facilitating of students' learning.

Galperin's pedagogical phases	Teacher actions
Orientation	• Setting up the learning process; • Revealing the potential of the available mediational resources for the needs of the learners (diagrams in the compare and contrast task);
Communicated thinking	• By interacting with digital animations, shaping students' conceptual understanding of mitosis and meiosis
Dialogical thinking	• Structuring and organising students' knowledge by helping learners to identify the essential features of the concepts of mitosis and meiosis

guidance about the task they were to engage with and the potential of the mediational resources they were to utilise. The teacher's close assistance at the beginning of the learning event may have helped the learners to develop their understanding about how to approach the task and to reveal the potential of the resources useful for solving this task. In doing so, the teacher may have enhanced the learners' understanding of how to engage with the task and, in more general terms, how to go about learning. In the phase of communicated thinking, by attracting learners' attention to the simplifications embedded in the animation, the teacher carefully assisted the development of learners' understanding of the target scientific process. The teacher's intervention triggered students' reflections about the real process that happens in human cells which may have contributed to learners' growing ability to productively engage in and solve the task and in doing so, develop their understanding about the target scientific phenomenon. In sum, the teacher's close assistance in the orientation and the phase of communicated thinking may have created positive premises for learners' to be able to engage with the task, propel themselves forward in their learning while developing their conceptual grasp about the processes of cell division. Such teacher's actions may have manifested in the learners' ability to structure and organise their knowledge in the phase of dialogical thinking, to complete the compare and contrast task and to enhance their agency in learning to learn.

Second, the analyses revealed that the teacher interplayed with a variety of resources while assisting students in different phases of the learning process. Thus, the teacher relied on students' own diagrams made during the whole class explanations session, when assisting learners' sense making of the diagrams in the task sheet in the orientation phase (Extract 1). In the phase of communicated thinking, the teacher interacted with the digital animations while assisting the development of students' conceptual understanding of meiosis (Extract 2). In the phase of dialogical thinking, the teacher relied on the diagrams in the task sheet and students' previous experience of working with digital animations to structure and organise their knowledge by identifying the essential features of the concepts of mitosis and meiosis (Extract 3). In doing so, the teacher dialectically interplayed with an array of the available mediational resources: the compare and contrast task, digital animations and the collaborating peers themselves. This interplay was particularly visible in the way these resources were utilised by the teacher and how they shaped teacher-student interactions. Figure 3 may serve as a visual representation of the dialectical interplay between the collaborating peers, teacher interventions, digital tools, and the compare and contrast task. For the clarity of the diagram: points A and B are the starting and the final points of the learning process and the curved line connecting them represents students' learning trajectory. The dialectical interplay of the mediational means of the compare and contrast task, collaborating peers, digital tools and teacher interventions creates a structure that scaffolds, supports and guides students' learning.

Third, while the patterns of the teacher facilitating of students' learning may reflect in general the way practitioners might facilitate the learning process with digital technology (Urhahne et al. 2010), the dialectical interplay between the teacher interventions and other mediational resources emphasise the complexity involved in students' move from orientation to communicated and dialogical thinking. These findings indicate that a variety of mediational resources that co-exist in the learning process (Strømme and

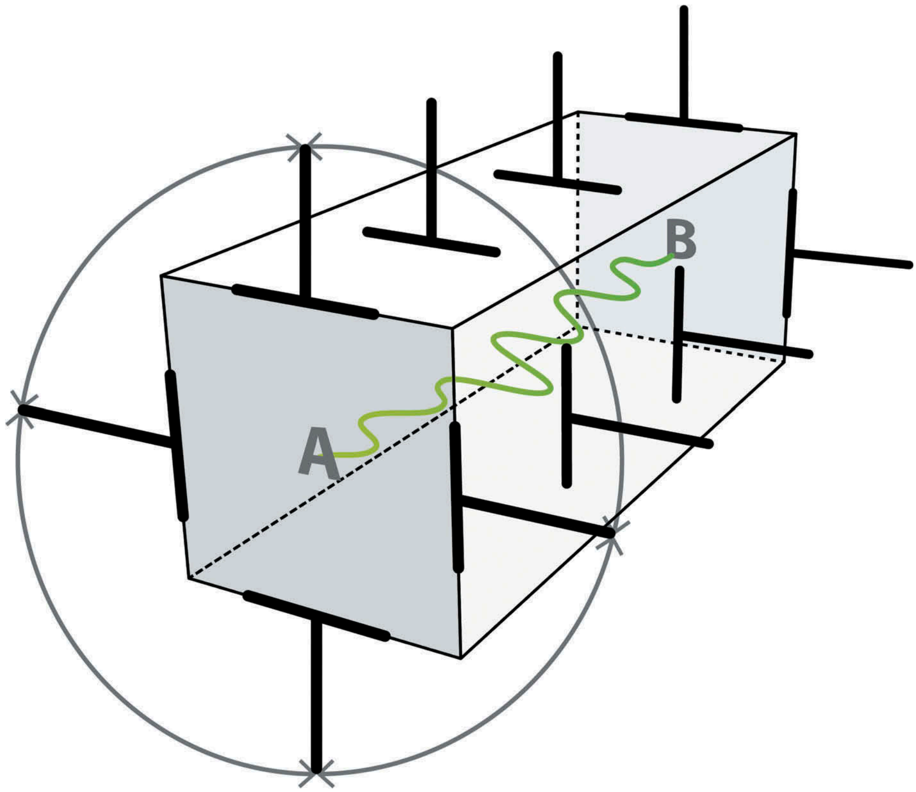

Figure 3. A structure created by the dialectical interplay between the compare and contrast task, digital tools, collaborating peers and teacher interventions in the learning process. The mediational resources are not marked on the diagram because of their interchangeable position.

Furberg 2015) and by being dialectically intertwined in a structure, they shape and affect the teacher interventions in students' learning. These findings may also indicate teacher dependency on the potential of the available mediational resources and support they provide to assist students' conceptual learning and enhance their agency in learning to learn. Galperin's types of orientation may serve as a cue in revealing how the potential of the available mediational resources affected teacher facilitating of students' conceptual learning in science.

From the perspective of Galperin's types of orientation, the students were exposed to the third type of orientation: complete, and constructed by learners following an approach of identifying the essential features of the target concept (Galperin 2002). The learners were to identify and utilise the resources that encapsulated the essential characteristics of the target scientific concepts (mitosis and meiosis) to assist them in solving the compare and contrast task. Therefore, it was the compare and contrast task that largely determined which resources were chosen and how they were utilised by the learners. The compare and contrast task, in turn, was directed at identifying the essential features of mitosis and meiosis and to develop students' understanding of these concepts. The analyses of teacher-student interactions in the phases of orientation, communicated and dialogical thinking showed that the teacher interventions were also directed at assisting learners in solving the compare and contrast task and identifying the key features of the target concepts. Again, it was the compare and contrast task that affected and shaped teacher-student interactions and demonstrated an approach to study scientific concepts. Such an approach was previously described in the works of Vygotsky (Vygotsky 1986) comprising identifying the essential features of a target scientific phenomenon. Therefore, by engaging in the compare and contrast exercise, the learners were exposed to an approach which potentially may be pursued when studying other scientific concepts. In doing so, students' understanding about how to go about learning in science may have been enhanced. The teacher interventions, in turn, drew learners' attention to and assisted the students in solving the compare and contrast task. In doing so, the teacher might have contributed to enhancing students' agency in learning to learn. The analyses of teacher-student interactions showed that technology (animations in Viten.no) demonstrated the complex scientific processes that were otherwise invisible for students and triggered group discussions.

In sum, by providing various types of support in the phases of orientation, communicated and dialogical thinking, the teacher assisted students in solving the compare and contrast task. In addition, the approach of comparing and contrasting aimed at identifying the essential features of mitosis and meiosis may have contributed to enhancing students' agency in learning to learn.

7. Implications and directions for further research

There are several implications for classroom pedagogy related to facilitating students' learning in science with digital technology.

First, the patterns in the assistance revealed what the teacher did when facilitating students' learning: set up the writing process in the orientation phase, assisted the development of students' conceptual understanding in the phase of communicated thinking and encouraged learners' reflections about the essential features of mitosis and meiosis in dialogical thinking. In other words, the educationist's guidance fulfilled the *orienting, executive* and *control* functions when facilitating students' group learning in science.

The *second* implication is that the available resources may affect teachers' facilitating of the learning process. One outcome of the simultaneous presence of other mediational resources: the compare and contrast task, digital animations and collaborating peers in the learning process, appeared to affect teacher interplay with these resources in different phases of students' learning. The study, therefore, raises questions about the need for practitioners' awareness of the type of support these resources provide. In the orientation phase, the teacher put particular effort in helping students to make sense of the diagrams in the task sheet and attract learners' attention to the available digital animations while revealing the potential of these animations for students' learning. In the phase of communicated thinking, the teacher interplayed with the digital animations to shape the development of students' conceptual understanding. In the phase of dialogical thinking, the teacher relied on the diagrams in the task sheet, students' previous experience of working with digital animations and the responses from the collaborating peers to structure and organise students' understanding and to solve the compare and contrast task. Therefore, the digital animations showed the scientific processes and enabled the students to explicate their (mis) understandings; the diagrams in the task sheet were used as a resource to help learners to structure and organise their knowledge and the collaborating peers presented themselves as resources to promote developing of learners' conceptual understanding. On the one hand, the compare and contrast approach affected the nature of teacher-student interactions and determined the way other resources were used by the students and the teacher. On the other hand, the compare and contrast task, coincided with the approach to study scientific concepts comprising identifying their essential features (Vygotsky 1986) and, therefore, may have contributed to enhancing students' understandings about how to go about learning in science. By providing assistance to learners that engaged in solving the compare and contrast task, the teacher, in turn, may have contributed to enhancing students' capacity to learn. The technology, however, carried the function of demonstrating the complex and otherwise invisible scientific processes and triggering group discussions. These findings may have implications for the design of digital technology and learning activities to assist students in recognising the essential characteristics of the target concepts and articulating the approach they may pursue when studying scientific concepts and, in doing so, develop as learners.

The *third* implication is that Galperin's pedagogical phases appeared to be helpful as a lens to understand the dialectics of students' learning and as a tool to examine and conceptualise the nature of teacher pedagogic interactions with groups of students in different phases in the learning process. Additionally, Galperin's types of orientation provided an explanation for the conditions of mediation in the Science class and revealed that it was the third type of orientation (complete and constructed by learners following a given approach) that might facilitate both conceptual learning and understanding of an approach that might be pursued in science learning. In this respect *learning activity* with the third type of orientation has the potential to not only help students to achieve learning outcomes but, it acquires a functional significance, becoming *a tool* in the learning process aimed at the development of students' understanding about how to go about learning in science. Such use of Galperin's conceptual contribution in empirical research might have implications for further studies that have learning and teaching process as a focal area. Further research, therefore, will benefit from a longitudinal study examining students' learning with the third type of orientation within and across curricula, to examine the development of students' understanding of the nature of learning in formal settings and their capacity to be in control of their own learning.

These findings, therefore, inform practitioners about the types of instructions teachers may give when facilitating group learning in science with digital technology. They also emphasise the crucial importance of teachers' awareness about the type of support technology and other resources provide with the purpose of integrating of these resources to enhance their pedagogy and student capacity to learn within and across subject domains.

Notes

1. See: http://www.viten.no/vitenprogram/vis.html?prgid=uuid%3A42241581-B892-15A9-626C-00000A2341CD&tid=1717509&grp=.
2. See:http://lokus123.lokus.no/static/flashEmbedder.jsp?contentItemId=37702931&selectedLanguageId=1&title=Celledeling.

3. See: http://intern.forskning.no/arnfinn/kromozoomflash/kromozoom_nonpop.html.
4. See: http://www.bion.no/temaer/arv-og-genetikk/for-skoler/.
5. See: http://www.viten.no/vitenprogram/vis.html?prgid=uuid:42241581-B892-15A9-626C-00000A2341CD&tid=uuid:42241581-B892-15A9-626C-00000A2341CD.
6. $p > .05$ indicates no significant statistical difference between the means of samples (Field, 2013).

Disclosure statement

No potential conflict of interest was reported by the author.

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Appendix A.

Transcript conventions

[]	Text in square brackets represents clarifying information.
=	Indicates the break and subsequent continuation of a single utterance.
?	Rising intonation.
:	Indicates prolongation of a sound.
(.)	Short pause in the speech.
[…]	Utterances removed from the original dialog.
-	Single dash in the middle of a word denotes that the speaker interrupts herself.
–	Double dash at the end of an utterance indicates that the speaker's utterance is incomplete.
((Italics))	Annotation of non-verbal activity.