LEARNING AND TEACHING WITH DIGITAL TOOLS: INSIGHTS FOR LEARNING ARISING FROM THE CULTURAL-HISTORICAL THEORY

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THESIS SUBMITTED FOR THE DEGREE OF PHILOSOPHIAE DOCTOR

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Faculty of Educational Sciences
University of Oslo
December 2017

Series of dissertations submitted to the
Faculty of Educational Sciences, University of Oslo
No. 285

ISSN 1501-8962

Cover: Hanne Baadsgaard Utigard.
Print production: Reprosentralen, University of Oslo.

Acknowledgements

My way to this PhD thesis has been almost a quarter of a century long: that many years have passed since I graduated from the University to somewhere very much unknown. The country I was born, grew up and got my education in had just vanished as well as the opportunity to enter a PhD programme and everything around was spinning in the whirlwind of change. Following this whirlwind of change, I have lived and worked in three different countries and every time a new move marked a new start: a new job, language, culture and many other things I never knew before. However, a dream to continue my education had never left me and I hoped that one day I would be able to get back to the University and appear in the atmosphere of sophisticated discussions and academic challenge I loved to be in when I was a student. This opportunity presented itself in Norway, which I am endlessly grateful for this chance to live up my dreams.

However, this PhD thesis would have never happened without enormous help and assistance from my supervisors: Professor Anders Mørch and Professor Anne Edwards. You have always believed in me and encouraged me to dare and to follow my ideas while providing me invaluable support in expressing these ideas and challenging me to move beyond them. I am deeply grateful to both of you for your time, constructive comments, orienting advice and sharing with me your knowledge and expertise – everything I relied on in my move forward. I am also extremely grateful to both of you for introducing me the art of academic writing, co-authoring with me two articles included in this thesis and all the support and assistance you have given me.

I would like to express my gratitude to Associate Professor Anniken Furberg and Associate Professor Ingvill Rasmussen for supervising me at the beginning of my PhD studies, introducing me to the method of Interaction Analysis and valuable comments on the early drafts of my work. My special gratitude to the whole Mediate Research Group, a member of which I have been since 2013 for constructive feedback on my work, thought-provoking academic seminars and inspiring presentations of the researchers invited by Mediate. I am also very grateful to Associate Professor Hans Christian Arnseth, Associate Professor Bjørn Skaar, Associate Professor Per Hetland, Associate Professor Kristinn Hegna, Associate Professor Ole Smørdal, Dr. Jan Dolonen, Dr. Anders Kluge, Dr. Rolf Steier, Dr. Leila Ferguson, Dr. Alfredo Jornet Gil and Dr. Dimitra Christidou for the interest you have shown in my work and your invaluable feedback on the texts I have presented.

A special thank you to Associate Professor Øystein Gilje for allowing me to join in the Ark & App project and participate in the two case studies that provided an opportunity to collect rich data used in my studies.

It was a privilege to be accepted as a member of the National Graduate School of Education (NATED), which significantly influenced my development as a researcher. My gratitude is to Professor Kirsti Klette for organising academic seminars and orchestrating vivid discussions about scientific articles and candidates' own contributions. I am also grateful to Professor Andreas Lund and Professor Jon Magne Vestøl for their genuine interest in my work and thoughtful feedback on my texts.

Furthermore, I am in debt to the Department of Education at the University of Oslo for funding my PhD project, giving me an opportunity to develop as a researcher and for the multi-layered support I have been provided. I am grateful for the positive and friendly environment, for the interest and willingness to listen and give advice. A special thank you to Professor Ola Erstad, Professor Helge Ivar Strømsø, Professor Tone Kvernbekk, Professor Monika Nerland, Solveig Løland, Yngvild Dahl, Olga Mukhina, Sarah Beate Klingseid, Miriam Segal, Terje Kristian Lian Thoresen, Rosa Valseth and many others.

I am also grateful to my colleagues PhD students: Renate Andersen, Caroline Cruaud, Jan Erik Dahl, Marianne Takvam Kindt, Kristin Aaland, Filipa deSousa, Line Ingulfsen, Emily Oswald, Jarmila Moan, Jo Inge Johansen Frøytlog and many others also from other departments for sharing experiences, joys and encouragements when I needed them.

Finally, I would like to express my gratitude to my family: my parents and my brother who, despite being far away, supported me and showed great interest in my work. I know that my PhD work has always been of great importance to my parents in Kharkov who have always believed in me, and I have done my very best not to disappoint them. My special thank you to you, my dear husband Bill and our son Christian for encouraging me to pursue my PhD studies, believing in me and being there for me during these years of being a doctoral student. Thank you for our evening discussions, letting me explain the ideas central to my work and sharing with me some joys and sorrows. Thank you for allowing me to follow my dreams, you both light up my life.

Irina Engeness,
Blindern, December 2017

PART I: EXTENDED ABSTRACT

PART II: THE ARTICLES

Article 1: Engeness, I. & Edwards A. (2017). The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools. *Scandinavian Journal of Educational Research 61(6)*, p. 650-667 doi:10.1080/00313831.2016.1173093

Article 2: Engeness, I., & Mørch, A. (2016) Developing Writing Skills in English Using Content-Specific Computer-Generated Feedback with EssayCritic. *Nordic Journal of Digital Literacy, 11(2),* p.118–135 DOI: 10.18261/issn.1891-943x-2016-02-03

Article 3: Engeness, I. (accepted for publication) What Teachers Do: Facilitating the Writing Process with the Feedback from EssayCritic and Collaborating Peers. *Technology, Pedagogy and Education.*

PART I

EXTENDED ABSTRACT

1.0 INTRODUCTION

1.1 Background and rationale

I belong to the generation that got its education before computers hit classrooms. People of my and older generations remember how we used to spend long hours in libraries reading books and searching for information. In an attempt to study something, we used to launch ourselves on a long journey, diving into the ocean of knowledge, admiring everything we met on our way to the knowledge we were striving for. Such long and complicated journeys required a particular understanding about how to navigate sources, selecting the important from the trivial and organising our learning. In addition, vivid imagination was needed to decode and animate the diagrams in the books that showed, for instance, complex scientific processes. All this required a particular understanding about the nature of learning in order not to get lost and to move ourselves forward as learners. The appearance of computers and the Internet in schools has brought enormous changes that have significantly simplified this journey for the learners, but has also brought challenges for our conceptualisations of pedagogy.

My introduction to pedagogical digital tools happened at the end of 1990s when I was teaching Science in an English school. The market had started to offer a variety of digital tools for classrooms and there were monthly presentations by publishers with newly designed digital products, offering attractive solutions to pedagogical challenges and creating opportunities for students and teachers. I remember getting my first laptop, the excitement of my teacher-colleagues in the Science department about the new digital resources and the expectations of something really ground-breaking that would create learning and teaching opportunities we had never known before. The 'honeymoon' with digital tools started with the use of digital animations of different scientific processes, which made my life as a teacher considerably easier. They meant I escaped drawing these processes on the blackboard and, at the same time, animating them with my hands and voice. Never before was demonstrating the movement of electrons and ions in the process of electrolysis and the changes that happened in cells, chromosomes and DNA in mitosis and meiosis that easy and artistically well-presented. Digital tools were seemed to revolutionise and improve teaching and learning.

However, my initial enthusiasm for the potential of digital tools gradually transformed into questions about whether the opportunities offered by computers had, in fact, transformed learning from 'diving into the ocean of knowledge' to 'surfing on the surface' and the fast scooping up of easily available information, without any need to develop an understanding about how to pursue learning. In this sense, the broader question became whether computers

had any potential to enhance learners' understanding of what learning was, in ways that would prepare them for life-long learning and unknown futures.

This study is premised in the belief that education is a preparation for the future. That means, as Claxton has explained, helping all young people to acquire the knowledge, skills, dispositions, and values they need to thrive and contribute to society, in the face of the challenges and opportunities they will meet (Claxton, 2013). From a more political perspective, Miliband similarly argued that one of the core functions of 21st century education is learning to learn in preparation for a lifetime of change and therefore pedagogy should at its best be about what teachers do that not only helps students to learn but strengthens their capacity to learn (Miliband, 2003). Of course, one of the ways of potentially building this capacity to learn is by embracing the pedagogical potential of new technology. Selwyn has argued (Selwyn, 2011) that technologies connected directly with these issues are of fundamental importance to contemporary society, arguing that technology has the potential to contribute fruitfully to the education of 21st century learners.

We have long been aware of aspects of that potential. In 1985 MacKenzie and Wajcman proposed that technology can be seen in three ways: i) the physical objects themselves; ii) the human activities that take place in conjunction with these objects and iii) as the human knowledge that surrounds these activities (MacKenzie & Wajcman, 1985). From this perspective, technologies are seen as profoundly cultural objects – a part of a body of knowledge shared between people and passed down from generation to generation (Goyder, 2005). A more recent way of conceptualising the social and the technical aspects of technology, offered by Lievrouw and Livingstone, echoes MacKenzie and Wajcman and presents three distinct but interconnected aspects: i) artefacts and devices: that is the technology itself and how it is designed and made; ii) activities and practices: that is what people do with technologies (including issues of human interaction, organising, identity, cultural practices); and iii) context: that is social arrangements and organisational forms that surround the use of technologies (including institutions, social structures and cultures) (Lievrouw & Livingstone, 2002). The interconnectedness of these aspects of technology manifests itself in the assumption underpinning the idea of the 'digital age', that digital technologies will define the way we live, learn, teach and be in the future (Zepke, 2008).

In many ways, therefore, the central concern of education and learning is closely interlinked with some of the main functions and processes of digital technologies (Selwyn, 2011). The past 20 years have seen digital technology become a prominent feature of the modernisation of education systems in various countries. In particular, there is a strong belief that technology is

capable of supporting a range of improvements to the core process of education. Perhaps the most frequently discussed benefit of its use is its role in supporting and enhancing learners' cognitive processes and thinking skills (Gertner & VanLehn, 2000; Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013; Weinberger, Stegmann, Fischer, & Mandl, 2007). Equally, digital technologies are often associated with constructivist forms of learning in collaborative and supportive social contexts. In this sense digital technology can link learners to other people and tools that may support and mediate effective learning (Ludvigsen & Mørch, 2010; Scardamalia & Bereiter, 2006; Stahl, 2006). In short, digital technologies are seen to be a valuable and integral part of the modern-day learners' and teachers' repertoires offering the possibility to explore and extend educational practice and improve learning experiences.

However, the educational imperatives of technology involve a fundamental rethinking of relationships between learners, knowledge, teachers and educational institutions. These changes include re-imagining the role of the teacher, the student, the educational institution and the parent (Kozma, 2003) and are related to the wider questions of what learning is and what we want education and learning to be.

In trying to the question of what is learning, back in the 1970s Säljö questioned ninety adult learners to explore their perceptions about education (Saljo, 1979). The three most common types of response viewed learning as a product:

- Learning as a quantitative increase of knowledge and acquiring information
- Learning as memorising and storing information that can be reproduced
- Learning as acquiring facts, skills and methods that can be retained and used when necessary

However, the fourth and the fifth most popular categories of answers pointed to different notion of learning where learning was described as an ongoing process rather than a finite product:

- Learning as making sense or abstracting meaning, relating parts of the subject matter to each other and to the real world
- Learning as interpreting and understanding reality in a different way and comprehending the world by reinterpreting knowledge (Saljo, 1979, p. 448).

These descriptions of learning as an ongoing process resonate with the definition of "conscientious learning" (Rogers, 2003, p. 26), where individuals are fully aware that the task they are engaged in involves some form of learning and therefore learning itself becomes a task. In a similar vein, Claxton reminds us about the words of Albert Einstein: "Education is what remains after one has forgotten everything one learned at school" (Claxton, 2013, p. 2). These

words point to education as an understanding of what learning is, the capacity to engage in learning and develop as a learner. In this thesis I shall argue that such education is important for the learners in the digital age.

There is still work to be done in making this and other arguments about the potential of digital tools in pedagogical work. While the past 20 years have seen substantial increases in the presence of digital technology in schools and universities, the much promised technology-led transformation of the processes and the practices of education has failed to materialise into tangible benefits (Selwyn, 2011). Although digital technologies may well have undoubted potential to support learners, educators and institutions, it seems that this potential is being realised only on occasion. As Laurillard has observed wryly, "Education is on the brink of being transformed through learning technologies; however, it has been on that brink for some decades now" (Laurillard, 2008, p. 1). Selwyn (2011) similarly comments that this gap between how educational researchers and practitioners would like technology to be used and how it actually ends up being used, suggests that we need to avoid imagining technology to be a ready-made solution to existing educational problems. Robins and Webster (1989) have observed that the 1980s were characterised by attempts to use the power of technology to solve educational problems that were non-technological in nature (Robins & Webster, 1989). These and later attempts to integrate technology in pedagogy resulted that technology which was designed inconsistently with the nature of the learning process, led to the need to adjust the learning process to the affordances of the technology. These observations indicate that there was a gap between the expectations imposed on technology in educating learners in the late 20th century and the way educational technology was used for learning and teaching in classrooms.

This gap persists and has encouraged researchers to respond in different ways; including helping learners and teachers understand and use the potential of the tools (Erstad, 2015; Furberg, 2016; Lund, et al., 2009; Rasmussen & Damşa, 2016, Vestøl, 2011). This thesis also addresses the gap, by focusing on what teachers and students do with digital tools in the course of the learning and teaching process, with the intention of being able to inform the learning of students as learners in the 21st century.

1.2 Overarching aim and research questions

The overarching aim of this thesis is two-fold:

- *To make explicit how adolescent students learn when using digital tools in Science and writing classes in English and how teachers facilitate students' learning in these conditions.*

- *To use and evaluate the pedagogical categories developed by Galperin as analytic resources to reveal students' actions in the classrooms with digital tools.*

To address these aims, I conducted two studies in Norwegian Secondary Schools, examining students' learning and teachers' facilitating of the learning process with digital tools, one in Science lessons and the other in English lessons. Three aspects of the learning process were examined from the cultural-historical perspective: 1) the complexity of learning with technology: how material digital tools, task design, social peer collaboration and teacher interventions interplay in supporting and guiding students' learning in Science; 2) how students learn in the writing process in English with the feedback from EssayCritic (a computer-based system that generates feedback on the content of students' essays) and the feedback from collaborating peers; and 3) how teachers facilitate students' writing process with the feedback from EssayCritic and the feedback from collaborating peers. The analyses reveal: (i) how digital tools as potential mediational means are used by students when working on classroom tasks; (ii) how the affordances of digital tools in interaction with other resources including teachers may facilitate student learning; and (iii) how teachers' facilitating of students' learning may become affected by the presence of technology as potential meditational means. The findings of the two studies are presented in three articles.

Article One examined the complexity involved in learning with digital tools and explored the relationship between the different mediational means while supporting students' learning with digital tools in science group work in a Norwegian lower secondary school. The research questions were: *i) What characterises the relationship between the digital tools, task design, peer collaboration and teacher interventions in students' learning?* and *ii) How do these mediational means support students' development of conceptual understanding in Science?* The qualitative analyses of teacher-student and student-student interactions were located in cultural-historical theory and drew on Galperin's conceptualisation of learning process. The study contributes to the overarching aim of the thesis by conceptualising the complexity of learning with digital tools and explaining the relationship between material digital tools and task design and social peer collaborations and teacher interventions. The article was published as:

Engeness, I. & Edwards A. (2017). The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools. *Scandinavian Journal of Educational Research 61(6)*, p.650-667. doi:10.1080/00313831.2016.1173093

Article Two examined and compared students' writing process in English in an upper secondary school in Norway with the feedback from the computer-based essay critiquing system (EssayCritic) (target class) and collaborating peers (comparison class). The research

question was: *How do different types of feedback assist students in their writing process?* The study employed mixed methods' approach and drew on Galperin's conceptualisation of learning process. The study contributes to the overarching aim by comparing and contrasting students' learning with digital tools (EssayCritic) (target class) and collaborating peers (comparison class). The article was published as:

Engeness, I., & Mørch, A. (2016) Developing Writing Skills in English Using Content-Specific Computer-Generated Feedback with EssayCritic. *Nordic Journal of Digital Literacy, 11(2),* p.118–135*,* DOI: 10.18261/issn.1891-943x-2016-02-03

Article Three examined and compared teachers' facilitating of the writing process of Norwegian upper secondary school students with EssayCritic (target class) and collaborating peers (comparison class). The research questions were: *i) How do teachers facilitate students' writing process with the feedback from EssayCritic and collaborating peers?* and *ii) How does EssayCritic affect teachers' facilitating of students' writing?* Quantitative and qualitative analyses of the teachers' assistance drew on Galperin's conceptualisation of learning. The study contributes to the overarching aim by comparing and contrasting teachers' facilitating of students' learning with EssayCritic and collaborating peers and provides an insight into how technology may affect teachers' facilitating of the writing process while downplaying an emphasis on augmenting students' capacity to be in control of own learning.

Engeness, I. (accepted for publication) What Teachers Do: Facilitating the Writing Process with the Feedback from EssayCritic and Collaborating Peers. *Technology, Pedagogy and Education.*

Together, the three articles examine how young people learn with digital tools across subject areas and how teachers facilitate students' learning in such conditions. In addition, Article Three places an emphasis on how the affordances of digital tools may augment students' capacity to be in control of own learning and affect teachers' facilitating. By examining these aspects, I seek to contribute to existing research in three ways.

First, this thesis contributes to research on learning with digital tools by examining students' learning with digital resources and reflecting on the learning to learn aspect of the 21st century learners. I seek to relate students' interactions with technology in group learning to broader questions about how students may enhance their capacity to learn when engaging with digital tools.

Second, this study emphasises the role of the teacher facilitating students' learning with technology. I intend to investigate the role of the teacher when students collaboratively engage

with digital tools and how teachers may assist learners in enhancing students' understanding about what learning makes.

The *third* contribution is in employing a cultural-historical perspective in examining learning and teaching with digital tools. The chosen cultural-historical perspective and the contributions of Galperin in particular provide analytical tools to analyse the data and investigate the implications of learning with computers for enhancing students' understanding about the nature of learning. At the same time, using these tools in digitally enhanced learning environments has provided an opportunity to assess the current usefulness of the categories developed by Galperin in his work in classrooms forty years ago.

Finally, the contributions of this study may have implications for the design of digital tools to enhance students' capacity to learn in becoming life-long learners in the 21st century. In the next section, I provide detail on the digital environments used in the empirical research in this study.

1.3 Computer-based learning environments Viten.no and EssayCritic

Aiming to answer the research questions, two case studies were conducted: Science in the lower secondary school and English in the upper secondary school. The computer-based learning environment Viten.no[1] (Furberg, 2009; Jorde, 2003; Mork, 2012; Strømme & Furberg, 2015) designed to support students' learning of Norwegian curriculum, was chosen as a learning resource for lower secondary school students in the science case. The details of Viten.no environment can be found in Article One in Part II in this thesis. Viten.no was widely used by the Science teacher who worked with the research team in the selected lower secondary school and the environment was well known by the student participants in the case study. The environment contained the step-by-step designed animations of the focus biological processes and therefore was well-suited to supporting students' learning of these processes. Based on these reasons the Viten.no environment was chosen to support students' learning in the Science case study.

The EssayCritic system used in the English case study is the third version of a web application for analysing written texts (e.g., short essays, <500 words). The details of the technical characteristics and training the system can be found in Articles Two and Three in Part II of the thesis. Overall, EssayCritic provides two types of feedback to students: covered subthemes and suggested subthemes and it belongs to a tradition of learning technology now

[1] See: http://www.viten.no/nob/

referred to as Learning Analytics. The ability of EssayCritic to give individually tailored feedback on multiple occasions and drafts was decisive in choosing the program to examine students' computer supported writing process and teachers' facilitating of this process. In this study the third version of EssayCritic was used and group discussions on the individual feedback given by EssayCritic were introduced to the design of the research. The intention was to explore and compare how students made sense of the feedback from EssayCritic (target class) and from collaborating peers (comparison class) in group discussions, and how students incorporated the ideas developed in these discussions in their essays. In addition, the research team was interested in examining teachers' facilitating of students' learning with the feedback from EssayCritic (target class) and collaborating peers (comparison class).

1.4 Outline of the thesis

This thesis comprises two parts, the extended abstract (Part I) and three articles (Part II). Following the introductory chapter, the extended abstract includes four more chapters.

Chapter 2 first offers a review of studies that discuss aspects of the learning to learn approach. The chapter then reviews the role of digital tools and teachers' facilitating to support student learning. The implications of the previous research for the current study are outlined.

Chapter 3 presents key aspects of cultural-historical theory, the theoretical perspective that has informed the analyses. These aspects centre on what the theory offers in relation to learning and development and comprise the contributions of Lev Vygotsky, Aleksei Leontiev, Piotr Galperin and Vasilij Davydov. The chapter introduces and justifies the use of analytic resources offered by these scholars to examine how engagement with digital tools may support students' learning and provide an insight into learning to learn aspect.

Chapter 4 presents the research design and the chosen methodological approach. It introduces the two case studies conducted within the frame of the project and the data used in this thesis. The chosen analytical approach and processes are discussed and the issues of validity, generalisation, reliability and ethical considerations are addressed.

Chapter 5 provides a summary of the three articles in this thesis, including the main findings.

Chapter 6 discusses the main findings of the three studies in relation to the overarching aims and the research questions of this thesis. The empirical, theoretical and methodological contributions are then outlined. Finally, the implications for teachers' facilitating of students' learning with digital tools and the design of digital environments are presented; the limitations of the current study and the directions for further research are also discussed.

2.0 REVIEW OF RELEVANT RESEARCH

2.1 Introduction

To position this study within existing research, the review chapter is organised around three main themes. The *first theme* focuses on the development of students' understanding of the nature of the activity of learning and their capacity to be in control of own learning. These notions are approached from the perspectives of learners and the teachers who are facilitating such learning. This theme positions the thesis by conceptualising the development of what Vygotsky termed 'higher order thinking' (Vygotsky, 1978) with students. The *second theme* concerns the role of digital tools to assist students' learning. The context of computer supported collaborative learning (CSCL) is very close to the empirical setting of group learning with digital tools used in the studies, therefore, particular attention has been paid to a review of the research examining the role of digital tools in students' learning in CSCL settings. Studies that have examined the role of peer collaboration in learning with digital tools are also reviewed in this section. This section situates the thesis by addressing how digital tools may support learning in formal situations and by conceptualising the types of student-student interactions that happen when learners engage with computers. The *third theme* addresses the role of the teacher in facilitating students' learning more generally. It situates the thesis by conceptualising the types of teacher – student interactions that may enhance students' capacity to learn. The chapter discusses each of these three themes in turn, starting with the first theme focusing on the notion of learning to learn as setting the lens for the review of the studies related to themes two (the role of digital tools and peer collaboration) to assist students' learning and three (the role of the teacher in facilitating students' learning) in order to finally position this thesis in relation to existing research.

2.2 Students' capacity in learning to learn

Research indicates that teaching and assessment focusing on the 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 the literature learning to learn is also defined as metacognition: knowledge and awareness about one's own cognition in general (Pintrich, 2002; Schraw, et al., 2006), which, together with motivational beliefs and cognitive strategies, constitute self-regulated learning (Winne, 1997; Winne & Perry, 2000). Research has shown that good self-regulators do much better academically than poor self-regulators (Zimmerman & Pons, 1986) and students' belief in their capacity to manage

their learning provides the power and enhances performance accomplishments (Bandura, 2001; Bandura, et al., 1996; Zimmerman & Bandura, 1994).

Acknowledging its importance in the development of learners, research has explored ways to improve metacognition and enhance students' capacity to learn through classroom instruction (Baird & White, 1996; Beeth, 1998; Gunstone & Mitchell, 1998; Mason, 1994). For example, in foreign language education, it has been suggested that teachers should: i) develop a profile of the metacognitive knowledge of their students by gaining an understanding of their learners' beliefs and knowledge about language learning; and ii) help learners develop a reflective and self-directed approach to language learning (Wenden, 1998).

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 et al., 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 (2002) earlier work 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. Latterly he has pointed to how learners' focus on how they activate, alter, and, sustain specific learning strategies in social as well as solitary contexts is especially relevant for their development as learners (Zimmerman, 2008).

In line with Zimmerman's attention to the social origins of students' self-regulation, guidance has also been offered to teachers, to encourage them to develop self-regulated learners. Pintrich (2002), for example, argues that explicitly teaching metacognitive knowledge across different subject areas and contexts to facilitate its development with learners is needed and conceptualises self-regulated learning as *"an active constructive process whereby learners set goals for their learning, monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features of the environment"* (Pintrich & Zusho, 2002, p.64). The most-widespread of these approaches can be found in studies of Assessment for Learning (AfL), which particularly emphasise the self-evaluation aspects of metacognitive awareness on the part of learners. Five general strategies for promoting AfL in classrooms have been identified (Wiliam, 2006), all of which exhibit the potential to enhance students' self-regulated learning. They are: (a) clarifying and understanding learning

intentions and sharing criteria for success, (b) promoting and supporting effective classroom discussions and developing activities and tasks that elicit evidence of learning, (c) providing feedback that moves learners forward, (d) activating students as pedagogical resources for one another and (e) activating students as the owners of their learning.

It has been argued that using AfL is effective not only for raising students' attainment on tests (Black, et al., 2003; Black & Wiliam, 1998; Clymer & Wiliam, 2007), but also for supporting the development of learning how to learn (James et al., 2007). The argument is that it enhances students' capacity to take control over own learning (Black, et al., 2006; James & McCormick, 2009). However, the metacognitive aspects of AfL have not always been picked up by teachers. 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 & McCormick, 2009; James et al., 2007). This outcome might be explained by the fact that many teachers lack sufficient knowledge about metacognition and they are in need of tools for implementing the 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, & Blöte, 2005; Veenman, Van Hout-Wolters, & Afflerbach, 2006).

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). Claxton (2007) suggests that in particular an epistemic culture will need to address the following areas: (a) the language which is aimed at supporting attention towards the process of learning and the ways in which people's learning dispositions (abilities one may be disposed to make use of) are growing and changing; (b) activities that focus on stretching each aspect of learning capacity and not on the acquisition of knowledge or completion of tasks; (c) using of so called 'split screen thinking' by teachers: maintaining a dual focus on the content of the lesson and the learning dispositions that are currently being expanded; (d) introduction of topics that genuinely engage and challenge students; (e) making the process of expanding students' learning capacity absolutely transparent; (f) active involvement of students in thinking about how to make the epistemic culture more effective; (g) encouraging 'transfer thinking' in which students will look for out-of-school applications and modifications of learning dispositions

developed in school; (h) developing a sense of progression, so that dispositions continue to get stronger, broader and richer; and (i) modelling of the learning dispositions as an important ingredient in an epistemic culture. In sum, Claxton argues that these epistemic cultures 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. Her analyses are based in the Vygotskian notion of social situation of development, where the learner can be seen as propelling themselves forward recognising and responding to the demands in tasks and with increasing competence, repositioning themselves within a knowledge domain. She also makes the connection between the metacognitive aspects of Zimmerman's work on self-regulation and Vygotsky's concern with education as the promotion of higher order thinking in learners, that is, the capacity to work with and recognise the connections between the concepts that make up a body of 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 in Vygotskian notions of learning has been suggested (Figure 2A).

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 2A. A model of task sequencing to promote learning
From Edwards, A. (2015). Designing tasks, which engage learners with knowledge. In I. Thompson (Ed.), *Designing Tasks in Secondary Education: Enhancing Subject Understanding and Student Engagement* (pp. 13-27): 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.

Summing up, previous research has argued that students' understanding of the nature of learning and their capacity to be in control of own learning comprise the development of metacognition, self-regulated learning which enhance students' capacity to learn. Various teaching and learning strategies have been suggested to facilitate the development of metacognitive thinking/knowledge and self-regulated learning. However, with very few exceptions (e.g. Edwards, 2015; James et al., 2007; James & McCormick, 2009) little attention has been paid to how learning activities students engage in classes and teachers' facilitating of these activities can enhance students' understanding of how knowledge is created in different subject areas, the nature of learning, how to approach learning and students' capacity to be in control of own learning.

2.3 The role of digital tools in student learning

Here I explore some of the ways in which psychological accounts of learning in the context of school have been reflected in research on computer-based learning over time. By taking such an approach I attempt to explain how computers have been adapted to serve specific purposes in educating students as learners.

The psychological tradition, which has had the longest influence on the development of computers for learning, is associationist theory which reached its most influential expression in the operant conditioning research of Skinner and colleagues in the 1950s. Light (1997) summarised the hallmarks of such approach as: (a) focusing upon achieving some desired patterns of behaviour; (b) generating desired behaviour patterns through small incremental steps; and (c) reinforcement of correct responses through the delivery of extrinsic rewards. Light went on to explain that Skinner suggested that a so-called teaching machine could be designed to carry out these same functions in respect of children's learning. Although studies comparing specific teaching machines with conventional teaching showed substantial advantages for machine instruction (Light, 1997), they were subject to many methodological limitations including an inability to predict, from intraprogram response data if any long-term learning occurred or knowledge and skills could be transferred to other contexts (Holland, 1965).

Later uses of computers to support learning addressed some of the shortcomings of the associationist approach and fell under the heading of *computer-assisted instruction* (CAI), which was based on the idea of assisting the teacher to achieve an instructional goal. CAI software offered drill and practice and facilitated the provision of feedback in respect of incorrect responses (Koschman, 1996). Software in the CAI tradition was widely used in schools in the late 1970s and early 1980s (Crook, 1996) and reviews and meta – analyses conducted in the 1980s suggested that CIA were moderately effective (Light, 1997).

Development of CAI software led to *intelligent tutoring systems* (ITS) that could take into account the pattern of errors made by a learner over time and create mental models of learners. ITS analysed student learning in terms of these mental models and responded to student actions based on occurrences of typical errors when comparing student activity with ideal models (Gray et al., 1991; Ritter, et al., 2007). The intention of extending students' control over their learning led to the design of Logo, a modular programming language, which provided simulation environments (micro worlds) for students to explore and to discover the power of reasoning (Kynigos, et al., 2014; Stahl, et al., 2006). The idea was that by using Logo to build programmes that did things, children would learn logical (computational) thinking (Wegerif, 2015). Programming in Logo was seen as linking intuitive and abstract levels of understanding and thereby fostering problem-solving skills and generalisable thinking (Harel & Papert, 1991). This assumption, however, was not supported by research (Pea & Kurland, 1984); only when Logo learning was sustained over a substantial period (50 – 60 hours) with active teacher input there was evidence of generalisable gains in students' problem-solving abilities (De Corte, Verschaffel, & Schrooten, 1992).

A specific type of ITS are *automated essay scoring systems* (AES) that assign scores to essays written for educational purposes. The score is dynamically computed by machine learning and statistical techniques, often based on learning algorithms driven by a set of training examples, in the range of 10 to several hundred, depending on the desired precision of the feedback (Dikli, 2006; Dikli & Bleyle, 2014; Hastie, et al., 2005). On the one hand, proponents argue for their success in terms of how well AES compare with the accuracy and reliability of human evaluation (Sireci & Rizavi, 2000). On the other hand critics have pointed out that AES systems do not promote students' creative writing and can often be fooled by intentionally gibberish essays, giving them high scores (Kukich, 2000; Winerip, 2012).

However, from the mid-1990s onwards the social dimensions of computer use have become a major research focus. Computer-supported collaborated learning (CSCL) researchers have explored how computers bring students together to learn collaboratively in small groups and in

learning communities (Ludvigsen & Mørch, 2010; Noroozi et al., 2012; Stahl, 2013). A large number of studies have demonstrated that, in order to improve students' learning outcomes in CSCL, attention should be paid to the nature of the learning processes. Concepts employed in these discussions include relevance, width and depth of discussion, justification, reasoning and knowledge creation (Noroozi et al., 2011; Stahl, 2006) and the external support in the form of: i) feedback from a computer; ii) use of multiple representations and simulations and iii) pedagogical agents in the form of categories, prompts and scripts that scaffold learning in CSCL environments (Azevedo & Hadwin, 2005; Ludvigsen, 2012; Mørch, Dolonen, & Nævdal, 2006; Furberg, 2009; Noroozi et al., 2011).

The affordances and possibilities, in particular of the visual mode in students' learning, have developed as technology for representing has developed (Knain, 2015). Several studies have reported a positive effect of using digital interactive animations, models and simulations on students' conceptual development (Rutten, van Joolingen, & van der Veen, 2012; Smetana & Bell, 2012; Williams, et al., 2012). In particular, it has been argued that multiple external representations can provide unique benefits for learning complex new ideas (Ainsworth, 2006) and virtual labs can add valuable experimentation and visualisation components (Baltzis & Koukias, 2009; Kluge & Dolonen, 2015; Kozma, 2003).

In line with digital representations in many computer environments, categories and prompts that point out what is central in the activities learners engage in (e.g. knowledge building categories) have become a foundational aspect of CSCL environments (Ludvigsen, 2012; Mørch, Dolonen, & Nævdal, 2006). Research has shown that these categories enhance the capacity of students for social and cognitive regulation and learning disciplinary knowledge and can make students aware of how a systemic orientation to knowledge can appear (De Jong et al., 2010; Furberg & Ludvigsen, 2008; Krange & Ludvigsen, 2008; Linn & Eylon, 2011; Mercer, Wegerif, et al., 2007; Quintana et al., 2004). When using knowledge building categories and conceptual-oriented prompts, the relation between a more general concept and simple facts therefore becomes easier to identify and students benefit by taking a critical stand towards new information (Furberg, 2009; Ludvigsen, 2012; Mørch et al., 2006).

In addition to various types of categories and prompts, collaboration, epistemic and argumentative scripts in digital environments are seen to scaffold students' learning. Collaboration scripts, for example, provide guidelines for how group members should collaborate to accomplish learning tasks (Weinberger, et al., 2007), epistemic scripts structure and sequence discourse activities with respect to content and task strategies (Weinberger & Fischer, 2006; Weinberger, et al., 2005), which may help learners to construct arguments and

contribute to solving problems (Noroozi et al., 2011) and argumentative scripts can be used to structure and formulate the construction of broad, deep and justified arguments in CSCL environments (Stegmann, et al., 2007; Weinberger et al., 2007). In line with the focus on the design and affordances of digital tools, the emphasis on the social dimensions, draws attention to the role of peer collaboration in learning with computers.

2.3.1 The role of peer collaboration in learning with digital tools

The 1990s saw considerable interest in the formation of groups, examples of that concern include studies of 'symmetrical' pairs (pairs with the same initial knowledge of the task area) which showed that they learned more effectively than 'asymmetrical pairs (Blaye, et al., 1991; Littleton, et al., 1992). This finding points to the importance of the quality of group interactions and the construction of a shared understanding through language (Azmitia & Montgomery, 1993; Kruger, 1993; Light, et al., 1994).

Mercer's work on pupil reasoning in group tasks, marked a shift away from group composition, to attention to the type of talk that occurs in joint activities and its relationship with reasoning. He identified categories of talk that students engage in and analysed student-student discussion in groups and its relationship with reasoning in group tasks (Mercer, 1995). The categories were: i) disputational talk - characterised by disagreement and individualised decision making and expressed by short exchanges consisting of assertions and challenges or counter assertions; ii) cumulative talk – in which speakers build positively but uncritically on what the other has said and is characterised by repetitions, confirmations and elaborations and iii) exploratory talk – in which partners engage critically but constructively with each other's ideas and statements and suggestions are offered to joint considerations. In exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk. Mercer and his colleagues (Wegerif & Mercer, 1996; Mercer et al., 2007) claimed that the typology offers a frame for understanding how talk is used by children to 'think together' in class and argued that encouraging and enabling students to use the exploratory talk promotes asking certain kind of questions, clear describing of events, accounting for outcomes and consolidating what has been learnt in words – everything that helps learners to understand and gain access to educated discourse.

These categories have added an extra discussion (D) dimension to the original Initiation – Response – Feedback (IRF) (Sinclair & Coulthard, 1975) coding applied to some type of exchanges occurring between students and computers (Crook, 1996; Fisher, 1993) transforming the IRF scheme to Initiation – Discussion – Response – Follow up (IDRF) scheme (Wegerif & Mercer, 1996) where discussion occupies the transitionary position between the

initiation and the response. Emphasising the importance of the discussion in student learning, Wegerif (1996) argues that to educate children to learn for themselves, first they should be taught to think with others and new technology can facilitate this process.

Following up on how discussion may enhance reasoning, a series of experimental and observational studies have shown that conceptual understanding in science is enhanced by learners' discussion of ideas during group work. Requiring that partners should try to achieve a consensus in their discussion has been found as particularly associated with solving complex problems (Howe & Tolmie, 2003) and the most productive interactions seem to involve students proposing ideas and explaining their reasoning to each other (Howe et al., 2007). In addition, the expression of contrasting opinion during group work was found as the single most important factor of learning gain (Howe, et al., 1992). The reason seems that dialogue primes children to make good use of subsequent experiences (Howe, et al., 2005). Similarly, it has been indicated that adults can guide children in using talk effectively as a cultural psychological tool, and there is evidence that this can make a significant contribution to children's self-regulated learning and their intellectual development, including the development of their reasoning (Mercer, 2008). A similar emphasis on using talk as a powerful tool was put forward by Wegerif (2016), who suggested a convergence between the idea of teaching for thinking and teaching for literacy in the Internet Age. His argument is that teaching for thinking and literacy education need to be understood within a larger context of teaching for involvement in dialogue through identifying relationships with others (Wegerif, 2016).

In general, research in 2000s has argued that peer collaboration when students engage with computers is beneficial to the process of knowledge construction (Linn & Eylon, 2011; Scardamalia & Bereiter, 2006; Schellens & Valcke, 2006; Schellens, et al., 2007). While some researchers suggest that student collaboration assists in developing inquiry learning skills (Van Joolingen, et al., 2007); others point to the role of collaboration in the development of students' ability to construct arguments (Linn & Eylon, 2011; Littleton & Howe, 2010; Noroozi et al., 2013; Scardamalia, & Bereiter, 2006) and several studies indicate that peer collaboration can improve students' conceptual understanding (Bell et al., 2007; Howe et al., 2007; Rummel & Spada, 2005).

In the last few years non-human feedback has also developed as a research area through the automatic analysis of educational data in the emerging research area referred as Learning Analytics (LA) (Chatti, et al., 2012; Ferguson & Shum, 2012; Greller & Drachsler, 2012; Siemens & d Baker, 2012). The possible objectives of LA include monitoring, analysis, prediction, intervention, tutoring, assessment, feedback, adaptation, personalisation,

recommendation and reflection. Among these objectives feedback, adaptation, personalisation, recommendation and reflection assist learners as they progress in the learning process by adaptively organising and making available resources, providing feedback and encouraging reflections that might be particularly useful in enhancing students' learning. The emergence of LA indicates that future research might be addressing the issue of developing effective LA tools that can be integrated into learning environments to minimise the time between the analysis and action to support learning. This development might lead to open, networked, personalised and lifelong learning environments to enhance students' capacity to learn (Arnold, 2010; Baker & Inventado, 2014; Chatti et al., 2012).

To conclude, research shows the duality of the role of the computer by providing instruction – either in the form of facts in CAI or in the form of feedback from ITS and AES - and supporting learners' collaboration by providing visualisations, media of communication, knowledge building scaffolding, prompts and scripts to enhance the capacity of students for social and cognitive regulation and learning disciplinary knowledge. In addition, evidence supports the view that focused, reasoned, sustained dialogue amongst peers engaging in learning with computers not only helps learners in solving problems together, but can promote learning and conceptual understanding of the individuals involved. In sum, the research has mainly explored what students do when engaging in learning with computers and how digital tools are used in group learning in formal settings to assist the development of conceptual understanding and students' reasoning. These previously investigated areas point to the existing gaps and indicate the need: i) to conceptualise the complexity involved in learning with computers by taking into account other support resources simultaneously present in formal situations (e.g. task, collaborating peers and teachers' interventions) and explore the interplay of digital tools with other resources that assist students' learning and ii) to examine how digital tools, teachers and other resources may contribute to the developing of students' understanding of the nature of learning and enhance the capacity to be in control of own learning. The emerging area of LA confirms the need of these future developments.

2.4 The role of the teacher in student learning with digital tools

Students' engagement in focused, reasoned and sustained dialogues in learning with computers has implications for educational practice. In addition, using of strategies (Schraw et al., 2006; Zimmerman, 2002; 2008; Wiliam, 2006) and specifically designed activities to enhance students' capacity to learn (Edwards, 2015; James et al., 2007; James & McCormick,

2009) places a particular emphasis on the role of the teacher as a designer and facilitator of such learning process.

The significance of teachers' 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 & Shayer, 1993). The implementation of that programme relied heavily on explicit linguistic bridging by the teacher, in order to help students perceive the relevance of what they have learned across different contexts (Wegerif & Mercer, 1996). 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 & Mercer, 1996). The authors offer the cumulative educational implication that students should be encouraged to practice exploratory talk in the classrooms. However, a significant problem to such approach they see in the asymmetrical nature of teacher–student relationship, whereas in modelling and coaching exploratory talk teachers have to simulate a situation of symmetry.

Like Wegerif and Mercer, Derry (2008) points out that the grasping of a concept requires committing to the inferences implicit in their use in a social practice of giving and asking for reasons because awareness of any concept is dependent on awareness of other concepts that constitute its meaning in the first place. Her argument continues that thought connects with reality because to be a thinker is to inhabit the so-called space of reasons, and powers of thought develop by being initiated into a language. The idea that the awareness of humans operates within the space of reasons, poses the task for educators not only to provide learners with rich data from which they can construct meanings but also to assist the learners' move from the space of reason within which they start to the knowledge domain they are studying. Effective teaching, therefore, involves providing the opportunity for learners to operate with a subject-specific concept in the space of reasons within which it falls and by which its meaning is constituted (Derry, 2008).

Creating such space of reasons involves asking questions by teachers and encouraging learners' asking for and giving reasons. However, the frequent use of questions by teachers during classroom interactions have been criticised by some educational researchers (Dillon, 2004; Wood, 1992) particularly if these interactions follow the IRF scheme. On the other hand,

others have argued that it is not valid to evaluate all teachers' questions as following IRF approach (Alexander, 2001; Gibbons, 2001; Mercer, 1995; Rojas-Drummond, 2000). In line with Derry's (2008) argument, Alexander (2001), for instance, suggests that teachers' questions can also: i) encourage children to make explicit their thoughts, reasons and knowledge and share them with class; ii) model useful ways of using language that children can appropriate for use themselves, in peer discussions and other settings and iii) provide opportunities for children to make longer contributions in which they express their current state of understanding, or to articulate difficulties. Based on these principles, a concept of 'dialogic talk' has been developed (Alexander, 2006), where the dialogic classrooms have been described as: collective (teachers and students address learning together), reciprocal (teachers and students listen to each other to share ideas and consider viewpoints), supportive (students articulate their ideas freely), cumulative (teachers and students build on their own and each others' ideas to chain them into a coherent lines of thinking and enquiry) and purposeful (teachers plan and facilitate 'dialogic thinking' with educational goals in mind. Alexander (2006) also argues that research into formative assessment emphasising the power of feedback in enhancing the teaching and learning process (Black & Wiliam, 1998; Hattie & Timperley, 2007), supports the concept of dialogic teaching where feedback is found to be particularly useful when it is used by teachers to adapt their teaching to the learning needs of students and offer guidance on what can be done to bring about improvements. Mercer (1995) has also shown that the way the teacher asks questions about the activity is useful for revealing learners' perspective on the task and stimulating reasoning. Another study (Wegerif, Mercer, & Dawes, 1999) have demonstrated that the learners' use of exploratory talk can be increased through teaching and asking questions to encourage reasoning.

In addition, a range of alternatives to teacher questions has been also suggested, including using provocative, open-ended statements, encouraging students to ask their own questions and providing thinking time for the students before they respond (Edwards & Westgate, 1994). Others (Nystrand, et al., 1997, p. 72) advocate that teachers need to pay more attention to how they evaluate student responses, so that there is more "high-level evaluation" whereby teachers incorporate student answers into subsequent questions. When such high level evaluation occurs, the teacher ratifies the importance of students' responses and allows them to inform the discussion in an unfolding exchange, which connects teacher questions and student responses with a conversation-like quality, encouraging more student-initiated ideas and responses, and, consequently, promoting higher-order thinking (Hardman, 2008).

In sum, the research has contributed to our understanding of the role of the teacher in creating space of reasons by asking questions to enhance students' reasoning and higher-order thinking (Adey & Shayer, 1993; Alexander, 2001, 2006; Derry, 2008; Hardman, 2008; Wegerif & Mercer, 1996). 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 a symmetrical teacher–student relationship in modelling and coaching exploratory talk. A later study of Hakkarainen and colleagues (2002), in turn, investigated the types of teachers' interventions in students' group learning with computers that were most effective with regard to their conceptual understanding (Hakkarainen, et al., 2002). The authors' 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. Another study (Strømme & Furberg, 2015) addressed a different dimension of the teacher's role in CSCL and showed that in technology rich 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 (Strømme & Furberg, 2015).

Overall, research on teachers' facilitating of students' learning in technology rich classrooms is still relatively scarce and the majority of the studies have examined the types of teacher-students' 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 actually do when facilitating students' learning with computers. In addition, research is needed to examine how teachers' facilitating of students' learning with digital tools can enhance learners' understanding of the nature of learning and their capacity to be in control of own learning.

3.0 THEORETICAL RESOURCES

3.1 Cultural historical theory on learning and development

In this chapter, I draw on the work of the cultural historical scholars (Vygotsky, 1978; Leontiev, 1978; Galperin, 2002; Davydov, 2008) as a theoretical framing of the analyses undertaken in the present study. In seeking to explain how digital tools, students as learners and teachers as mediators interact in classroom settings, I have selected analytical resources, which are rooted in non-dualist accounts of human learning. Such an approach argues that mediated actions and societal conditions are intertwined; consequently, we recognise that all actions are mediated. This set of assumptions has considerable implications for how classrooms and the activities in them are examined and in terms of the present study provides the conceptual framing and an overarching aim of this thesis, namely: i) to make explicit how adolescent students learn when using digital tools in Science and writing classes in English and how teachers facilitate students' learning in these conditions, and ii) to use and evaluate the pedagogical categories developed by Galperin as analytic resources to reveal students' actions in the classrooms with digital tools.

3.1.1 The contribution of Lev Vygotsky to cultural-historical theory

Vygotsky's analyses (1980, 1986) were the first to suggest a social, historical approach to understanding the development of human mind (Leontiev, 2005). His non-dualist approach to mind and society argued that higher mental functioning (an ability to think in abstract terms) is rooted in social life (Wertsch, 1991). Consequently, in order to understand cognition, one should turn to the real life, which is stimulated by the development of the relationships among humans involved in practical activities (Vygotsky, 1980). Vygotsky considered that participation in social practical activity, using tools, was the main factor influencing the development of human mind.

Vygotsky's focus was on the role of tools, both material and conceptual, as the meditational means connecting a person and society. His argument was that tool mediation during practical activity determines the changes in human mind and these tools acquire special meanings: tools-signs. The tools used in the practical activity are directed outside and lead to changes in the surrounding environment; whereas the tools-signs are directed inside and lead to the changes in the human mind (Vygotsky, 1986).

In Vygotskian thought, tools-signs are mediating psychological processes and they cause changes in the structure of these processes and the development of new relationships between them.

"The sign as a tool reorganises the whole structure of psychological functions. It forms a structural centre, which determines the composition of the functions and the relative importance of each separate process. The inclusion in any process of a sign remodels the whole structure of psychological operations" (Vygotsky, 1997, p. 421)

Through his conceptual work on tool-sign Vygotsky offered insights with considerable pedagogical implications. His argument was that such a systemic approach to the analysis of human psyche showed a way of considering human cognition as a dynamic, dialectically developing system rather than a sum of unchangeable psychological processes.

"Higher mental functions are not built up as a second story over elementary processes, but are new psychological systems that include merging of elementary functions that will be included in the new system, and themselves begin to act according to new laws; each higher mental function is, thus, a unit of a higher order determined basically by a unique combination of a series of more elementary functions in the new whole." (Vygotsky, 1997, p. 43)

The movement from society to mind, which has implications for teaching, is encapsulated in his central thesis that mediating tools first appear as external and material, employed in the collective activity and gradually become internal, psychological tools used for managing one's own behaviour and psyche.

"… every function in the cultural development of the child appears on the stage twice, in two planes, first the social, the psychological, first between people as an intermental category, then within the child as a intramental category… Genetically, social relations, real relations of people, stand behind all the higher mental functions and their relations."(Vygotsky, 1997, p.106)

The dialectical underpinning of this explanation of mediation is made explicit in his argument that tools themselves undergo changes in the course of the practical activity: initially they are present in an external, material form, later on they get internalised and transformed to the inner, ideal form. A defining property of higher mental functioning is the fact that it is mediated by tools and sign systems such as natural language (Wertsch, 1991). This argument suggests that language, as the main system of signs mediating human psychological activity, also repeats the pathway of internalisation: from being used externally for communication with others and then individually in the form of inner speech (Vygotsky, 1986). The argument continues that speech has evolved as a particular form of human social relationships, which originated in practical work. Vygotsky concludes that human mind does not develop in the practical work itself, but in the new social relationships that arise in the course of the practical activity (speech) and the products of human culture (language). Hence, the cultural-historical origin of human mind (Leontiev & Luria, 1999).

Although Vygotsky's theory embraced human mind as a whole, Vygotsky was primarily interested in the development of language in its relation to thought (Kozulin, 1986). Language plays a double role in Vygotsky's psychological system: on the one hand it is a psychological tool that helps to form other mental functions; on the other hand it is one of these functions that also undergoes a cultural development. In Vygotskian understanding, the process of the development of the mediated forms of cognition was the process of the development of meanings; where meanings were encapsulated in words. Hence, it was important to trace the process of a word acquiring its meaning. Vygotsky, however, did not make any distinction between meanings and concepts, potentially because both could be expressed with the same Russian word *'ponyatie'*. English translations indicate that Vygotsky studied the development of concepts as a reflection of the process of the formation of higher mental functions. It was claimed that the level of the development of concepts with humans had a direct link with the human ability to reflect the surrounding environment and identify possible practical interactions with it.

In analysing conceptual development, Vygotsky introduced the categories of spontaneous and scientific concepts. The categorisation was based on the way learners made sense: a child makes sense of spontaneous concepts during everyday 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 the teacher highlights systemic learning of concepts, for example, definitions, by 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.

To summarise, Vygotsky suggested that: i) the source of the development of human mind lies on the external (social) plane, and the higher mental functions form during practical social activities with an adult or a more capable peer; ii) tools (material and linguistic) that mediate these activities are initially directed outwards, connecting the learner with the surrounding world and, by acquiring a particular meaning, transform into signs directed inwards, to the mental plane of the learner, iii) mediated meanings are transferred to the internal (mental) plane of the learner and can cause changes in the existing psychological functions and create new relationships between these functions.

3.1.2 The contribution of Aleksei Leontiev to cultural-historical theory

While Vygotsky was very clear about the primary role of a practical activity in the development of human mind, he focused on the investigation of the role of tools, while the role of the activity that employed these tools appeared to be downplayed. However, Leontiev and Luria (1999) argued that the presence of tools, although important, did not fully explain the relationships that emerged in the course of human activity. In his foreword to *Lev Vygotsky: Critical Assessments*, Leontiev wrote:

"Even if Vygotsky did not arrive in his own works at a consistent materialist understanding of mental processes as the product of the development of complex forms of human activity (this position was developed later in the Soviet psychology), the significance of the propositions outlined above for how to move beyond ideas about invariant "mental functions" are extremely important" (Leontiev, 1999, p.11).

Having acknowledged the significance of the foundations laid by Vygotsky, Leontiev suggested that neither concepts and meanings, nor tools and signs on their own, but real life, determined the development of human mind as a whole and its separate psychological functions (Leontiev, 1978). Consequently, he identified the activity connecting an individual with the surrounding environment as a subject of psychology (Leontiev, 1978). Attention was directed to examining the structure of the activity with the purpose and the motive as crucially important. The notions of *action, activity* and *operations* were introduced, where an *action* was explained as an active attitude of the subject to the reality characterised by the concurrence of the motive and the purpose: the action of a subject was caused by the purpose and was directed to achieve it (Leontiev, 1978). An *activity* was defined as initiated by a motive realised in the course of this activity and *operations*, according to Leontiev, were the means of realisation of the activity adequate not to the purpose or the motive, but the conditions in which the activity was carried out. In addition, Leontiev introduced the notion of the *personal meaning* of an action or activity which he understood as relationships between the motive and the purpose (Leontiev, 1978). Leontiev paid particular attention to the division of labour among several participants as a motor driving the action forward. He emphasised that collaborative activity caused the development of new types of psychological functions that reflected the relationships between an individual, other participants and the surrounding world. In these conditions tools acquired a particular meaning as accumulating and encapsulating the public experience expressed in the language.

In brief, Leontiev suggested that learning happens in the process of transformation of the external practical social activity of humans into the internal, ideal activity. However, even on the ideal internal plane the activity retains its structure and is directed to solving tasks

emerging from the person's interaction with the surrounding environment. In this way, human mind is not seen as something opposite to the external activity, but as originated in and transformed from the external activity. Such an approach allowed Leontiev to argue that human cognition and external activity are linked together as one is a product of another. On the one hand, this means that external and internal activities have a similar structure consisting of actions, activities and operations; while the similarity in the structure allows mutual transformations between the external practical activity and the human mind.

With these arguments Leontiev formulated the principles that determined the further development of cultural-historical psychology: i) an activity approach to the subject of psychology; ii) social nature of human psychological activity and iii) unity of the external practical and the internal human psychological activity in learning and development.

3.1.3 The contribution of Piotr Galperin to cultural-historical theory

The principles of the activity approach to studying psychology, the social nature of human psychological activity and the unity of the external practical and the internal psychological activities posed a further question about *how* external activities transform into internal activities. An answer to this question was given by Galperin, who connected the advances made by Leontiev with the ideas of Vygotsky.

Galperin's contribution centred on the question: *how* the mental, psychological (Vygotsky's legacy) emerges out of the "material", non-psychological (Leontiev's legacy). His approach was based in three premises: (a) the leading role of teaching and learning in development; (b) conceptual development involves material or materialised actions; and (c) a recognition of the importance of cultural tools and social interaction in human development.

Galperin suggested that a learning activity comprised orienting, executive and control features. These different parts of learning activity were developed in detail in his work, to create a complex system aiming at examining processes of teaching and learning in formal educational settings. Figure 3A presents Galperin's conceptualisation of the Orienting and the Executive parts of a learning activity. For the clarity of understanding of the diagram: the Orienting part with detailed planning of the activity precedes the Executive part. The Control part is not presented in the diagram.

In the ***orienting*** part Galperin combined two subsystems (see Figure 3A): A) motivational and B) operational (which were separate in Leontiev's work). The operational subsystem consisted of four components: 1) building an image of the present situation; 2) revealing the potential of the individual components of the present situation for the learners; 3) planning the learning activity; and 4) further facilitation of the activity in the course of its

execution. The ***executive*** part, in turn, comprised three subsystems (see Figure 3A): C) the conditions for constructing of the activity; D) possibilities for the acquisition of the desired properties of the activity and F) the transfer of the original external activity to the ideal plane of the learner, transforming the activity into a new psychological function. The ***control*** part (not shown on Figure 3A. for the space reasons) Galperin envisioned as the developing of learners' attention and their ability to analyse and reflect on their own learning and suggesting ways of further improvement. In summary, Galperin's analytic framing conceptualised in great detail learning activity which aimed at facilitating the development of new psychological functions from the external activities with material or materialised tools.

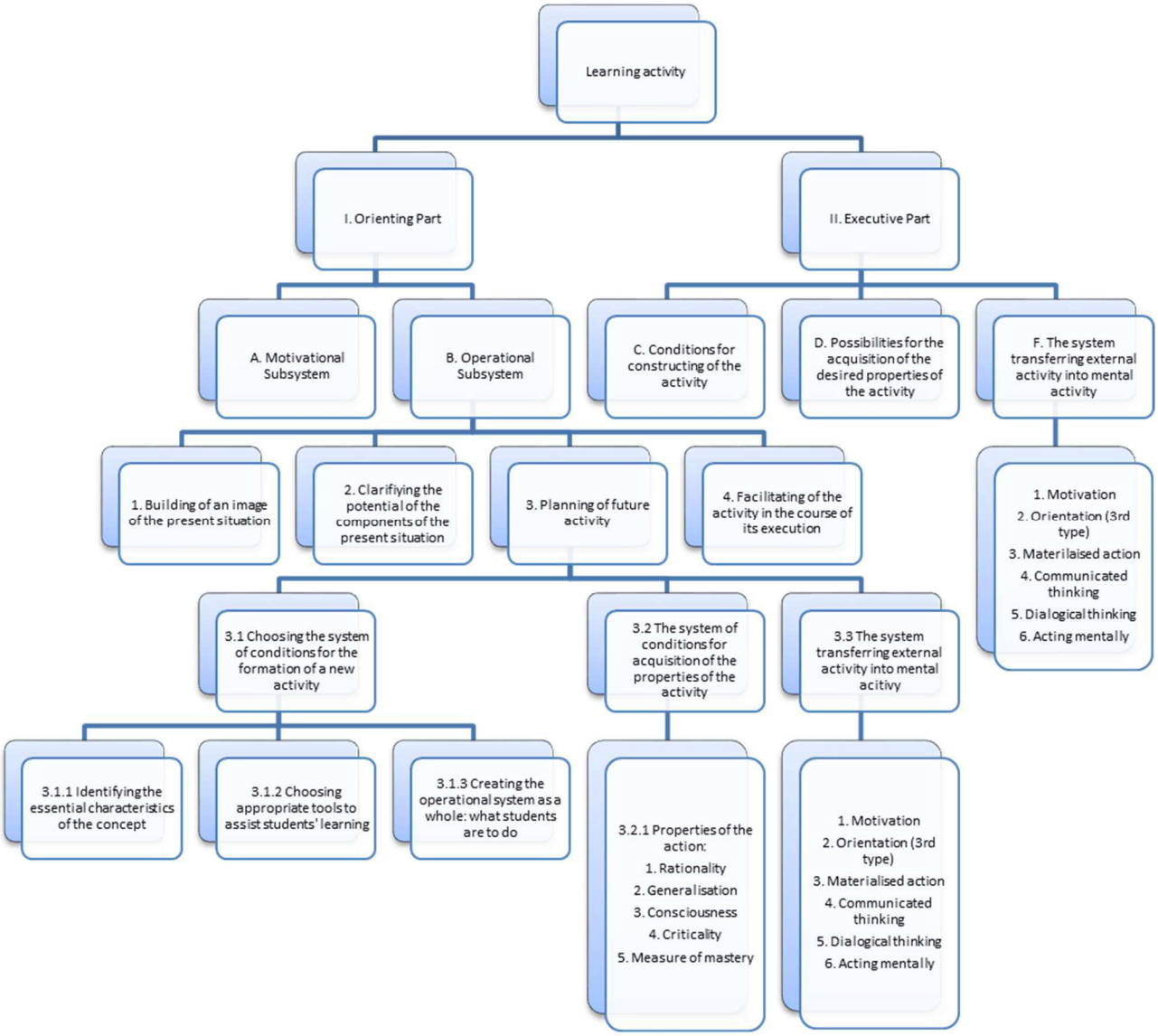

Figure 3A. P. Galperin's conceptualisation of a learning activity (Based on *Lectures in Psychology*, Moscow, Higher School, 2002)

In line with Vygotsky and Leontiev, Galperin's learning and teaching methodology, which arose from the detailed breakdown of orienting, executive and control function, aimed at identifying the essential characteristics of a concept. However, Galperin went further by showing the necessity for creating activities specifically aimed to reveal the essential characteristics of concepts for learners. Following Vygotsky and Leontiev, he believed that new types of psychological activity were initially formed on the external plane in the material form in the course of social activities and were then transferred to the internal, psychological form. Galperin's contribution was in describing *how* this transformation happens by offering the system of independent characteristics just outlined.

The orienting, executive and control function of learning and teaching activity were the foundation of the dialectically developing phases or forms (Galperin, 1969) of the transformation of the external activity with material or materialised objects into the internal psychological activity. The dialectics in the development of the forms of activity was understood by Galperin in line with Hegel and Marx who postulated that individual features acquire meaning and value only when taken together, as an inseparable unity, connected with a dialectical link (Hegel, 1995; Marx, 1973/1858). This dialectical link implies that each previous form of activity gives rise and is gradually transformed to the next form. In the course of this transformation external objects or tools were substituted by their images and concepts and the practical operations were replaced with mental theoretical operations.

Having conducted extensive research in schools, Galperin (2002) concluded that the approach suggested by this analysis allowed the development of conceptual understanding with much younger learners (5-6 years old) and with a significantly higher proportion of high achieving students than was suggested by Vygotsky. Moreover, the learning process happened faster, was easier and excluded memorising. The learners formed their understanding of all the essential characteristics of the concepts simultaneously and were able to use these concepts in various contexts. Galperin also saw the benefits of such approach in educators' effort at exteriorising and unravelling the learning process for students, which he believed was 'left behind the brackets' (Arievitch & Stetsenko, 2000) in the approaches suggested by Vygotsky and Leontiev. Indeed, it has been argued out that Galperin's perspective, through revealing the content of the processes that link leaning and development, adds an important insight into what constitutes developmental change (Arievitch & Stetsenko, 2000).

In an attempt to conceptualise what constitutes developmental change, Galperin operationalised the ideas of Vygotsky and Leontiev to examine *how* actions are transformed from material to mental forms in the course of specifically designed learning activities

employing cultural tools. In doing this, he suggested the innovative analysis of instructional practices based on different types of cultural tools and outlined the developmental potential of different kinds of instruction (Stetsenko & Arievitch, 2002).

In summary, Galperin's contribution was in: i) specifying the unique character of human mental development emerging in social activities and cultural, tool-mediated practices; ii) conceptualising the nature and functions of human psychological processes as specific forms of activity by outlining its structure and identifying the subject of psychology in studying of object-oriented activity in its ontogenesis and iii) identifying the role and the function of tools as imbued with relevant social experience and mediating learning activity.

In doing so, Galperin made an attempt to consolidate the contributions of Vygotsky and Leontiev in that he operationalised them and showed how they could be implemented in educational practice to promote learning and development. His colleagues and students took the ideas of Galperin forward, particularly Vasilij Davydov who outlined the principles of the *developmental learning* and implemented them in educational practice.

3.1.4 The operationalised principles of developmental learning

The contributions of Vygotsky, Leontiev and Galperin were operationalised in the concept of *developmental learning* introduced by Davydov (2008, 2004) and Elkonin (1989) and implemented in educational practice in the former Soviet Union in the 1970s and -80s. These principles were elaborated most explicitly by Davydov whose extensive research revealed that the traditional education did not ensure the development of students as learners, but only trained and reinforced those mental functions that were already developed with children in the preschool age: sensory observation, empirical thinking and utilitarian memory. Davydov suggested reorganising learning processes so that that they focused not on studying separate concepts and phenomena, but at examining relationships between them. Based on this principle, learning activities are transformed from having a *reproductive* character directed at acquiring knowledge and skills to being *productive,* characterised by learners' active engagement in analysis, synthesis, compare and contrast, classification, analogy and generalising. Including these forms of activities in, particularly, mathematics curricula was, according to Davydov, central to implementing developmental learning in schools. His guiding principle was *theoretical thinking:* a process of taking the learner *from abstract to concrete*. The process of theoretical thinking from abstract to concrete can be described as follows: students with the help of teachers analyse the content of educational material, identify the essential characteristics and relationships within and across the target concepts/phenomena, present these characteristics and relationships in a symbolic form and, in doing so, learners

develop an abstract generalised understanding of the studied material. When solving specific problems, learners identify and analyse links between the created representation of the essential characteristics/relationships and the specific case or problem and, in this way, they attempt to generalise the studied material. Such an approach, according to Davydov, creates informative generalisation of the relationships within and across concepts, followed by reconstructing of this system by learners themselves, based on the identified characteristics and the relationships between the concepts. Developmental learning through theoretical thinking allowed Davydov to formulate the principles of *didactics of learning and teaching* rooted in cultural-historical psychology. Among other principles of didactics, such as continuity and conscientiousness in learning and teaching and the accessibility of knowledge, Davydov particularly focused on the principle of visualisation, which aimed at developing abstract thinking in learners by presenting the target concept in symbolic form as a model.

3.2 An analytical framework to examine learning and teaching with digital tools

3.2.1 Learning and development

The contributions of these cultural-historical scholars indicate that learning and development involve engaging in social experience and aim at initiating changes in the existing psychological functions by forming new relationships between these functions. Therefore, the development of the learner comprises quantitative and qualitative changes. Quantitative changes are characterised by the formation of new psychological functions, the acquisition of new skills and learners' ability to apply these skills in various contexts. Qualitative changes are characterised by modifying the structure of the psychological functions and establishing new relationships between these functions across contexts to enhance learners' capacity to be in control of their own learning.

The relationship between learning and development, in turn, was described in Vygotsky's zone of proximal development (ZPD) – as an ability of a child to perform tasks with assistance from a teacher or a more capable peer (Vygotsky, 1986, p.198). For Vygotsky the quality of teachers' instructions and teacher-students' collaboration in the learning activity was crucial. This evokes an emphasis on the agency of the teacher and the learner in bringing about quantitative (e.g. acquisition of new skills) and qualitative changes (e.g. establishing the relationships between skills across contexts and practices to enhance the capacity to be in control of one's own learning) in the psychological functions of the learner. Students' capacity to learn how to master new types of learning activities constitutes *learning to learn,* which

brings about qualitative changes in the psychological functions and the development of the learner. This analysis indicates the need for activities aimed at enhancing students' capacity in learning to learn. Galperin suggested such an approach to creating activities by introducing three types of orientation.

3.2.2 Examining learning as an oriented activity

The classroom research conducted by Galperin and his collaborators identified that orientation was of particular significance in any learning activity. In Figure 3A, orientation is shown as a constituent of the system transferring external activity to internal, which is found in the Orienting and Executive Parts in the model. The Orienting Part urges careful planning of the type of orientation learners are going to be exposed to in the Executive Part of the learning activity. Galperin argues that orientation can be specific for a particular task or it can be used in several situations, comprising the essential characteristics of a concept or several concepts belonging to the same class. In addition, the orientation can be either supplied to the learner in its final form ready to be used in a learning activity or it can be constructed by learners. The construction of the orientation by learners, in turn, can happen either by the method of trial and error or by the approach offered by the teacher.

Based on these premises, Galperin identified three types of the orientation: i) incomplete, where mediational tools and the essential characteristics of the concept are identified by learners through trial and error. In this case, learning happens very slowly with many mistakes and the activity of learning is extremely sensitive to the slightest changes in conditions; ii) complete, where learners are informed about all the essential features of the concept necessary to solve a particular problem. However, these essential characteristics are specific and can be used only in one case, for example, when solving a particular problem. Learning happens quickly and with minimum mistakes; however, the transfer of the skills formed in the course of such activity is possible only when there is close similarity in the learning situations and iii) complete, but being constructed by learners following the approach offered by the teacher aimed at identifying the essential features of the target concept. By using the approach offered to the learners by the teacher, a specific orientation can be constructed by learners suited for the particular case. With the third type of orientation (complete but being constructed by learners following an approached offered by the teacher), learning happens quickly, with minimum mistakes and the skills formed in the course of this activity are transferrable to other learning situations.

The similarity between the first type of orientation (incomplete) and the third type (complete but being constructed by learners following an offered approach), is that in both cases the essential characteristics of the concept are identified by learners, however, the ways these

characteristics are being identified differ: in the first type by 'trial and error' and in the third type by the approach given to the learners. The benefits of the third type of orientation Galperin saw in the 'wholeness' of the approach to learning instead of studying various phenomena/concepts separately. This type of orientation offers a new way of storage of information: instead of memorising a great amount of separated facts and concepts, a unified method of systematisation is offered which can be reused by learners in other activities. Galperin emphasised that the second type of orientation (complete and provided to learners) develops empirical thinking without getting into the essence of the phenomena; whereas the third type of orientation reveals the essence of learning and promotes theoretical abstract thinking. The third type offers a unified approach to learning and forms the basis for creating links between sciences and approaches to studying them. By applying the third type of orientation learners master the essence of learning through studying a phenomenon which carries a new function: not as a studied object, but as a tool for studying the essence of the learning. In doing so, students develop their understanding about the nature of the activity of learning across contexts and subject areas and their agency as learners is being enhanced.

The recognition that orientation of the third type may enhance learners' agentic capacity as confident and effective learners informs the theoretical framing for the analysis of students' learning in this thesis.

3.2.3 Examining the dialectics of learning and teaching

The Orienting part of a learning activity was considered by Galperin as a 'managing device' whereas the Executive part was seen as a 'working device' transferring the activity from the external plane to the internal. For Galperin, the transformation of the learning activity is described by the measure of its acquisition by learners engaged in the activity i.e. when transferred from the social external to the internal plane.

During 20 years' of school research, Galperin outlined the dialectically developing forms this transformation may go through: (1) motivation, (2) orientation, (3) materialised action, (4) communicated thinking, (5) dialogical thinking, and (6) acting mentally (Galperin, 2002). In the initial motivational form, a learner's attitude and relation to the learning outcomes that have to be achieved is formed. In the orientation form, Galperin identified three types of orientation which were presented in detail in the previous section. In the third form of a materialised action learners interact with material (real objects) or materialised objects (models, simulations, animations, schemes, etc), 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 form, communicated thinking, which reflects learners' activity with material

or materialised objects. It should be noted that communicated thinking does not imply learners' ability to explain the activity they are involved in, but to complete the activity by talking. In the form of communicated thinking an activity already acquires the characteristics of ideal, theoretical activity, but it is still 'visible' and available for monitoring from outside. The fifth form, dialogical thinking, establishes a dialogue of a learner with him or herself so that the activity is being transformed mentally. In dialogical thinking a mental activity: i) presents itself as a reflection of the materialised activity on the ideal plane where material or materialised objects are substituted with their images; ii) is directed to the images of the material or materialised objects and iii) reflects learners' ability to perform the activity with the images of the material or materialised objects mentally. The transformation of communicated thinking to dialogical thinking happens by substituting the externally oriented speech with its image. In dialogical thinking the activity is directed inside the learner establishing communication with him/herself (as another person). Learners' ability to perform an activity in the form of dialogical thinking reflects the pathway the activity has undergone: from its materialised to dialogical form. In the final form of acting mentally, an activity has become a pure mental act with the focus on its outcome. The activity is performed with the inner speech that does not include the dialogue with a learner as 'another person', but becomes a purely individual activity completed 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 forms of the transformation of the external social activity to the internal plane of a learner are used as analytic resources for understanding the learning processes underway in classrooms where learners are supported by digital tools, a teacher and collaborating peers.

4.0 RESEARCH DESIGN AND METHODOLOGICAL APPROACH

4.1 Mixed Methods Approach

Chapter 1 explained that the research in this study was guided by the desire to examine students' learning in group work with digital tools and teachers' facilitating of such learning. Within that framing, the empirical focus is on whether and how students may develop conceptual understandings in classroom tasks and an understanding of the process of their own learning. The focus on making explicit *how* young people learn when using digital tools in classrooms; *how* teachers facilitate students' learning in these conditions; together with the implications of the use of digital tools for the development of students' conceptual understanding and their understanding of what learning is, has required me to carry out in-depth analyses of how the digital tools are used by learners in classrooms and the impact of the use of digital tools and teacher's facilitation on student learning. In order to address these questions the study has employed a mixed methods approach. Much has recently been written about employing both qualitative and quantitative methods (Bazeley & Kemp, 2012; Dolonen, 2014; Hagen, 2012; Johnson & Christensen, 2014; Johnson, Onwuegbuzie, & Turner, 2007). One definition of mixed methods research is the following:

> … the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration (Johnson et al., 2007, p. 123).

This definition, though useful, does not offer a proper justification of how methods are mixed and why. For that, we need to turn to efforts at classifying rationales (typologies) for mixing methods in research design.

Greene's work has been particularly influential in this regard. In 1989, with colleagues, she analysed published studies using mixed methods to produce a typology (Greene, Caracelli, & Graham, 1989), which she returned to in her later work (Greene, 2007). In her 2007 discussion, she distinguished the following five purposes for employing mixed methods:

> 1. Triangulation seeks convergence, corroboration, correspondence of results from different methods;
> 2. Complementarity seeks elaboration, enhancement, illustration, clarification of the results from one method with the results from the other method;
> 3. Development seeks to use the results from one method to help develop or inform the other method, where development is broadly construed to include sampling and implementation, as well as measurement decisions;
> 4. Initiation seeks the discovery of paradox and contradiction, new perspectives of frameworks, the recasting of questions or results from one method with questions or results from the other method;

5. Expansion seeks to extend the breadth and range of inquiry by using different methods for different inquiry components (Greene, 2007, p. 18).

In the past 25 years, this classification has been supplemented by several others. On the basis of a review of the reasons for combining qualitative and quantitative research, Bryman's classification (Bryman, 2006) breaks down Greene et al.'s (1989) categories into several aspects, and adds a number of additional features, such as the following:

(a) Credibility – refers to suggestions that employing both approaches enhances the integrity of findings.

(b) Context – refers to cases in which the combination is justified in terms of qualitative research providing contextual understanding coupled with either generalizable, externally valid findings or broad relationships among variables uncovered through a survey.

(c) Illustration – refers to the use of qualitative data to illustrate quantitative findings, often referred to as putting 'meat on the bones' of 'dry' quantitative findings.

(d) Utility or improving the usefulness of findings – refers to a suggestion, which is more likely to be prominent among articles with an applied focus, that combining the two approaches will be more useful to practitioners and others.

(e) Confirm and discover – this entails using qualitative data to generate hypotheses and using quantitative research to test them within a single project.

(f) Diversity of views – this includes two slightly different rationales – namely, combining researchers' and participants' perspectives through quantitative and qualitative research respectively, and uncovering relationships between variables through quantitative research while also revealing meanings among research participants through qualitative research. (Bryman, 2006, p. 106)

To achieve its aim and examine the complexity of learning and teaching with technology, detailed qualitative analyses of student-student and student-teacher interactions were undertaken in this study. However, examining the complexity of learning and teaching with technology begged for credibility to these analyses and therefore, quantitative evidence about both processes of tool use and outcomes were provided. In this respect my rationale for using mixed methods comprised triangulation, complementarity, development, initiation and expansion (Greene, 2007); and credibility and illustration (Bryman, 2006). For instance, to achieve triangulation, the results of qualitative analyses of student-student interactions were examined to corroborate with the quantitative analyses of the pre- and posttests of the students' grades. Complementarity and development in Greene's categorisation and credibility and illustration in Bryman's typology was achieved, for example, by illustration and elaboration of qualitative analyses of teacher-student interactions with the quantitative analyses of the number of teachers' interventions in students' work. Therefore, combining of qualitative and quantitative analyses were crucial for initiation and expansion (Greene, 2007) and creating new perspectives on the complex phenomenon of learning and teaching with technology.

In the rest of the Chapter 4, I present the research design, the rationale for the choice of the case studies, selection of empirical sites, the data corpus and analytical approaches. The issues of reliability, validity and ethics are also discussed.

4.2 The two-phase design

In the practical typology of mixed designs, mixed methods research has been conceptualised as a function of two dimensions: i) time orientation of the qualitative and quantitative components and ii) paradigm/research approach emphasis (Johnson & Christensen, 2014). Time orientation refers to whether the qualitative and quantitative components or phases of the study occur at approximately the same point of time (i.e., concurrently) or whether they are organised into phases over time (i.e., sequentially). Paradigm/research emphasis refers to whether the qualitative and quantitative parts of the study are given approximately equal emphasis or whether one paradigm clearly has more weight than the other (i.e., qualitatively driven design or quantitatively driven design). To examine the complexity of learning with digital tools, how students learn with technology and how teachers facilitate students' learning in such conditions, a two-phase research design was chosen with a research emphasis on the qualitative paradigm (Johnson & Christensen, 2014). Phase 1 was aimed at exploring and conceptualising the complexity of learning with digital tools in Science and Phase 2 examined how students learn with technology and how teachers facilitate students' learning with digital tools in English. The intention to investigate learning and teaching with digital tools in different subject areas was underpinned by the need to examine how digital tools and teachers may assist learners in developing syntactic knowledge (Schwab, 1982) across subjects, which is best seen as the ways of thinking that are expected of experts in the selected subjects. Science and English subjects belong to the two (out of three: Mathematics and Natural Sciences, Languages and Social Sciences) main subject areas in the Core Curriculum[2] in Norway and therefore findings from the analyses of students' learning with digital resources in these subjects would contribute to conceptualising of how digital tools and teachers may assist learners in developing syntactic knowledge (Schwab, 1982) across subjects. The choice of Science and English subjects was also determined by my educational background and my experience of teaching these subjects for twenty years in different educational systems (Norway and UK). Analyses of the data from different subject areas may have implications for the design of pedagogical technology. Table 4A presents the structure of the two-phase design of the mixed methods approach used in this

[2] See: http://www.udir.no/laring-og-trivsel/lareplanverket/fag/

thesis and the analytical process for each article. In line with Johnson and Christensen's terminology the design is labelled a *sequential-concurrent design* (Johnson & Christensen, 2014).

Table 4A
Sequential – concurrent design and analytical process for each article

	Phase 1: Science case study **QUAL** 	**Phase 2: English case study** **(QUAL + quant)**	
	Article One *The complexity of learning: Exploring the interplay of various mediational means in group learning with digital tools*	**Article Two** *Developing writing skills in English using content specific computer-generated feedback with EssayCritic*	**Article Three** *What teachers do: facilitating the writing process with the feedback from EssayCritic and collaborating peers*
Research questions	1. What characterises the relationship between the digital tools, task design, peer collaboration and teacher interventions in students' learning? 2. How do these mediational means support students' development of conceptual understanding in Science?	1. How do different types of feedback assist students in their writing process?	1. How do teachers facilitate students' writing process with the feedback from EssayCritic and collaborating peers? 2. How does EssayCritic affect teachers' facilitating of students' writing?
Data	a) Video data transcribed verbatim in Norwegian of student-student and teacher-student interactions.	a) Grades of 48 pre-posttests in the target and comparison classes; b) number of subthemes included in the pre-posttests in both classes and c) Video data transcribed verbatim in English of student-student interactions in the target and comparison classes.	a) Number of teachers' interventions in similar phases of the writing process in both classes and b) Video data transcribed verbatim in English of teacher-student interactions in similar phases of the writing process in the target and comparison classes.
Analytical strategies	*Interaction analysis* of the selected data extracts that represent episodes in which students engaged in the group task with digital tools supported by the teacher's interventions	*Interaction analysis* of the selected extracts that represent episodes in which students were making sense of the feedback given by EssayCritic (target class) and collaborating peers (comparison class) in the similar phases of the writing process	*Interaction analysis* of the selected extracts that represent episodes of teacher-student interactions in the target and comparison classes in the similar phases of the writing process
	Analysis of the selected data extracts from the perspective of the observable forms of the external activity: i) materialised action; ii) communicated thinking and iii) dialogical thinking	*Analysis* of the selected data extracts from the perspective of the observable forms of the external activity: i) materialised action; ii) communicated thinking and iii) dialogical thinking	*Analysis* of the selected data extracts from the perspective of the observable forms of the external activity: i) materialised action; ii) communicated thinking and iii) dialogical thinking

		Statistical tests: *Paired t-test:* i) analysed the improvement between pre- and post-tests and ii) assessed the increase in the number of subthemes from pre- to post-test *Cohen's d:* estimated the effect size of such improvement *Independent t-test:* i) assessed statistical difference between the results of the pre- and post-tests and ii) assessed statistical difference between the number of subthemes in the pre- and post- tests	*Statistical test:* *Mann-Whitney test*: was used to calculate statistical difference between the number of teachers' interventions in the target and comparison classes in similar phases of the writing process
Findings	Digital tools, task design, peer collaboration, and teacher's interventions dialectically interplay to shape how learners use mediational means: (1) digital tools are the resources that enable students to explicate their (mis)understandings; (2) compare-and-contrast tasks promote analytical thinking; (3) peers present themselves as resources who promote development of conceptual understanding; (4) the teacher guides learners' attention towards the potential of the mediational resources, elicits, organises, and structures students' knowledge. The dialectical interplay of these mediational means creates a system that supports and guides students' learning.	The students in both (target and comparison) classes significantly improved their grades. In the target class, the feedback from EssayCritic gave content-specific cues and the students included more ideas in their essays than the students in the comparison class, who struggled when giving feedback to each other.	Findings reveal patterns in the teachers' guidance of the writing process with and without EssayCritic that comprise: i) setting up the learning process in the orientation phase; ii) assisting the development of students' conceptual understanding in the phase of communicated thinking; and iii) bringing learners' attention to the essential requirements of the essays in the phase of dialogical thinking. The Mann-Whitney test revealed that the teachers in both classes provided more assistance in the phases of orientation and communicated thinking than in the dialogical thinking. The differences arising from the use of EssayCritic are outlined: by interacting with EssayCritic the teacher assisted the learners in completing the specific task, although little attention was paid to the development of their assessment for learning (AfL) practices. In the comparison class the teacher paid attention to the development of students' AfL practices by emphasising the general approach to the analysis and the essential requirements of the essays.

The symbol system is based on (Johnson & Christensen, 2014):

- The letters QUAL stand for qualitative research
- The letters quant stand for quantitative research
- Capital letters denote priority, weight and a role in the study
- A plus sign (+) represents a concurrent collection of data
- An arrow (→) represents a sequential collection of data
- The combination of symbols QUAL+quant indicates a design in which the qualitative paradigms are given more weight and higher priority than the quantitative paradigms (QUAL are in caps) and are conducted concurrently (see the plus sign).

In the sequential-concurrent design the primary and the core component is qualitative and the quantitative data that were gathered have a supplementary status aimed at giving credibility to the qualitative analyses by providing evidence of tool use and its outcomes. The two Phases included in the design were conducted sequentially and they answer different research questions. Phase 1 involved examining the complexity of learning with digital tools by exploring the relationships between material (digital tools and task) and social (peer collaboration and teacher interventions) mediational means when supporting students' learning. In Phase 2 the objectives were to (i) examine students' learning in the writing process, with the feedback from the computer-based EssayCritic compared to the learning process with the feedback from collaborating peers; and (ii) analyse how teachers facilitate students' learning in these conditions. However, Phases 1 and 2 complement each other and contribute to achieving the overarching aim of this study: i) to make explicit how adolescent students learn when using digital tools in Science and writing classes in English and how teachers facilitate students' learning in these conditions and ii) to use and evaluate the pedagogical categories developed by Galperin as analytic resources to reveal students' actions in the classrooms with digital tools.

The collection of the data in both Phase 1 and Phase 2 occurred in the frame of the research project Ark & App[3], led by Associate Professor Øystein Gilje conducted in Norway in 2013-2015 and financed by the Ministry of Education of Norway. Aiming to examine learning and teaching with digital tools across subject areas, I participated in two case studies of the project: Science in the lower secondary school and English in the upper secondary school.

4.3 Phase 1: The Science case study (Article One)

The data collected in the Science case study were used in Article One to investigate and conceptualise the complexity of learning with digital tools. The analyses addressed the following research questions:

[3] See: http://www.uv.uio.no/iped/forskning/prosjekter/ark-app/

RQ1: What characterises the relationship between the digital tools, task design, peer collaboration and teacher interventions in students' learning?

RQ2: How do these mediational means support students' development of conceptual understanding in Science?

4.3.1 Empirical context

Seventy six Year 10 students (aged 15-16) from two classes, a teacher and three researchers participated in the project in spring 2014. The two classes were taught by the same Science teacher who followed similar teaching plans for each class. The students studied the topic Genes and Inheritance for the period of 12 school hours over the course of four weeks. The teacher divided the classes into groups of four students, who worked together during the whole project. The teaching sequence over the four weeks is presented in Article One in Part II of this thesis.

A group task aimed at the development of students' conceptual understanding of mitosis and meiosis was designed by the researchers together with the teacher and integrated in the teaching flow. The processes of mitosis and meiosis are challenging for learners (Kindfield, 1994; Lewis & Kattmann, 2004; Lewis & Wood-Robinson, 2000; Marbach-Ad & Stavy, 2000; Tsui & Treagust, 2003) and offer possibilities for a compare and contrast exercise to outline similarities and differences between these processes, identify the essential characteristics of these scientific phenomena and hence, facilitate the development of learners' both the substantive knowledge and syntactic knowledge (Schwab, 1982) of a subject.

The details of the compare and contrast task are presented in Article One in Part II. Chapter 1 and Article One introduce and describe the Internet-based digital resource Viten.no used by the learners in the Science case study.

4.3.2 Data collection

Video recordings of the classroom activities in two classes, including student-student and teacher-student interactions, were taken during the whole project in the period 26.02 – 20.03. Five cameras were used to capture the events: one camera video recorded the whole class teaching, another camera followed the teacher and three cameras recorded student-student and teacher-student interactions during group work in five different groups in both classes. Field notes were taken by using a pre-designed form to supplement the video recordings.

At the beginning and at the end of the project the students completed pre- and posttests aimed at evaluating learners' conceptual understanding in genetics. The test was designed in collaboration with the teacher and consisted of twenty nine multiple-choice questions, which addressed various aspects of the topic Genes and Inheritance. Seventy-nine students participated in the pre- and posttests and fifty three students completed both tests. The teacher

graded the tests using a 0–1 point scale where a '0' was awarded if a student gave a wrong answer and a '1' was awarded if the chosen answer was right. At the end of the project the three groups of students and the teacher were interviewed. A summary of the length of the video recordings is presented in Table 4B.

Table 4B

Time of the video recordings of the target groups and the teacher

Group /Teacher	Learning Time, min	Interview Time, min	Total, min
Group 1	174	37	
Group 2	180	29	
Group 3	174	34	
Group 4	84		
Group 5	84		
Teacher (whole class teaching and group interventions)	678	45	
Total	**1374**	**145**	**1519**

My role in the data collection, in collaboration with three other researchers who participated in the project, comprised filming both the whole class teaching and students' learning in groups, taking field notes and conducting interviews with the teacher and one of the target groups.

4.4 Phase 2: The English case study (Article Two and Article Three)

The data in the English case study were used in Article Two and Article Three to address the following research questions:

In Article Two:

How do different types of feedback assist students in their writing process?

In Article Three:

RQ1: How do teachers facilitate students' writing process with the feedback from EssayCritic and collaborating peers?

RQ2: How does EssayCritic affect teachers' facilitating of students' writing?

4.4.1 Empirical context

One hundred and twenty five students (aged 16-17) from five classes wrote an essay on the topic *English as a Global Language* based on the information studied previously in class and the content of a chapter in the textbook *Passage* (Burgess & Sørhus 2009). The text of the assignment was created in collaboration between five teachers and two researchers: *"Write an essay on the topic of English as a Global Language: Explore how English was spread around the globe, and present the most important reasons for this development" (*300-400 words).

The sequence of the activities in the writing process and detailed descriptions of the writing process are presented in Article Two and Article Three in Part II. The writing process in the target and comparison classes happened on consecutive days (05.11. and 06.11.) due to video recording capacities. Chapter 1 and Articles Two and Three introduce the computer-based EssayCritic system used in the English case study.

4.4.2 Data collection

Video recordings of classroom activities took place during the whole project in the period of 28.10.–06.11. On 28.10. one camera recorded the students' individual writing of the first draft of the essay in two classes. On 05.11. and 06.11. three cameras recorded the activities, student-student and student-teacher interactions in the three groups in the target and comparison classes during the writing process. Another camera followed the teachers in both classes. Field notes were taken to supplement video recordings and specify the resources that were used.

The students submitted their first and last drafts of the essay on the learning management system *It's Learning* used by the school. These drafts were copied to the researchers' hard drives for research purposes. All the drafts submitted by the students in the target class to the EssayCritic system were copied and stored by the researchers, who also stored the screen shots of EssayCritic with the feedback on the covered and suggested subthemes provided to each of the drafts submitted by the students in the target class.

The six groups of students (three in the target and comparison classes) and the classroom teachers were interviewed at the end of the project. The interviews with the students were video recorded and the interviews with the teachers were audio-taped. A summary of the length of the video and audio recordings is presented in Table 4C.

Table 4C
Time of the video recordings of the target and comparison classes and the teachers

Class	Group/Teacher	Learning Time, min	Interview Time, min	Total, min
Target	Group 1	270	30	
	Group 2	270	32	
	Group 3	270	28	
	Teacher	270	44 (audio)	
Comparison	Group 4	270	35	
	Group 5	270	29	
	Group 6	270	27	
	Teacher	270	44 (audio)	
Total		**2160**	**269**	**2429**

My role in the data collection, in collaboration with two other researchers, comprised video recording of teachers' facilitating of students' learning in groups during the writing process and conducting interviews with the classroom teachers and six groups of students in

the target and comparison classes. The overview of the data corpus collected in the Science and English cases is presented in the next section.

4.5 Data corpus and justification of methods

The data corpus collected in Phases 1 and 2 consists of observation data, interview data and documents. *Observations* were recorded with a video camera.

The *interview data* were used to contextualise the observations and reveal students' and teachers' reflections on teaching and learning in Science and in English writing classes within and beyond the projects. The data consist of semi-structured interviews with the teachers and the students.

Finally, *relevant documents and artefacts* were collected. These documents included: i) field notes taken during class observations (in both the Science and English case studies), which were used to contextualise the collected video data (Derry et al., 2010), and ii) the artefacts produced by the students: the completed task sheets in the Science case, student drafts and screen shots in the English case and pre- and posttests in both the Science and English cases. A rich set of data was collected in line with the ethnographic approach (Hammersley & Atkinson, 2007), which ensured the variety of the types of data and offered a choice of which data to use to address the research questions in the studies. The overview of the data corpus is presented in Table 4D. The data that were used in the analyses in the studies were given a primary status (PS) and the data that were used to contextualise the primary data were given the secondary status (SS).

Table 4D
The overview of the data corpus
(PS – Primary Status; SS – Secondary Status)

	Video recordings of classroom observations	**Pre-post tests**	**Student interviews**	**Teacher interviews**	**Artefacts of student work**	**Field notes**
Phase 1: Science case						
Article One	PS	SS	SS	SS	SS	SS
Phase 2: English case						
Article Two	PS	PS	SS	SS	PS	SS
Article Three	PS	SS	SS	SS	SS	SS

Article One reports on how qualitative methods were used to investigate the relationships between social (peer collaboration and teacher interventions) and material (digital

animations and paper based task) mediational means in Science learning. Qualitative analysis is recognised as suitable for exploring in particular the complexity of the examined phenomenon (Creswell, 2012; Johnson & Christensen, 2014). Therefore, the video recordings of the classroom observations including student-student and teacher-student interactions were selected as primary data in this study.

Article Two employs a mixed methods approach with a dual focus on exploring the learning process the students engaged in and the results achieved in the writing process with the feedback from EssayCritic and the feedback from collaborating peers. Aiming at a dual focus in Article Two, the video recordings of student-student interactions and students' pre- and posttests were selected as primary data. Article Three also uses mixed methods in an attempt to examine and compare teachers' facilitating of students' writing process with different types of feedback. In order to do so, the video recordings of teacher-student interactions were given primary status in the conducted analyses. In the next section I provide details on the analytical approach and processes used in the analyses of the data.

4.6 Analytical approach and processes

In this section I explain the assumptions and analytical strategies guiding the analyses performed in the studies. First, the key assumptions that informed the analysis and reflected the theoretical grounding in the cultural-historical theory are outlined. Thereafter, the process of moving from the empirical and analytical focus of Phase 1 to the corresponding foci in Phase 2 is presented. Finally, I describe the analytical strategies for each Article.

4.6.1 Analytical assumptions

The first assumption of the analytical approach is that students' learning in groups can be traced through their interactions with other students and teachers, where talk is seen as to represent the process of collaborative sense-making (Linell, 2009; Mercer, 2000). This conceptualisation should allow treating talk as a reflection of how students' learn and how teachers facilitate students' learning. Therefore, attention can be paid to how learners interact with material and social artefacts and how these interactions contribute to the sense-making process. This assumption invites the analytical focus on sequences in the student-student and teacher-student interactions resulting in the joint achievements of sense-making among the participants.

The second assumption, which arises from the cultural-historical accounts of learning and development (Vygotsky, 1978), it is that learning, which enhances the development of students as learners, is of a social origin. From this perspective learning originates in a person's

activity with material or materialised tools: what Vygotskian analysts term the external plane. In the process of transfer from the external to the internal plane (i.e. the internalisation of aspects of the ideas being worked with) an activity undergoes certain transformations, which, as I outlined in Chapter 3, can, according to Galperin, be observed in four main forms: i) orientation, ii) materialised action; iii) communicated thinking and iv) dialogical thinking (Galperin, 2002). These moves towards internalisation reflect the process of acquisition of conceptual understanding by the learner. Therefore, examining the process of learning in each of these forms may contribute to understanding *how* growing understandings in social learning activities are being transferred to the internal plane of the learners. These forms of transformation are employed in the analysis as ways in to identifying key phases in the process of learning. However, it was important to remain open to the possibility that the use of digital tools might change the learning processes delineated in Galperin's work in non-digital learning environments.

4.6.2 Analytical strategies

Data analysis was characterised by an iterative process in which emergent findings informed the next steps. One part of the analytical process in both Phases 1 and 2 examined how students learn with digital tools and how teachers facilitate students' learning in these conditions. The focus on the process of learning determined the choice of the method of qualitative analysis inspired by the method of interaction analysis (Jordan & Henderson, 1995). The analyses examined student-student and teacher-student verbal interactions, turn taking and use of material resources during interactions, including the digital tools. The use of interaction analysis was underpinned by the assumptions that learners' talk may reflect the process of collaborative sense making and that human cognition is social in origin. The analytical focus was on the sense making occurring in collaborative activities as reflected in the use of language. By this, I chose a subset of the repertoire of interaction analysis judged sufficient to answer my research questions, and the finer details of a linguistics analysis of the interactions were not tackled.

The data (1374 minutes in the Science case and 2160 minutes in the English case) were transcribed by the investigator, contributing to a growing awareness of which episodes of interaction would be most open to in-depth analysis of students' learning with digital tools. The transcription of the data was performed according to the standardised Jeffersonian transcript conventions (Appendix 1) (Jefferson, 2004).

A substantial number of episodes (18 episodes in the Science case and 22 in the English case), which represent student-student and 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 student-student and student-teacher interactions in the articles. Hence, the selected extracts in each of the articles represent a narrative structure of the story the study was intended to convey.

The interactions in the selected extracts were analysed sequentially implying that each utterance was analysed in relation to the previous one in the ongoing interaction. 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 student-student and 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.

The process of moving from the overall data corpus to the theoretical and empirical focuses of Phases 1 and 2 was informed by both the analytical assumptions and the characteristics of the data, summarised as follows:

Phase 1: Science case study

The complexity of learning: Exploring the interplay of different mediational means in group learning with digital tools (Article One): In the classrooms when students engage with digital tools other mediational means are inherently present to potentially support the learning process. These means usually include: collaborating peers; the design of the task; and the teacher. The simultaneous presence of material and social mediational means constitutes the complexity of the educational setting. The analytical intention in Phase 1 was to investigate the relationships between various mediational means as they support learners' conceptual understanding of mitosis and meiosis. Aiming to do so, video data of student-student and teacher-student interactions were analysed qualitatively by employing interaction analysis. Due to the space restrictions four interaction extracts were selected and presented in Article One. The extracts represented patterns of student-student (two extracts) and student-teacher (two extracts) interactions in the groups and at different times in the learning process. In particular, the

analysis explored the relationship between and the role of the social and material mediational tools – as learners engaged with them. Extract 1 demonstrates how the analysis was conducted:

Extract 1:

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, can you see the similarity ((*refers to the chromosomes in different cells in Viten animation*)).
7.	Andreas:	Now they are dividing. There 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 real 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, it's simplified in the animation.
13.	Henrik:	Otherwise, it would have been too many chromosomes.
14.	Teacher:	And it would have been difficult to understand ((*leaving the group*)).

Level one: Description of the student-teacher interactions

Henrik is commenting on the changes in the chromosomes in the animations in Viten.no (line 1) and Andreas identifies the similarity between the chromosomes in the cells (line 2). The teacher seeks confirmation of students' understanding (line 3) and Rita reports that the process in Viten.no is different from the ones depicted on the diagrams in the task sheet (line 4). The students elicit their understanding in lines 5 and 7, the teacher confirms and emphasizes the similarity of the process the chromosomes in different cells have undergone (line 6). The educator points to the number of chromosomes at the beginning of cell division (line 8) and refers to the number of chromosomes in human cells (line 10). Andreas suggests that the animations represent the simplified process (line 11), Henrik confirms (line 13) and the teacher summarises the complexity of the process of cell division in humans (line 14).

Level two: Analysis of student–teacher interactions from the perspective of the research question

While the students are making sense of the stages of meiosis, the teacher confirms their understanding and emphasises the similarity of the changes in chromosomes in different cells (line 6). Having received a confirmation of students' understanding of meiosis, the teacher directs learners' attention to the initial number of chromosomes shown in the animations which might prompt that meiosis in human cells involves a greater number of chromosomes than the animation presents. In doing so, the teacher helps the learners to shape their understating of the

process of sex cell division and make a connection between the steps of the animation and the real process happening in human cells.

Level three: Outlining of emergent findings

The teacher relies on the digital animation while assisting students' learning and the digital animation determines the content of teacher-student interactions revealing a dialectical interplay between material digital tools and teacher interventions.

Once the interaction analysis was completed, the interactions were examined through the analytic lens offered by Galperin's dialectically linked pedagogic forms of learning activity to unpack how the mediational means supported students as learners at different times in the learning process. Specifically, analytical attention was directed at examining the activities students engaged in at different times of the learning process and how these activities were performed in the course of student-student and teacher-student verbal interactions and participants' interactions with material digital tools. The interactions of the participants were analysed against the descriptions of the forms of learning activity introduced and empirically tested by Galperin and his colleagues (Galperin, 2002). In doing so, Galperin's forms of activity situated the analysed extracts in the flow of the learning activities the students engaged in. The analyses were performed with an open mind and Galperin's theory was not imposed on the analysed data; rather the analyses of the data were aimed at challenging Galperin's conceptualising of learning. Therefore, the data were analysed in relation to how well they matched with Galperin's analytical descriptions of the forms of the learning activity and Galperin's theory was used as a set of analytical tools to 'dig' into the data. The detailed description of Galperin's conceptual contribution is given in Chapter 3 in Part I and Articles One, Two and Three in Part II of this thesis.

Phase 2: English case study

Developing writing skills in English using content-specific computer-generated feedback with EssayCritic (Article Two): The research questions in Article Two examine and compare how students learn with and without technology. The target group received feedback from EssayCritic; and a comparison group received feedback from peers. The analytical focus on the learning process justified the method of interaction analysis employed to analyse qualitatively 2160 minutes of video data of students' learning under different conditions. Due to the space restrictions, two interaction extracts were presented: one from each class. Galperin's pedagogic forms of activity and the types of orientation were used to reveal how students learnt in the writing process under these different conditions. A more detailed explanation about how Galperin's theory was used is presented in Chapter 3 in Part I and Article Two in Part II in this

thesis. The analytical interest in the results achieved by the students through the quality of the essays produced under different conditions required the use of mixed methods (Greene, 2007; Johnson & Christensen, 2014). To analyse the data quantitatively, in line with Field (2013), the aim was to select appropriate statistical procedures driven by the research questions. The analyses of the data employed the *paired t-test*, *Cohen's d* (Cohen, 1992; Field, 2013) and the *independent t-test* (Cohen, Manion, & Morrison, 2011; Field, 2013). The details of the analyses performed in the study are presented in Article Two in Part II. Combined, the mixed methods allowed examining and comparing how students engaged in learning with the feedback from EssayCritic and the feedback from collaborating peers.

What teachers do: facilitating the writing process with the feedback from EssayCritic and collaborating peers (Article Three): The research questions addressed in Article Three aimed at: i) examining and comparing teachers' facilitating of students' writing process with the feedback from EssayCritic and collaborating peers and ii) investigating how EssayCritic affects teachers' facilitating of students' writing. With this analytical focus, mixed methods (Greene, 2007; Johnson & Christensen, 2014) were applied to analyse the data. To examine and compare teachers' facilitating in the target and comparison classes, the quantitative analyses of the data employed the *Mann-Whitney test* (Mann & Whitney, 1947; Field, 2013), which was used to calculate statistical difference between the number of teachers' interventions in both classes in similar phases of the writing process. The details of the analyses are presented in Article Three in Part II in this thesis. To examine teachers' facilitating of students' writing, teacher-student interactions were analysed qualitatively inspired by the method of interaction analysis (Jordan & Henderson, 1995). Six interaction extracts (from target and comparison classes) are presented in the Article, representing patterns of teacher-student interactions in the writing process. Once the interaction analysis was completed, the interactions were examined through the analytic lens offered by Galperin's types of orientation to explain the conditions of mediation in both classes and forms of learning activity to unpack what teachers did and how they facilitated the writing process in both classes. Detailed accounts of the analytical strategies employed in the articles are given in Part II in this thesis. The analytical processes for each article are summarised in Table 4A.

The data corpus and the analytical strategies provide both opportunities and limitations. The main benefit of the data corpus is, on the one hand, that it has been collected across different subject areas which may contribute to the opportunity of analysis and reflections on learning with digital tools across educational contexts. In addition, the large amount of video data collected (1374 minutes Phase 1 and 2160 minutes in Phase 2) allowed for the selection of the

extracts reflecting the examined phenomena and representing patterns of student-student and teacher-student interactions. A limitation of the data corpus is that the analyses are not linked to a longitudinal analysis of students' development as learners. Suggestions for possible modifications of EssayCritic emerged from the analyses in Phase 2 may potentially be implemented and used in a future longitudinal study to examine students' learning with technology and the development of students as learners.

4.7 Research credibility and ethical considerations

4.7.1 Reliability

Several attempts have been made to ensure the reliability of the studies in this thesis. *First,* video recordings that capture both visual and audio data offer higher reliability than other forms of data collection, e.g., field notes or simply audio recordings. *Second,* the interactions were transcribed according to the standardised Jeffersonian transcript conventions (Appendix 1) (Jefferson, 2004). The use of these conventions allowed for detailed descriptions of the interactions and the activities that accompanied these interactions. *Third,* the method of interaction analysis ensured the transparency of the performed analysis by step-by-step guidance of the reader through the analysis: close description of the events followed by the analytical judgements and summarised by outlining emergent findings add to the transparency of the interaction analysis and the reliability of the studies. *Finally*, the *inter-rater reliability* was achieved between the grades awarded by the classroom teachers and the independent teacher on the pre- and posttests in the target and comparison classes in the English case study where these data had a primary status in the analyses and assessed by calculating the Cohen's kappa[4]. The results are presented in Table 4F.

Table 4F
Cohen's kappa between the grades awarded by the classroom and independent teachers on the pre- and posttests in the target and comparison classes

Class	Cohen's kappa, pretest	Cohen's kappa, posttests
Target class	0.226	0.229
Comparison class	0.318	0.296

Measured on the scale 0.2-1.0 (Field, 2013) the obtained results of Cohen's kappa indicate fair inter-rater reliability between the assessments of the classroom and independent teachers.

[4] See: http://dfreelon.org/utils/recalfront/recal2/

4.7.2 Validity

Validity has been defined as the extent to which an account accurately represents the social phenomena to which it refers (Hammersley & Atkinson, 2007). Validity does not refer to the data themselves (Creswell & Miller, 2000); rather it is connected to judgement and whether the inferences drawn from the data are trustworthy. It has been suggested that mixed methods research may provide more valid inferences. If the results from quite different strategies such as qualitative and quantitative converge, the validity of the corresponding inferences and conclusions will increase more than with convergence within each strategy (Lund, 2012). Validation permeated the entire process of investigation (Kvale & Brinkmann, 2009) and assessing multiple validities may contribute to minimising threats to the research:

> This term (validity) refers to the extent to which the mixed methods researcher successfully addresses and resolves all relevant validity types, including quantitative and qualitative validity types […] as well as the mixed validity dimensions. In other words, the researcher must identify and address all the relevant validity issues facing a particular research study (Johnson & Christensen, 2014, p. 309).

Theoretical validity refers to the degree to which a theoretical explanation developed from a research study fits the data and is therefore credible and defensible (Johnson & Christensen, 2014). Maxwell points out that any theory has two components: the concepts or categories that the theory employs and the relationships that are thought to exist among these concepts. Corresponding to these aspects of theory are two aspects of theoretical validity: the validity of the concepts and the validity of the postulated relationships among the concepts. The first refers to the validity of the blocks from which the researcher builds a model and the second refers to the validity of the way the blocks are put together (Maxwell, 1992).

A strategy to promote theoretical validity pursued in this study was, in line with Johnson & Christensen (2014), extended fieldwork. A large amount of time was spent in the field and 3534 minutes of video recordings collected and analysed in Phases 1 and 2 ensured that the patterns of students' learning with digital tools and teachers facilitating of such learning were stable so that they could be analysed from the perspective of the questions *why* and *how* these patterns occurred. In addition, in line with Maxwell (1992), a *pattern-matching strategy* was used to develop theoretical explanations of the studied phenomena. This strategy involves making predictions based on the theory followed by testing the accuracy of these predictions (Johnson & Christensen, 2014). The well-tested cultural-historical accounts of learning and development (Vygotsky, 1978), is that learning originates in a person's social activity with material or materialised tools, determined a particular focus on the situations where students were interacting with the digital tools while in groups. In addition, 18 extracts in the Science

case and 22 extracts in the English case of student-student and teacher-student interactions were analysed against the empirically tested four main forms of learning activity: i) orientation; ii)materialised action; iii) communicated thinking and iv) dialogical thinking. However, to ensure the theoretical validity, I also searched for the data extracts that did not match any of the three forms of learning activity and which resulted in the emergence of the situations that demonstrated the dynamic nature of these forms and reflected the non-linearity of the process of transformation from one form to another. This finding emerged in the analyses and is elaborated further in the discussion section in this thesis. In addition, the analytical assumptions arising from the cultural-historical theory guided the research across different subject areas in both cases and provided a powerful tool for conceptualising learning and teaching with technology. In this respect these analytical assumptions applied across subject contexts contribute to the theoretical validity of the findings.

Peer review is another useful strategy. This validation approach was employed in Articles One, Two and Three to ensure reflection and transparency. I have presented and discussed the data and interpretations in various settings: with my supervisors, as a member of the national graduate school NATED since 2013 and as a member of the research group MEDIATE at the University of Oslo since 2013. I have taken the feedback into consideration and reflected on it to ensure that the inferences made in the studies were adequate and valid. Finally, when developing a theoretical explanation, the issues of *internal* (causal) validity and *external* (generalising) validity were addressed.

Internal validity is the degree to which a design successfully demonstrates that changes in a dependent variable are caused by changes in an independent variable (Clark-Carter, 2010). Internal validly has been addressed in the design by examining and comparing students' learning in the target and comparison classes. The target class was exposed to the use of EssayCritic which affected the content of the students' final drafts and the learning process they and the teachers engaged in. *History*, i.e. any events, other than any planned treatment event that occur between the first and the second measurements of the dependable variable, might be a threat to internal validity (Johnson & Christensen, 2014). In particular, the history threat is worrisome if a) when something in addition to the treatment occurs between the pre- and posttests measurements of the dependent variable and b) when the time interval between pre- and posttests measurement is lengthy. To minimise the history threat to internal validity in the English case study, the students did not have any English lessons between the pre- and posttests. The short period of time between the pre- and posttest contributed to minimising the threat to internal validity due to a) *maturation* through physical or mental changes that may occur within

individuals over time, such as aging, learning, boredom, hunger and fatigue that might affect an individual's performance on the dependent variable and b) *regression artefact* which refers to the fact that extreme (high or low) scores will tend to regress or more toward the mean of a distribution on a second testing or assessment possibly because of extraneous factors (Johnson & Christensen, 2014). Another threat to internal validity concerns *instrumentation* that refers to any change that occurs in the way the dependent variable is measured (Johnson & Christensen, 2014). To minimise this threat the students in the target and comparison classes were exposed to similar learning resources, the time slots for group discussions and writing sessions were also identical. The only difference between the classes was the use of EssayCritic (dependent variable) by the students in the target class. Finally, *testing* that refers to, changes that may occur in participant's scores obtained on the second administration of a test as a result of previously having taking the test (Johnson & Christensen, 2014) did not affect the internal validity of the results as the students in both classes did not rewrite the same essay, but used different types of feedback to improve their essays.

The use of mixed methods also contributes to validity by comparing multiple data sources throughout the design (*triangulation*) (Brevik, 2015). *Triangulation* allowed me to draw on different data sources (qualitative and quantitative) to look for consistency and nuances of the same phenomena (Bazeley & Kemp, 2012; Greene, 2007; Johnson & Christensen, 2014). Through this validation approach I searched for convergence of results by integrating multiple data sources: the extracts of student-student and student-teacher interactions, the extracts from students' essays, pre- and posttests' grades, the number of subthemes included in the pre- and posttests and the number of teachers' interventions at different times.

A threat to validity associated with all research that is overt is the *issue of reactivity* (Blikstad-Balas, 2014), how people have a tendency to change their behaviour whenever they know that they are being studied (Boeije, 2009). However, I do not consider reactivity to be a threat to the validity of this study. First, it is believed that people get used to being observed after an initial period (Haw & Hadfield, 2011; Heath et al., 2010). Second, the students in the observed groups did not show any signs of being affected by the presence of the camera and/or the researchers: they were engaged in group discussions and stayed on task. Third, in the individual and class interviews the students did not express they experienced any inconvenience from the camera.

Statistical conclusion validity refers to the validity with which one can infer that two variables are related and the estimated strength of this relationship is accurate (Johnson & Christensen, 2014). This type of validity refers to statistical inferences and was addressed in

the studies by employing a number of statistical tests: paired t-test, independent t-test, Cohen's d and one-way ANOVA test. More detailed descriptions of how these tests were implemented are in Articles Two and Three in Part II in this thesis. The statistical conclusion validity is closely related to internal validity as both are concerned with the relationship between treatment and outcome (Shadish et al., 2002).

Specific to the mixed methods approach is *sequential validity* that refers to the extent to which one has appropriately built on the prior stage in a sequential design in an attempt to understand whether the results would have been different had the phases been conducted in a different order (Johnson & Christensen, 2014). The complexity of students' learning with digital tools examined in Phase 1 affected the research design in Phase 2: the examined interplay of material and social mediational means in the learning process in Phase 1 (Article One) determined the introduction of group discussions of the feedback provided by EssayCritic in Phase 2 (Articles Two and Three). Therefore, the chosen sequential–concurrent design comprising the studies conducted in a particular order (a qualitative article in Phase 1 followed by two mixed methods articles in Phase 2) contributes to the sequential validity of this thesis.

Lastly, the legitimation specific in mixed research is *multiple validities*. This term refers to the extent in which the mixed methods researcher successfully addresses and resolves all relevant aspects of validity, including qualitative and quantitative validity as well as the mixed validity dimensions. In this section I have made every attempt to address the types of validity applicable to qualitative, quantitative and mixed methods research design by using the contributions that discuss the issues of validity in the respective fields (Creswell, 2012; Greene et al., 1989; Johnson & Christensen, 2014; Shadish et al., 2002).

4.7.3 External validity

External validity refers to the *generalisability* of the findings and concerns inferences about the extent to which a causal relationship holds over variations in persons, settings, treatments and outcomes (Shadish et al., 2002). Generalisability can be both qualitative and quantitative (Creswell, 2012; Silverman, 2011) and both are relevant to this thesis.

In *quantitative research* generalisability has been defined as a standard aim which is normally achieved by statistical *sampling* procedures (Silverman, 2011). The sampling should ensure its representativeness and such representativeness allows making broader inferences. The number of students involved in the studies (seventy six in the Science case and one hundred and twenty five students in the English case) does not meet the requirement of a population of students. In addition, the selection of the classes and, hence, the participants was not random but was based on the willingness of the teachers to participate. This implies that the effect

EssayCritic had on the final drafts of students' essay does not guarantee that the same effect can be achieved elsewhere. Based on these premises the quantitative findings are not generalizable. However, the findings in Articles Two and Three were discussed in relation to the previous research with EssayCritic and they corroborated the earlier findings.

In *qualitative research* random sampling of cases is not achievable (Silverman, 2011) and therefore, generalisability of qualitative findings is questionable. Nonetheless a few attempts to increase the strength of the qualitative results have been perceived. *First*, a large number of student-student and student-teacher interaction extracts in both cases were analysed which allowed identifying the patterns of interactions across groups and classes at various times. The principle of patterns was used when selecting extracts for the analysis in all three studies. *Second*, similar findings emerged in the analysis of students' learning with technology in Science and English (Articles One and Two) and in the analysis of teachers' facilitating of students' learning (Articles One and Three). Such patterns representing students' learning and teachers' facilitating of the learning process across subject areas may contribute to confidence in the findings. Based on these efforts it is likely that some of the findings may be transferable to similar learning situations.

4.7.4 Ethical considerations

I now elaborate on the ethical issues from the perspectives of the Guidelines for Research Ethics in the Social Science, Law and Humanities[5] (Guidelines) adopted by the National Committee for Research Ethics in Norway[6] (NESH).

The notification for the data collection was approved by The Norwegian Centre for Research Data[7] (NSD) at the beginning of the Ark & App project.

The recruitment of the schools to the case studies was in line with the obligation to respect integrity, freedom and right to participate of §6 and §8 of the Guidelines. Introductory meetings were held for the staff in both schools and the students were also informed about the purpose of the research and the consequences of the participating in the project. Central to the Guidelines is the idea of *informed consent*. The right to be informed means that the potential research subjects should be given a detailed but non-technical account of the nature and aims of the research (Silverman, 2011). Due to the ages of the students, a written letter of consent was sent home with the students to be signed by their parents or guardians. The letter explained

[5] See: https://www.etikkom.no/en/ethical-guidelines-for-research/general-guidelines-for-research-ethics/
[6] See: https://www.etikkom.no/
[7] See: http://www.nsd.uib.no/nsd/english/index.html

the objectives and the intended outcomes of the project and the practical methods that were going to be used during data collection. The participants were informed that all collected data would be saved on the University server and would be accessible only by the research team. The letter also asked for parents' permission to use anonymous photos of students in the project disseminations. It was emphasised that the participation in the project was completely voluntary and the student could withdraw from the project at any time. The letter ensured confidentially and use in the research purposes only of the collected video data, in line with §14, §15 and §16 of The Guidelines.

Following §21 on public administration of The Guidelines the research team was flexible regarding the dates and the time of the project. The data collection timeline was adjusted to the existing timetable and the demands of the schools.

In line with the requirement for independence (§23 of The Guidelines), the research team took a role of independent observers and did not interfere in the teaching process happened in classes. The teachers had the main responsibility for preparing teaching resources, conducting teaching in classes and managing the students.

In the analysis of the data, an objective approach to interpreting data was taken in line with the §40 of The Guidelines and following the §41, 45, 46 of The Guidelines where knowledge is treated as a collective benefit, the findings of the research have been reported in the articles available in the open access for the community of researchers.

5.0 SUMMARY OF THE THREE ARTICLES

This chapter presents the summaries of each of the three articles included in this thesis.

5.1 Article One

Engeness, I. & Edwards A. (2017). The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools. *Scandinavian Journal of Educational Research 61(6)*, p. 650-667 doi:10.1080/00313831.2016.1173093

This article is based in the premise that when students engage in learning with digital tools in classrooms, other mediational means are also inherently present in the learning situation. It explored the landscape of the mediational means present in classroom learning and examined the relationships between these means while supporting students' learning. The support components that have been selected for investigation were: digital tools, task design, peer collaboration and teacher interventions. The research questions addressed in the study are:

RQ1: What characterises the relationship between the digital tools, task design, peer collaboration and teacher interventions in students' learning?

RQ2: How do these mediational means support students' development of conceptual understanding in Science?

The analysis uses a cultural-historical perspective on learning that allows examining how tools, which may be social and linguistic as well as material artefacts, operate as mediational means, which carry the meanings that are of value in a culture (Vygotsky, 1980). The article's claim to originality is that the analysis draws on Galperin's conceptual contribution, which suggested seeing learning as the gradual transformation of socially constructed mental activities by identifying dialectically developing forms of socially meaningful activity. These forms of activity, termed by Galperin as phases of the leaning process, lie at the core of the analysis in the article. The study also employs Schwab's understanding about how curricular knowledge is defined in ways which are compatible with cultural-historical approaches to pedagogy (Schwab, 1982).

The Year 10 students' learning was supported by the compare and contrast task, digital animations, mainly from Viten.no web-based environment, peer collaboration and the teacher's interventions. Student-student and teacher-student interactions were analysed employing interaction analysis (Jordan & Henderson, 1995); and Galperin's dialectically linked forms of activity situated the analysed extracts in the flow of the learning activities the students engaged in.

By employing Galperin's categorisation it findings reveal that material digital tools and task design and social peer collaboration and teacher interventions dialectically interplay to

shape how learners use each of the mediational tools: i) digital tools were the resources that enabled students to explicate their (mis)understandings; ii) a compare and contrast task promoted analytical thinking; iii) peers presented themselves as resources, who promoted development of conceptual understanding; and iv) the teacher guided learners' attention towards the potential of mediational resources, elicited, organised and structured students' knowledge. It is argued that the dialectical interplay of these mediational means created a system that supported and guided students' learning. In particular, it allowed learners to acquire the relevant substantive knowledge of the scientific concepts and their relation to each other together with the syntactic knowledge of scientific thinking in the form of analytical comparing and contrasting.

The recognition of the dialectical relationships in the system of interplaying material and social mediational means both draws and gives support to Galperin's detailed attention to the dialectically linked forms of social activity/phases involved in learning in formal settings. The analysis has shown that in the phases of orientation, materialised action and communicative thinking it is the dialectical interplay of material and social mediational tools shapes how each of them is used by learners. Applying Galperin's theory in this study appeared to be a helpful addition to the method of interaction analysis to understand what students did at different times as they progressed in their learning. The article suggests that this approach may offer new pathways for the use of Galperin's conceptual contribution in further research exploring teaching-learning process, design of learning activities and educational technologies.

5.2 Article Two

Engeness, I., & Mørch, A. (2016) Developing Writing Skills in English Using Content-Specific Computer-Generated Feedback with EssayCritic. *Nordic Journal of Digital Literacy, 11*(2), p.118–135, DOI: 10.18261/issn.1891-943x-2016-02-03

In this study, based on the findings from Article One which argued that material and social mediational means dialectically interplay in supporting the learning process, 'the social interaction' component was integrated into the research design. The students in both classes (target and comparison) worked in groups of four during the writing process to discuss and make sense of the feedback given by EssayCritic (target class) and the 'manual' feedback provided by collaborating peers (comparison class). The study addresses the following research question:

RQ: How do different types of feedback assist students in their writing process?

Cultural-historical perspectives (Vygotsky, 1980) on learning and development are employed in Article Two to examine students' learning with and without technology and Galperin's types of orientation and dialectically developing forms of learning activity/phases are at the core of the discussion in the article.

The data were collected in the frame of Phase 2: the English case study, when one hundred and twenty five students from the upper secondary school engaged in the writing process in English. The students were to write an essay based on the content of the chapter in the textbook *Passage* (Burgess & Sørhus, 2009) and other learning activities the students had previously engaged in English classes. The topic of the essay was collaboratively created between the classroom teachers and the researchers: *"Write an essay on the topic of English as a Global Language: Explore how English was spread around the globe, and present the most important reasons for this development"* (300-400 words). In the first round the students in five classes wrote the first draft (pre-test) of the essay using only a laptop as a writing tool. The classroom teachers marked the essays and eleven essays that were awarded grades 4, 5 and 6 (on 1–6(max) scale) from three classes were selected to code for the subthemes of the topic "English as a Global Language" and to train EssayCritic. A more detailed description of the EssayCritic system is presented in Article Two and Article Three in Part II of the thesis.

The remaining two classes (48 students) were assigned as the target and comparison classes. The students of the target class uploaded the first draft to EssayCritic and after they had discussed the feedback received from the system with their peers, they produced the second draft. The students of the comparison class read each other's essays and gave advice on how to create the second draft. All students repeated the process of receiving feedback and revising their essays one more time, which resulted in the production of the third draft (posttest) handed in to the teachers for final evaluation. The classroom teachers and an independent teacher marked the anonymised essays (pre- and posttests) on the scale 1-6 (6 max).

Qualitative analyses of student-student interactions reveal that the feedback from EssayCritic gave content-specific cues that shaped the discussions in groups and were incorporated in students' essays in the target class. However, in the comparison class the students struggled when giving feedback to each other. In addition, quantitative analysis of students' pre- and posttests showed that the students in both classes significantly improved their grades, although the students in the target class included significantly more subthemes in their posttests than the students in the comparison class.

On the one hand, the article argues for the usefulness of EssayCritic in generating feedback based on text-based artefacts and providing formative feedback, which is dynamically

computed by comparing individual essays with the best essays produced by the community of learners, suggesting further improvements in a cycle of writing activities. On the other hand, it is pointed out that the feedback given by EssayCritic was framed by the contextual constraints of the textbook *Passage* and the pedagogical choices of the teachers made when identifying eleven subthemes to train the system, which might have affected the produced final drafts by narrowing the content of students' essays. In addition, the individually tailored feedback given by EssayCritic supported the frame of the complete orientation (Galperin, 2002) assisting the students to complete a specific task by providing the feedback about the task, but not about the processing the task (Hattie & Timperley, 2007). In doing so, the feedback given by EssayCritic downplayed the development of students' AfL skills and their capacity in learning to learn. This has implications and suggests potential for further improvements of EssayCritic. In the comparison class, however, the students were exposed to the complete orientation, created by learners following an offered (AfL) approach (Galperin, 2002). Despite the fact that learners experienced difficulties when giving feedback to each other, their previous experience in the AfL practices served as an approach offered by the teacher, which the learners were able to pursue to enhance their agency in learning to learn. The findings outlined in Article Two suggested the need to examine and compare what actually classroom teachers did when facilitating students' learning with and without EssayCritic.

5.3 Article Three

Engeness, I. (accepted for publication) What teachers do: facilitating the writing process with the feedback from EssayCritic and collaborating peers, *Technology, Pedagogy and Education*.

The study investigates how teachers facilitate learners' capacity in the writing process with the feedback from EssayCritic (target class) and the feedback from collaborating peers (comparison class). Cultural-historical perspectives on learning and development (Vygotsky, 1980) and Galperin's conceptualisation of learning (Galperin, 2002; Haenen, 2001; Rambusch, 2006) were chosen to provide explanation for the different conditions of mediation in both classes and as a lens to examine teachers' facilitating of students' learning in similar forms of activity/phases of the writing process. The study addressed the following research questions:

RQ1: How do teachers facilitate students' writing process with the feedback from EssayCritic and collaborating peers?

RQ2: How does EssayCritic affect teachers' facilitating of students' writing?

The data were collected in the frame of Phase 2: the English case study. Qualitative analysis of teacher-student interactions when the learners engaged in the similar forms of activity of the writing process in the target and comparison classes revealed the patterns in

teachers' facilitating. The findings showed that the teachers in both classes: i) set up the writing process in the orientation phase; ii) assisted the development of students' conceptual understanding in the phase of communicated thinking and iii) brought learners' attention to the essential requirements of the essays in the phase of dialogical thinking. In sum, the teachers fulfilled the orienting, executive and control functions when facilitating students' writing.

On the other hand, the article argues that the presence of EssayCritic in the writing process affected the teachers' facilitating in the target class: the instructions given by the teacher were focused on integrating EssayCritic, relying on it and interacting with the programme over time, indicating an occurring dependency of the teacher on the technology comprising: i) introducing the technology to learners, revealing its potential and integrating EssayCritic in students' learning in the orientation phase; ii) relying and interacting with EssayCritic when assisting the development of students' conceptual understanding in the phase of communicative thinking and iii) taking advantage of EssayCritic when initiating the learners' reflections about the essential requirements in the phase of dialogical thinking. In addition, the feedback given by EssayCritic determined the complete orientation of students' learning (Galperin, 2002) providing specific instructions about how to solve a particular task: write an essay on the chosen topic with the requirement of a variety of subthemes. The teacher's close interaction with EssayCritic and the specific cues given to students by EssayCritic appeared to be at the expense of the development of students' AfL skills and capacity to control the writing process. However, in the comparison class by emphasising the essential feature of the essays (a variety of subthemes) for the learners in the orientation phase, the teacher appeared to offer a general approach, drawing on students' previous experience of AfL strategies, to help them when writing, analysing and shaping the drafts of the essay. In doing so, the teacher appeared to contribute to the development of students' understanding of how to approach to the analysis of the essential requirements of the essays, the development of learners' AfL skills and greater control over the writing process.

Quantitative analyses of teachers' interventions in the writing process revealed that the teachers in both classes offered more assistance in the phases of orientation and communicated thinking than in the dialogical thinking, which might potentially indicate that learners require more guidance at the beginning and the middle of the writing process rather than in its final phase. The teacher in the target class, however, provided significantly less guidance in the first two phases of the writing process than the teacher in the comparison class, which might indicate that the feedback given by EssayCritic might have occasionally substituted the teacher's assistance.

Article Three outlines the implications of the findings for pedagogical practice and the design of digital tools: i) conceptualising of teachers' guidance by fulfilling the orienting, executive and control functions when facilitating the writing process; ii) the need for practitioners' awareness of whether the technology supports the development of, for example, AfL skills required in ESL/EFL writing classes; and iii) the need for further modifications of EssayCritic to incorporate the requirements of Galperin's the third type of orientation: complete and created by learners following an offered approach, such as AfL (Galperin, 2002). Such modification would assist students in recognising and articulating the AfL approach learners may pursue in the analysis of essays, and developing their understanding of what demands the essays are making and how well they are meeting them.

In addition, Galperin's forms of learning activity appeared to be helpful as a lens to reveal the dialectics of students' learning and as a tool to examine and conceptualise the nature of teachers' pedagogic interactions with groups of students at different times of the learning process. The findings also showed that the linearity of the transformation from the orientation to dialogical thinking, suggested originally by Galperin, was disrupted by the presence of EssayCritic in the writing process. The recursive nature of students' engagement with EssayCritic might have implications for the design of digital tools and teachers' facilitating of learning activities with technology. Another potential implication for further studies that have learning and teaching process as a focal area, is that Galperin's types of orientation provided an explanation for the conditions of mediation in the target and comparison classes. Overall, the findings in Article Three may inform the practitioners about the types of instructions teachers give when facilitating the writing process and emphasise the crucial importance of teachers' awareness about the type of support technology provides with the purpose of integrating of technology to enhance their pedagogy and student learning.

6.0 DISCUSSION: LEARNING AND TEACHING WITH DIGITAL TOOLS

6.1 Introduction

The overarching aim of this thesis is:

- *To make explicit how adolescent students learn when using digital tools in Science and writing classes in English and how teachers facilitate students' learning in these conditions.*
- *To use and evaluate the pedagogical categories developed by Galperin as analytic resources to reveal students' actions in the classrooms with digital tools.*

In this chapter I consider the empirical, theoretical and methodological contributions of the thesis and outline the potential implications for the design of digital tools and use of technology in classrooms to facilitate students' understanding of what learning makes. Finally, the limitations of the present study and the directions for future research are discussed.

6.2 Characteristics of learning and teaching with digital tools

6.2.1 Dialectics in learning and teaching with digital tools and the usefulness of Galperin's pedagogic categories

The findings reported in Article One offered an account of the interplay of the mediational means of task design, peer collaboration, teacher interventions and digital tools to create a structure that supported and guided students' engagement with the curriculum. Figure 6A may serve as a visual representation of the findings reported in Article One, reflecting the complexity of learning with digital tools. 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 interplay of the mediational means of task design, peer collaboration, digital tools and teacher interventions creates a structure that supports and guides students' learning.

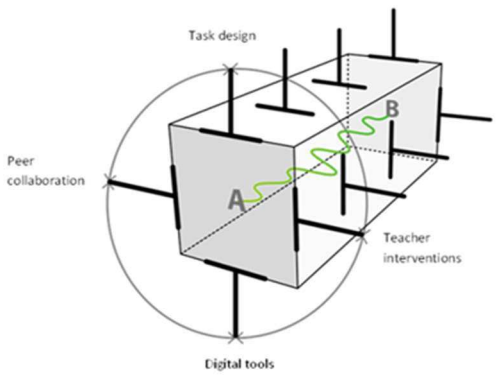

Figure 6A. Interplay between mediational means in the learning process

The analyses in the Science case study showed that the interplay of the mediational means allowed students to acquire relevant substantive and syntactic knowledge (Schwab, 1982) and revealed how each of the mediational means assisted students' learning: i) digital tools were the resources that enabled students to explicate their (mis)understandings; ii) a compare and contrast task promoted analytical thinking; iii) peers presented themselves as resources who promoted different conceptual understandings and iv) the teacher guided learners' attention towards the potential of the mediational resources, elicited, organised and structured students' knowledge. This interplay of material and social mediational means has several implications for classroom pedagogy which are discussed in detail in Article One in Part II in this thesis.

The characteristics of learning and teaching with digital tools were examined further by analysing how students engaged in learning by interacting with others and with digital and other support tools. Galperin's categorisation of forms of activity (orientation, materialised action, communicative and dialogical thinking) were visible in the interactions with others and material resources in both Science and English case studies (Articles One, Two and Three). In both case studies, the initial form of the learning activities was orientation, where the teacher oriented the learners by introducing the task, the available support resources and indicated their potential. The orientation phase was followed by material or materialised action, comprising learners' involvement with material or materialised objects. In both case studies, students engaged with materialised objects: with the digital animations in Viten.no (Article One), with the computer-based system EssayCritic (target class) and with the drafts of essays and other resources used by the students in the comparison class (Articles Two and Three). In both studies, the digital and other materialised resources encapsulated the essential characteristics of the target concepts. The analyses revealed that these resources triggered students' discussions and their interactions with these resources contributed to their accomplishing of classroom tasks. These findings suggest the importance of choosing materialised resources that encapsulate the essential characteristics of the target concept to support students' conceptual learning as a dialectical process between tool use and learning. The findings might also have implications for the design of digital tools, indicating the need to encapsulate the key features of the target concepts in software. Students' learning, arising from the involvement with the materialised resources, was reflected in student-student and student-teacher interactions and in doing so, learning as an activity was transformed, from materialised action to communicated thinking.

The analyses of students' learning in communicated thinking through student-student and student-teacher interactions in the Science (Article One) and the English case studies (Articles Two and Three) revealed that this form of activity reflected the earlier materialised

action. The target concepts in the communicated thinking remained the same; however, the form of the activity was different: the learners reflected on the concepts while they were making sense (of mitosis and meiosis in Science and writing process with different types of feedback in the English case study) through talking. In both studies, the learners were performing the activity by talking about the essential features of the concepts offered in the models they engaged with: the essential features of mitosis and meiosis in Viten.no and the feedback from EssayCritic based on the model of an 'ideal essay'. In communicated thinking, learners' thinking processes became accessible to other students and the teacher and allowed building up, correcting, organising and structuring of the ideas by all the participants.

6.2.2 The affect of digital tools on the sequential linearity of Galperin's pedagogic categories

However, the findings in both case studies showed that the sequential linearity of the transformation from materialised action to communicated thinking, suggested originally by Galperin, was disrupted by the presence of the digital tools in the learning process. In both case studies, the learners relied on the digital tools during both group discussions and individual work. There was a constant move between materialised action, communicated and dialogical thinking, which had not been captured in Galperin's work and could not be easily anticipated as his research was carried out before computers entered the classroom.

In both case studies, there was evidence of dialogical thinking, where, by formulating their answers and explicating their thoughts in writing, the learners reflected on what they had learnt during the previous three forms of activity. Again, the linearity underpinning Galperin's categorisation could be questioned. While undertaking dialogical thinking the learners also engaged with images of the materialised models: for instance, in the Science case study when writing their answers, they used the diagrams of mitosis and meiosis in the task sheet and the digital animations in Viten.no and in the English study they matched their final drafts to the 'ideal essay' containing the key requirements of the assignment. The analysis therefore showed students' moves in both directions: from dialogical to communicated thinking, when seeking clarifications from the rest of the group or the teacher; and returning to materialised action when calling on digital animations at Viten.no and the feedback from EssayCritic. These findings indicate non-linearity of the sequence of Galperin's forms of activity when students engage in learning with digital tools while in groups. The iterative nature of students' engagement with the task and the resources available to them might have implications for the design of digital tools and learning activities with technology. In addition, the findings in Article 1 revealing the dialectical interplay of social and material tools when students engage in learning with

technology contribute to the complexity of students' move from one form of learning to another. The underpinnings of this complexity comprising the dialectical interplay of social and material tools were not (and could not be) explained by Galperin and his colleagues.

In sum, the findings from the two cases studies revealed the complexity of learning with digital tools, in particular the dialectical interplay of material and social mediational means and the lack of sequential linearity of Galperin's forms of activity as students' own sense-making was propelling the activity.

The implications of these findings for classroom pedagogy indicate the importance of introducing both material and social support resources to assist students' move from orientation to dialogical thinking. In both cases, the materialised objects, digital tools, encapsulated the key characteristics of the target concepts, both substantive and syntactic knowledge in Schwab's terms. The continuing reliance of students on these representations at different stages in the learning process may have implications for the design of digital tools to support conceptual understanding. Learning aimed at the understanding of the key features of a target concept may therefore lay foundations to an approach to learning that can be applied across contexts and tailored to different subject areas. Such an approach may empower students in developing their understanding about what how knowledge is created in different subject areas, what learning takes and gaining control over own learning. This aspect is discussed in more detail in the next section.

6.2.3 Orienting learning with digital tools and the implications for the development of student's agentic capacity in learning to learn

The findings presented across the three articles have shown that students' learning with technology was at least in part shaped by how the teachers framed and facilitated the learning process. This framing was examined from the perspective of different types of orientation (Galperin, 2002) particularly in Article Three, though it also features in Articles One and Two.

The findings of Articles One and Three revealed visible similarities in teachers' actions aimed at orientation across subject areas: they introduced the available mediational resources to learners, indicating their potential, oriented the students towards the task and ensured learners' understanding of what they were expected to do. However, the findings also showed that the availability of the mediational resources and the support they provided (described in Articles Two and Three) informed how the students engaged in learning and affected the development of their conceptual understanding and their capacity to be in control of own learning. For instance, in the English case study (Articles Two and Three) the findings revealed that the students in the target class engaged with the feedback from EssayCritic and were exposed to

so-called complete orientation (Galperin, 2002). This implied that the mediational resources to assist learners in completing a specific task were available: EssayCritic provided individually tailored feedback about how to improve students' essays by advising the learners about the covered and suggested subthemes.

Nonetheless, analyses also revealed that this dependence on EssayCritic had some costs. On the one hand, the findings in Article Two showed that the feedback given by EssayCritic triggered the groups' discussions and was incorporated in the learners' essays, consequently the students in the target class included significantly more subthemes in their posttests than the students in the comparison class. On the other hand, Article Three argued that the complete orientation determined by EssayCritic assisted the students in completing a specific task, but did not augment the development of students' conceptual grasp and their understanding of AfL strategies. This might have implications for learners' capacity to be in control of their own writing process. In addition, the findings in Article Three, focusing on what teachers do, showed that the complete orientation determined by the feedback from EssayCritic affected the teacher's facilitating of students' learning in such a way that the teacher developed some dependency on the technology when assisting learners in the writing process. Therefore, Articles Two and Three, in different ways, argue that the individually tailored feedback from EssayCritic and the teacher in the target class did not contribute overtly to developing of students' conceptual understanding and enhancing students' capacity to be in control of their own writing was downplayed.

The findings in the English case study also showed that the students in the comparison class were exposed to Galperin's third type of orientation: complete and constructed by learners. The findings revealed that students' previous experience in AfL strategies, articulated by the teacher, appeared to contribute to the development of students' understanding of the approach to be taken to task accomplishment, by pointing to the demands and key features of the essay the students had to write. Such an approach built on students' knowledge of AfL and had the potential to contribute to their control over the writing process. These findings may have implications for further modifications of EssayCritic, where learners are directed towards the third type of orientation and they are invited to consider AfL strategies. Such a modification may contribute to facilitating the development of learners' understanding about the nature of the writing process and enhance their agentic capacity in learning to learn.

The discussion about the type of orientation in students' learning with digital tools in Science was not emphasised in Article One. Instead, the analysis of the dialectical interplay of the mediational means showed students acquiring relevant knowledge and indicated how each

of the mediational tools assisted students' learning. In these conditions students were exposed to Galperin's third type of orientation: complete and created by learners after guidance from the teacher. The teacher's approach was framed by the compare and contrast exercise the learners engaged with. Through comparing and contrasting they identified the key features of the target concepts. The compare and contrast approach also determined the choice of the learning resources (digital animations) and how the learners used them. Comparing and contrasting established the frame for the third type of orientation, revealing an approach for studying scientific concepts previously described in the works of Vygotsky (Vygotsky, 1986) as identifying the essential characteristics of a studied phenomenon. The technology (animations in Viten.no), in turn, demonstrated the complex scientific phenomena that were otherwise invisible for students and triggered group discussions. This finding may have implications for the design of digital animations in Science so that animations are able to facilitate and promote students' understanding of how to approach studying scientific concepts by identifying their essential characteristics.

Summing up, the findings in both Science and English case studies showed that the third type of orientation (complete and constructed by learners following an offered approach) may indicate a way of learning that facilitates not only conceptual understanding of the curriculum, but it may also contribute to the development of learners' understanding of an approach to learning in different subject domains. By adopting such an approach, a learning activity may be aimed at bringing about (i) acquisition of new conceptual knowledge and ways of working in a subject area; and (ii) the development of students' understanding of the nature of learning, and enhancing their capacity in learning to learn.

In this respect *learning activity* with the third type of orientation has the potential to not only achieve learning outcomes, but, it acquires also a functional significance, becoming *a tool* in the learning process aimed at the development of students' understanding of an approach to learning. As mentioned in Chapter 3, the development can be found when there are qualitative changes in a person's orientation and actions across different practices. 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 in different subject domains and enhancing their agentic capacity to be in control of their own learning.

6.3 Learning and teaching with digital tools and insights for learning to learn

I have already begun to indicate that the findings discussed in all three articles may also have implications for the design of digital tools and learning activities in classrooms. In particular there may be a need for some modifications to the tools used to enhance students' capacity in learning to learn. One of the practical implications may be future modifications of EssayCritic to account for the requirements of the third type of orientation aimed not only at assisting students in completing a specific task, but facilitating the development of learners' understanding of the approach revealing the nature of the writing process. With regard to animations depicting scientific processes, the findings of this study indicate that other resources may be introduced to reveal the approach that may assist the development of students' understanding of the nature of learning. As reflected above, in the Science case study (Article One), the compare and contrast task carried this function, by offering an approach of analytical comparing and contrasting that assisted learners in identifying the essential features of the studied scientific concepts. In addition, the teacher fulfilled an important orienting function by drawing students' attention to the available resources, the compare and contrast exercise and revealing the potential of these resources for the learners.

Summing up the findings from the case studies, I suggest that some tentative approaches might be pursued when designing digital environments aimed at enhancing students' capacity to be in control of own learning. *First*, when designing a digital environment it seems important to clearly identify the essential features or structural parts of the target concepts. *Second*, if a learning activity is to adequately assist the development of learners' understanding of the essential features of the concept it might be organised according to the third type of orientation. *Third*, some of the resources to assist learners in the development of their understanding of the essential features of the target concept may be presented in material or materialised form. In both case studies the students interacted with materialised resources in the early stages of their learning and this experience informed later interactions and activities. *Fourth*, social interactions of learners in the form of group discussions should be integrated in the learning process. These social interactions may contribute to learners' understanding of the target concept and transform students' learning activity from materialised action to communicated and dialogical thinking. *Finally*, the role of the feedback and teacher's facilitating of the learning process need to be accounted for in the design: the feedback provided to learners by digital tools or a teacher might assist students both in identifying the essential characteristics of the target concept and as an approach to enhance students' understanding about what learning

makes. As indicated above, these approaches are tentative and might be examined in further research. The further empirical, methodological and theoretical contributions of this thesis are outlined in the next section.

6.4 Empirical, theoretical and methodological contributions

6.4.1 Empirical contributions

This thesis makes several empirical contributions to the field. *First*, the findings in the Science case conceptualise the complexity involved in students' learning with digital tools by emphasising a dialectical interplay between social and material mediational resources. This dialectical interplay of the material and social mediational means creates a structure that supports and guides students' learning.

Second, the analysis of the empirical data in the Science case demonstrates that digital animations used to support learning in Science are the resources that enable students to explicate their (mis)understandings and hence, contribute to the development of learners' conceptual understanding (Ainsworth, 2006; Ainsworth & VanLabeke, 2004). However, it was the analytical approach of comparing and contrasting that allowed the students to identify the essential features of the target concepts. Focusing on both the concepts and revealing the methods by which the learning occurred, may facilitate the development of learners' understanding of how to study concepts and therefore, may empower students with an approach to learning in Science and other curricula.

Third, the feedback given by EssayCritic in the writing process in the English case study (i) provided orienting cues that triggered students' discussions; (ii) was incorporated in students' essays; and (iii) resulted in the significant increase in the number of subthemes included in the final drafts. However, the feedback did not augment learners' capacity to be in control of their own writing processes. The findings in the English case study may therefore indicate that individually tailored specific feedback about the task (complete orientation) may assist learners in solving a particular task; while the combination of the feedback about the task (covered and suggested subthemes) and about the processing of the task (analysis of essays aimed at identifying the essential characteristics in the form of covered and suggested subthemes by learners themselves – the third type of orientation: complete and created by learners following an offered approach) may reveal an approach to the writing process and therefore, augment learners' capacity to be in control of their own writing and enhance their agentic capacity in learning to learn.

The *fourth* empirical contribution considers the role of the teacher facilitating technology-enhanced learning. The findings in Articles One and Three included in this thesis reveal that the teachers: i) set up the learning process, introduced the available mediational means for learners and indicated their potential; ii) assisted and guided learners in the development of their conceptual understanding in the course of the learning process by eliciting, structuring and organising students' ideas and iii) encouraged learners' reflections about the requirements of the assignment and how well their work matched them. In doing so, teachers fulfilled *orienting, executive* and *control* functions. These functions performed by teachers in this study contribute to conceptualising the role of the teacher facilitating students' learning with digital technology while in groups.

The *fifth* empirical contribution is that digital technology may affect teachers' facilitating of the learning process and the practitioners may experience dependency on technology (Article Three). This raises a question about the need for educators' awareness of the type of support technology provides when they incorporate technology in their pedagogy.

6.4.2 Theoretical and methodological contributions

This thesis makes also several theoretical and methodological contributions to understanding of students' learning with digital tools. Regarding its *methodological contribution,* this thesis argues that it is the dialectical interplay of material and social mediational means that assists and guides students' learning and allows for learners acquiring relevant substantive and syntactic knowledge (Schwab, 1982): concepts and their relation to each other and scientific thinking in the form of analytical comparing and contrasting. Understanding the dialectical nature of learning indicates some of the challenges of teaching in digitally enhanced environments. Such a complexity of learning in digital environments therefore, draws analytical attention to both material and social support tools when examining students' learning in these conditions.

One of the *theoretical contributions* considers the role of the teacher facilitating learning in digital environments. Previous research has mainly focused on the types of feedback teachers give on students' writing showing that specific, ideas-based, meaning-level feedback in the context of multiple-drafts can be effective in promoting student revision (Hyland, 1990). In addition, research has shown that teachers' feedback is preferred to feedback from peers in English as a second language (ESL) writing class (Paulus, 1999; Tsui & Ng, 2000; Yang, Badger, & Yu, 2006; Zhang, 1995). Articles One and Three outlined what teachers did when students engaged in learning with computers and Article Three summarised these practitioners' actions as: i) orienting (setting up the learning process, introducing the available mediational

means for learners and revealing their potential), ii) executive (assisting and guiding learners in the development of their conceptual understanding in the course of the learning process by eliciting, structuring and organising students' ideas and iii) control (encouraging learners' reflections about the requirements of the assignment and how well their works match them) functions. This conceptualisation of the teachers' role when students engage with computers contributes to a perspective of research (i.e., teachers' facilitating) of technology-enhanced learning.

The other *theoretical* contribution of this thesis is introduction and use of Galperin's pedagogical concepts in the analyses of the data in both Science and English case studies. Galperin's dialectically linked pedagogical forms of activity appeared to be a helpful addition to both the quantitative (outcome analysis) and qualitative (interaction analysis) methods used in Articles One, Two and Three, revealing what students and teachers did at different times as they progressed in their learning. An important finding and contribution of this thesis is that the sequential linearity of the forms of activity students and teachers engaged in offered originally by Galperin, was disrupted by the presence of digital tools. In both case studies, it was the digital tools that triggered students' move from, for example, dialogical thinking to materialised action or communicated thinking. In doing so, the digital tools contributed to the complexity of learning comprising the dialectical interplay of material and social tools that support students' engagement with curriculum. This contribution extends Galperin's pedagogical categories by accounting for learning with digital tools. Galperin's types of orientation also conceptualised the type of learning (the third type of orientation) that reveals an approach to learning that may enhance the students' capacity to be in control of their own learning. Such use of Galperin's conceptual contribution may have implications for further research that has learning and teaching process with digital technology as a focal area and may lay foundations for the design principles of digital tools and environments aimed at enhancing students' agentic capacity to take themselves forward as learners.

6.5 Limitations, future research and concluding remarks

I conclude this thesis by discussing its limitations and pointing to the potential areas for future research. In learning with digital tools in groups, several features of interactions may contribute to the development of students' conceptual understanding, including for example, bodily movements and gestures. Therefore, further research may benefit from exploring the relationships between the material, social and bodily aspects that facilitate, support and guide learning in groups in formal settings.

In this study I have reported on the findings emerged from the analyses of the data collected in the case studies that examine how digital tools are used by students in learning activities. Therefore, a longitudinal design to study students as writers would have provided a more comprehensive insight into the development of students as both writers and learners. A longer-term study would have been able to examine whether, for example, students are able to apply their text analysis and feedback-giving skills developed when using EssayCritic and provide orienting feedback about the task and about processing of the task without EssayCritic across educational contexts.

If I were to repeat this study again, I would have put more analytical attention to the development of students' understanding of what it means to learn in Science. I have made an attempt to overcome this limitation by reflecting on this aspect in section 6.1, however, similarly to the English case study, a long-term study would have provided opportunities for examining the development of students' agentic capacity in learning to learn in Science.

There are also implications for further research. The design of EssayCritic supported the complete orientation of students' learning by providing individually tailored feedback and assisting the learners in task completion. In doing so, the feedback appeared to downplay an emphasis on the learners' capacities for self-assessment and forming their understanding of what was needed in the essays. Therefore, further research is needed with a modified version of EssayCritic that would adopt the requirements of the orientation of the third type: complete and constructed by learners following an offered approach. Regarding the finding about the learners' and teacher's dependency on digital tools in different forms of activity, further research could be done to examine and conceptualise this dependency in a more comprehensive way.

Finally, this study has employed only a fraction of the contribution made by Galperin and his colleagues and students (Vygotsky, 1978; Leontiev, 1978; Davydov, 2008). Further research would benefit from exploring other aspects of the pedagogical approach offered by this cultural-historical scholar by, for example, examining learning that involves eventual reduction of the forms of activity learners engage in or the development of attention and control functions with learners, enhancing their growing control over own learning. In addition, a longitudinal study could aim to examine students' learning in the phases of motivation and acting mentally. Such research may contribute to providing a more comprehensive insight into learning and teaching with digital technology and the development of students as learners in the 21st century.

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Appendix 1

Transcript conventions used in the analysis of interaction in three studies

[ ]	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
`Courier`	`Verbatim reading from screen (typed text)`

PART II

THE ARTICLES

Article 1

Engeness, I. & Edwards A. (2017).
The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools.
Scandinavian Journal of Educational Research 61(6), p. 650-667
doi:10.1080/00313831.2016.1173093doi:10.1080/00313831.2016.1173093

Scandinavian Journal of Educational Research

ISSN: 0031-3831 (Print) 1470-1170 (Online) Journal homepage: http://www.tandfonline.com/loi/csje20

The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools

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To cite this article: Irina Engeness & Anne Edwards (2016): The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools, Scandinavian Journal of Educational Research

To link to this article: http://dx.doi.org/10.1080/00313831.2016.1173093

Published online: 23 May 2016.

SCANDINAVIAN JOURNAL OF EDUCATIONAL RESEARCH, 2016
http://dx.doi.org/10.1080/00313831.2016.1173093

Routledge
Taylor & Francis Group

The Complexity of Learning: Exploring the Interplay of Different Mediational Means in Group Learning with Digital Tools

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ABSTRACT

The relationship between the different mediational means for supporting students' learning with digital tools in science group work in a Norwegian lower-secondary school is examined. Analyses of teacher-student and student-student interactions are located in cultural-historical theory and draw on Galperin's conceptualisation of learning processes. Findings show that digital tools, task design, peer collaboration, and teacher's interventions dialectically interplay to shape how learners use mediational means: (1) digital tools are the resources that enable students to explicate their (mis)understandings; (2) compare-and-contrast tasks promote analytical thinking; (3) peers present themselves as resources who promote development of conceptual understanding; (4) the teacher guides learners' attention towards the potential of the mediational resources, elicits, organises, and structures students' knowledge. The dialectical interplay of these mediational means creates a system that supports and guides students' learning.

ARTICLE HISTORY
Received 21 April 2015
Accepted 11 February 2016

KEYWORDS
Learning with digital tools; science education; cultural historical theory; Galperin

1. Introduction

The aim of this study is to examine the interplay of different mediational means, including digital tools, in supporting student learning in a classroom setting. Over the last few decades, studies have provided valuable insight into how students' understanding of science concepts is enhanced in learning with digital tools. Many of these studies have emphasised various forms of digital learning environments and tools that can promote students' learning. Examples include resources aimed at assisting conceptual reflection and scientific argumentation, such as simulations and transactive scripts (Linn & Eylon, 2011; Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2013; Quintana et al., 2004). Some studies have shown the benefits of efficient structural support in task design for students' learning (Lund & Rasmussen, 2010; Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012), others have explored the role of peer interaction in computer-based learning settings (Noroozi, Busstra et al., 2012; Schellens & Valcke, 2006; Stahl, 2006; Stahl, Koschmann, & Suthers, 2006; Wegerif, 1996). However, despite general agreement on the importance of teachers in group learning with digital tools (Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010; Webb et al., 2009), surprisingly few studies scrutinise their pedagogic role (Strømme & Furberg, 2015).

While important to know, concepts in genetics are challenging for students (Brown, 1990; Lewis & Kattmann, 2004; Lewis, Leach, & Wood-Robinson, 2000; Mertens & Walker, 1992; Moll & Allen, 1987;

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Slack & Stewart, 1990; Tsui & Treagust, 2003) and the subcellular processes of mitosis and meiosis are considered to be central to the development of understanding of biology (Kindfield, 1994). This study examines students' development of conceptual understanding of mitosis and meiosis in group work with digital tools and the teacher's facilitating of their learning. It was set in a lower-secondary school in Norway, where students aged 15–16 were undertaking classroom tasks on mitosis and meiosis as part of the genetics curriculum. The analyses to be presented reveal the complexity involved in students' group learning with technology by drawing on cultural-historical theory (Edwards, 2005; Galperin, 1969; Hedegaard & Fleer, 2008; Vygotsky, 1981). In particular, the study introduces Galperin's (1969) conceptual foundations and employs them as a tool for the analysis of student learning processes.

1.1. Research on Support Components of Students' Learning

The field of computer supported collaborated learning (CSCL) is closely related to the present study. It is concerned with how information and communication technologies might support learning in groups (located and distributed) (Ludvigsen & Mørch, 2010; Noroozi, Biemans, Busstra, Mulder, & Chizari, 2011; Noroozi, Busstra, et al., 2012). A large number of studies have demonstrated that, in order to improve students' learning outcomes in CSCL, attention should be paid to the nature of the learning processes. Concepts employed in these discussions include relevance, correctness, width and depth of discussion, justification, and reasoning (Noroozi et al., 2011), and external support in the form of scripts that scaffold learning in CSCL environments (Azevedo & Hadwin, 2005; Noroozi et al., 2011), where collaboration, epistemic, and argumentative scripts in digital environments are seen to scaffold students' learning.

Collaboration scripts, for example, provide guidelines for how group members should collaborate to accomplish learning tasks (Weinberger, Stegmann, Fischer, & Mandl, 2007). They can be used to specify and sequence learners' interaction strategies such as eliciting (asking critical questions) and transactivity (responding critically to their partners' contributions) (Weinberger, Ertl, Fischer, & Mandl, 2005).

Epistemic scripts structure and sequence discourse activities with respect to content and task strategies (Weinberger, Ertl, et al., 2005; Weinberger & Fischer, 2006; Weinberger et al., 2007), which may help learners to construct arguments and contribute to solving problems (Noroozi et al., 2011). It has been shown that epistemic and collaborative scripts can reduce off-task activities and help students to discuss relevant ideas (Weinberger, Ertl, et al., 2005; Weinberger et al., 2007).

Argumentative scripts can be used to structure and formulate the construction of broad, deep, and justified arguments in CSCL environments (Stegmann, Weinberger, & Fischer, 2007; Weinberger et al., 2007). Studies have shown that argumentative scripts can lead to more elaborated, justified, deeper, and broader arguments, which in turn can effectively facilitate the discourse processes of knowledge construction when it comes to warranting and qualifying claims (Stegmann et al., 2007; Weinberger et al., 2007).

Collaboration, epistemic, and argumentative scripts have provided valuable structuring support for students' learning, the present study therefore builds on this work by taking a cultural-historical perspective, which allows a wider focus on the tools that are used when working on tasks. The approach directs attention to the relationships between and the roles of both social and material support components in students' learning in groups. The study reported here examined the relationships between and the role of the material digital animations and task design and social peer collaboration and teacher's guidance in students' learning.

Studies in this area have tended to examine the role of one support component, such as digital tools, peer collaboration, task, or teacher intervention. Several studies have reported a positive effect of using digital interactive animations, models, and simulations on students' conceptual development (Rutten, van Joolingen, & van der Veen, 2012; Smetana & Bell, 2012; Williams, Montgomery, & Manokore, 2012). In particular, it has been argued that multiple external representations can provide unique benefits for learning complex new ideas (Ainsworth, 2006) and virtual labs can add valuable experimentation and visualisation components (Baltzis & Koukias, 2009; Kozma, 2003).

Peer collaboration is also identified as beneficial to the process of knowledge construction (Linn & Eylon, 2011; Scardamalia & Bereiter, 2006; Schellens & Valcke, 2006; Schellens, van Keer, Valcke, & de Wever, 2007). Again, a major focus is the learning process. While some researchers argue that student collaboration assists in developing inquiry learning skills (Van Joolingen et al., 2007), others point to the role of collaboration in the development of students' ability to construct arguments (Linn & Eylon, 2011; Littleton & Howe, 2010; Noroozi, Biemans, Weinberger, Mulder, & Chizari, 2013; Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013; Noroozi, Weinberger, et al., 2012, 2013). Others, however, emphasise that this collaboration cannot be taken for granted and that students' collaboration skills have to be developed, and certain rules of conducting a discourse have to be introduced to frame and make peer interaction productive (Howe et al., 2007; Mercer, 2010). Such effort appears worthwhile, as several studies indicate that peer collaboration can improve students' conceptual understanding (Bell et al., 2007; Howe et al., 2007; Noroozi, Weinberger, et al., 2013; Rummel & Spada, 2005).

There has also been a long-term interest in task design. Cohen (1994) observed that challenging but clear tasks can stimulate learners' collaborative skills; however, a strong structuring of the task might hamper the student collaboration. Other studies have suggested, nonetheless, that a clear task structure is needed to foster cognitive processing and academic performance (Dillenbourg, 2002; Roschelle & Pea, 1999; Weinberger, Reiserer, Ertl, Fischer, & Mandl, 2005).

The role of a teacher intervention in the technology-driven learning process, however, remains an area requiring more exploration (Greiffenhagen, 2012; Urhahne et al., 2010; Webb et al., 2009). Research suggests that teachers tend to work with individual students or small groups rather than do whole-class teaching (Chin & Hortin, 1993; David, 1991). Technology-rich classrooms are therefore often regarded as student-centred (Collins, 2001; Hancock & Betts, 1994) and the teacher's role has shifted from being the source of information to being a coach (Sheingold & Tucker, 1990), facilitator (Chin & Hortin, 1993), and guide on the side (Cifuentes, 1997). In technology-driven classrooms, teachers may become concerned about creating 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 (Strømme & Furberg, 2015). However, although the observations indicate a major change in how teachers may be able to work with students, studies tend to lack detail on what teachers actually do when interacting with students in these new conditions.

Attempts to shed light on the complexity of learning in technology-rich environments have been made by several researchers (Lund, 2009; Lund & Hauge, 2011). We have examined this complexity by placing the lens of cultural-historical theory, and in particular Galperin's pedagogical phases (Galperin, 1969), on students' group learning with digital tools. Analysis of student-student and student-teacher interactions from these perspectives allows an exploration of the relationship between and the role of material digital animations, task design, peer collaboration, and teacher interventions in an example of secondary school science learning.

1.2. Cultural-Historical Perspective on Learning

In examining the relationship between and the role of digital tools, task design, peer collaboration, and teacher interventions we have drawn on cultural-historical theory, which is based in the work of Vygotsky (1980) and those who picked up his legacy (Cole, 1988; Daniels, 2004; Edwards, 2005; Wertsch, 1986). In particular, it allows an examination of how tools, which may be social and linguistic as well as material artefacts, operate as meditational means that carry the meanings that are of value in a culture. There are some key premises to this approach. First, all deliberate actions are tool-mediated. Second, how tools are used will depend, at least in part, on how well the actor understands their potential. Third, learning involves increasingly informed use of these meditational means as learners make sense of and act in and on tasks. 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.

There is considerable pedagogic potential in these basic Vygotskian ideas, some of which were taken forward by Galperin. In an attempt to resolve the dualistic dichotomies – individual versus social and external versus internal – Galperin suggested seeing learning as the gradual transformation of socially constructed mental activities (Arievitch, 2003) by identifying dialectically evolving phases of socially meaningful activity. In elaborating this transformation, Galperin suggested six dialectically linked phases of the pedagogic, teaching-learning, process: (1) motivation [*motivacionnaya osnova deistviya*], (2) orientation [*orientirovochnaya osnova deistviya*], (3) materialised action [*deistviye v materialnoj forme*], (4) communicated thinking [*gromkaya socializirovannaya rech*], (5) dialogical thinking [*deistviye vo vneshnej rechi*], and (6) acting mentally [*skrytaya rech*] (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: (1) incomplete, where mediational means are identified by learners through multiple trial and errors; (2) complete, where learners are informed about all the mediational means necessary to solve a particular problem; and (3) complete, but being constructed by learners themselves following a general approach. In the third phase of a materialised action, learners interact with material 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 has become a pure mental act, with the focus on the outcome of the action. The action is performed by means of mental images and concepts, which help a learner to deal with similar or differing situations on the basis of previous experience. Galperin was concerned with how mental activity, which originates in material activity, evolves through formal and informal instruction by adults (Haenen, 1996; Rambusch, 2006).

The importance placed on culturally-valued knowledge within cultural-historical theory is also relevant to the present study. Neither Vygotsky nor Galperin paid significant attention to curriculum, consequently we have turned to Schwab (1982) to clarify how curricular knowledge is defined in ways that are compatible with cultural historical approaches to pedagogy. Focusing on science education, Schwab pointed to the need to acquire both the substantive knowledge of a subject, made up of concepts and relations to each other, and syntactic knowledge, which is best seen as the ways of thinking and representing that are expected of experts in the subject (Edwards, 2014).

We suggest that these two types of knowledge help reveal the complexity of students' progress as learners and the demands made on them as learners of curriculum subjects. The cultural historical view of conceptual development, which Galperin's work exemplifies, is that a child's psychological structure is always reflecting a relation to the social and the material (Chaiklin, 2003), where the learner is an active agent in that relationship. From this starting point we attempt to address the following research questions:

RQ1: What characterises the relationship between the digital tools, task design, peer collaboration, and teacher interventions in students' learning?
RQ2: How do these mediational means support students' development of conceptual understanding in Science?

2. Methods

2.1. Participants and Setting

A total of 76 year 10 students from two classes, a teacher, and three researchers participated in the project in spring 2014. The school was selected based on its previous successful participation in research projects. The two classes were taught by the same Science teacher, who followed similar teaching plans. The students studied the topic Genes and Inheritance for the period of 12 school hours over the course of four weeks. The teacher divided the classes into groups of four students that worked together during the whole project. Every Science lesson contained a combination of whole-class activities, individual work, and group activities. The teaching sequence over the four weeks is presented in Table 1.

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

A group task was designed by the researchers together with the teacher and integrated in the teaching flow on 12.03 (see Table 1). It followed a 60-minute teacher's whole-class explanation session on mitosis and meiosis, supported by animations from Viten.no projected on the whiteboard. The task itself focused on building students' conceptual understanding of normal and sex cells division (mitosis and meiosis, respectively) in group discussions using digital animations and a compare-and-contrast exercise. At the start of the group work the teacher handed out a task sheet to each of the students, who were sitting in groups of four. The students were asked to read the assignment carefully and, using the recommended digital resources, the textbook, and the diagrams provided in the task sheet, to describe in the course of group discussions the stages of mitosis and meiosis, compare them, and identify similarities and differences between these processes. The groups had 60 minutes to complete the task. Each group had a PC available and each student had to produce responses to the assignment by writing on the task sheet. 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, they could also use their Science textbook, *Eureka!* (Hannisdal & Haugan, 2008).

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

[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/

The teacher, in his late-30s, had taught Science for 11 years and had a Master's degree. During group activities the teacher circulated among the groups providing various types of support. Students' answers in the task sheet were presented and summarised in the following lesson (on 17.03) during a whole-class discussion led by the teacher. The researchers did not intervene in the teaching. Ethnographic notes described the class observations were taken by the researchers.

2.2. Viten.no Environment

Despite of the variety of digital resources that 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 programmes on topics included in the Norwegian secondary Science curriculum. The programmes contain textual information, illustrations, interactive tasks, and animations/simulations. In the present study, students were expected to use the programme "Cells."[5] The programme contains animations that progressively show the stages of mitosis and meiosis. Each stage is supplied with the textual information on the screen. Figure 1 shows the interface of the animation representing the first stage of meiosis.

2.3. Data and Analysis

Five mixed (gender and abilities) target groups of four students from different classes, 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. Twenty-three hours of transcribed video recordings constitute the data material of this study. Fieldnotes 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. Groups 1–3 belong to one class, which was filmed during the whole project , while Groups 4 and 5 belong to another class which was filmed only when the students were working on the group tasks on 12.03 and 17.03. These learning situations were particularly interesting for us as the students engaged in the group task solving with digital tools supported by the teacher's interventions.

Detailed analysis of interactions in Groups 3 and 5 (40.8 and 51 minutes, respectively) working on the task on mitosis and meiosis on 12.03 (see Table 1) were undertaken, along with the analysis of teacher's interventions in these groups. Four interaction extracts are presented: two extracts of students' interactions in Groups 3 and 5 and two extracts of the teacher's interventions in these groups. These extracts represent typical students-student and student-teacher interactions that happened in groups and the exchanges represent different points in students' understandings of the science concepts. The analysis explored the relationship between and the role of the social and material mediational tools as students engaged with them.

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

Group /teacher	Time (minutes)
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**

[5]See: http://www.viten.no/vitenprogram/vis.html?prgid=uuid:42241581-B892-15A9-626C00000A2341CD&tid=uuid:42241581-B892-15A9-626C-00000A2341CD

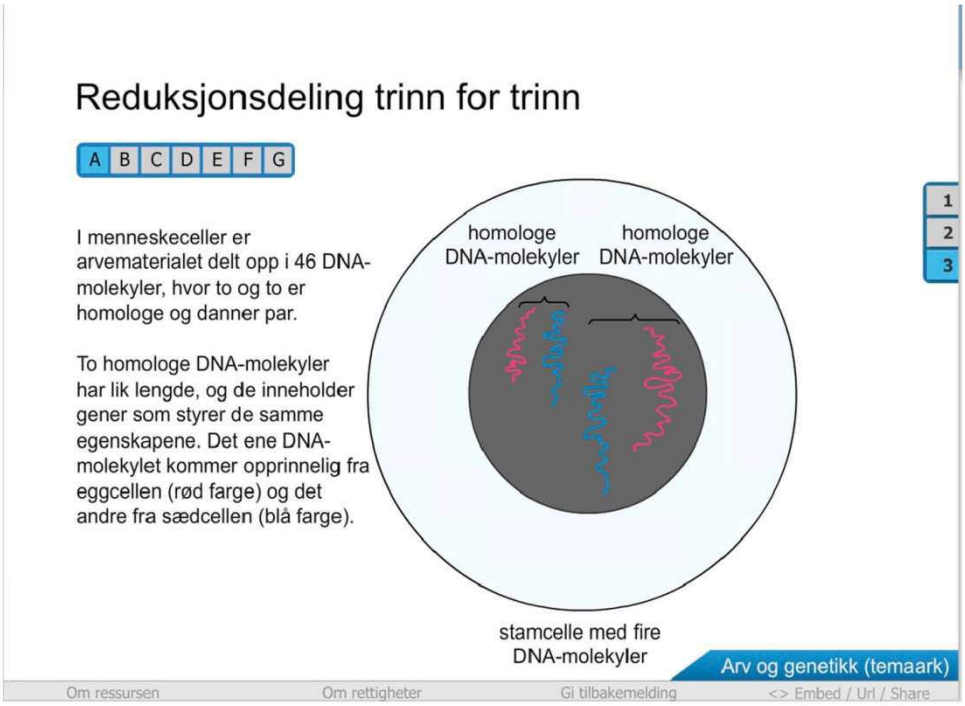

Figure 1. The interface of Viten.no/ Cells/ Meiosis.

The initial analytical procedure was inspired by interaction analysis, where interactions between interlocutors are analysed sequentially (Jordan & Henderson, 1995). Each utterance was analysed in relation to the previous one in the ongoing interaction. The primary unit of analysis was sequences and turns within sequences rather than isolated utterances (Linell, 2009). Therefore, analytical descriptions are oriented toward the interactional achievements of the participants. This approach implies that the focus is not on the meaning of single utterances but instead on how meaning is created within the exchange of utterances (Mercer, 2010). The description of the setting precedes each interaction sequence (Geertz, 1973), which provides situational meaning for the chosen extracts. The analysis was performed in two steps (Linell, 1998; Roschelle, 1992): in the first step we described what happened in the interaction sequences by referring to the distinctive lines of interactions and in the second step we analysed the interactions from the perspective of co-construction of understanding and the relationships between and the role of material and social mediational means in students' learning. Once the interaction analysis was completed, the interactions were examined through the analytic lens offered by Galperin's dialectically linked pedagogic phases to begin to unpack how the meditational means supported students at different times of the learning process. Such use of Galperin's theory was innovative and we were interested to explore whether the lens of the dialectically linked pedagogic phases would help in our analysis of the complexity of students' group learning in Science with digital tools. The video recordings were transcribed according to the Jeffersonian transcription notations (Atkinson & Heritage, 1984) (Appendix, Table A1). The discourse was conducted in Norwegian and the material presented in the study was translated by the wider research team.

3. Results

In the extracts presented, 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 2.1) assigned by the teacher.

3.1. Analysis of Students' Interactions of Group 5 and the Teacher's Interventions in this Group

Extract 1a presents the teacher's intervention right at the beginning of the group work. The students have just read the text of the assignment – according to Galperin's phases the students are in the orientation phase. We start when the teacher approaches the group while circulating in the class.

Extract 1a:

1.	Teacher:	Use the task sheet, please!
2.	Danny:	I am just drawing the diagrams.
3.	Teacher:	Do you understand what happens at the beginning?
4.	Kelly:	Yes, how the chromosomes – the difference between normal cells and sex cells. The number of the chromosomes that divide: there will be just 46 and f46 chromosomes ((*points at the mother and daughter cells in mitosis*)), but here there will be 23 from 46 ((*points at the daughter and mother cells in meiosis*)).
5.	Teacher:	OK, right. So you are on the differences. Do you know what happens at the very stages of these processes?
6.	Felix:	It was difficult to see what happens when you showed Viten during your explanation. I was sitting at the back and saw only black dots, so I did not get anything. But here we can see everything very clearly ((*looks at the diagrams in the task sheet*)).
7.	Teacher:	Yes.

Right at the start of their work, the teacher encourages the students to write their answers in their task sheets (line 1), although Danny chooses to draw the diagrams in his exercise book (line 2). In response to the teacher's attempt to check students' understanding of his explanation during the whole-class session (line 3), Kelly summarises one of the differences between mitosis and meiosis (line 4). The teacher draws students' attention to the actual stages of mitosis and meiosis (line 5). Felix complains that he had some difficulties seeing the animation during the whole-class session, but looking at the diagrams in the task sheet, he confirms that he can distinguish the stages of the processes (line 6).

What makes the teacher's intervention important right at the beginning of students' learning in the so-called orientation phase (Galperin, 2002)? One way of interpreting this is that the teacher's intention is to ensure that the students understand the task and follow the steps of the assignment consecutively. Doing so may bring the students to the same starting point and build common grounds for further productive peer collaboration. Danny prefers to draw his own diagrams in his exercise book, which eliminates him from the group discussion. He joins the conversation when he has finished drawing and only then is he able to participate and contribute. The teacher performs a guiding role, and this function is of particular importance in the orientation phase as it creates a basis for the establishment and presence of the support tools to assist students' learning. Moreover, by encouraging the students to use their task sheets, the teacher emphasises the potential of the task as a mediational resource.

The events in Extract 1b chronologically follow the events in Extract 1a. The students of Group 5 are attempting to turn the laptop on; however, this takes long time. While waiting for the laptop to load, they start discussing the task based on the teacher's explanation, the notes they have taken, and the Viten.no animation they saw on the screen during the whole-class explanation session. Being involved in the group discussion, the students are in the phase of communicative thinking (Galperin, 2002).

Extract 1b:

1.	Adam:	The first thing in meiosis is that it reduces the number by half, right? I mean the number of the chromosomes.
2.	Kelly:	Yes, meiosis is reduction division.
3.	Adam:	The first stage –

4.	Felix:	The first stage is exactly the same as in normal cell division.
5.	Adam:	DNA is copied –
6.	Felix:	Each chromosome makes a copy of itself and the membrane of the nucleus of the cell dissolves. Then they come together –
7.	Adam:	DNA is copied and it torques into chromosomes again afterwards.
8.	Felix:	Yes, here each of the chromosomes makes a copy of itself and they get closely together for recombination. The chromosomes exchange small parts of the DNA and they divide first into two new cells and then into four cells. This is exactly the same as in the picture. What did he [teacher] say about this at the beginning?
9.	Adam:	((*writing*)) The chromosomes exchange genes, can we say so?
10.	Felix:	Yes, we can say so in the process of recombination. But you see here, in a normal cell division, two new cells are formed that are completely finished ((*points at the daughter cells in mitosis in the task sheet*)) and here two cells are formed that are pulled from each other at once ((*points at the daughter cells in meiosis*)). They repeat the process again straight away.
11.	Adam:	Here there won't be copies, but four new cells, versus two identical cells here.
12.	Felix:	Here they divide at once, so they aren't copies of the original cell, but four new cells. If they did it one more time again, there would have been two completely identical cells produced, exactly the same as those two ((*points at the daughter cells in meiosis*)). But in this case four different cells are produced.

Adam points out that the process of meiosis leads to the reduction of the number of chromosomes by half (line 1), which Kelly summarises as a reduction division (line 2). By eliciting each other's reasoning (lines 3–11), Adam and Felix give an account of the stages of meiosis, comparing them with mitosis, and Felix concludes that four completely different cells form, versus mitosis where two identical daughter cells are produced (line 12).

The interacting learners are moving between the phases of a materialised action and communicated thinking (Galperin, 2002) and the impact of the compare-and-contrast task is reflected in the way the students conduct their discourse by drawing parallels between the processes. In lines 10, 11, and 12, Felix and Adam compare the daughter cells form in mitosis and meiosis and emphasise the differences in these cells. With this, the compare-and-contrast task promotes scientific thinking. The boys take leading roles in the discourse and there are numerous examples of how these students extend each other's accounts: lines 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12. By eliciting their ideas, the peers present themselves as a resource that promotes development of their conceptual understanding. Hence, the task design, requiring compare-and-contrast, affects students' discourse and is linked with the peer collaboration.

In the phases of a materialised action and communicated thinking (Galperin, 2002) the students rely on the diagrams provided in the task sheet to support their explanations. Felix identifies the process of recombination with its representation in the diagram in the task sheet (line 10), and he refers to the diagrams to compare the daughter cells produced in mitosis and meiosis and outline the differences between them. By using the diagrams, Felix makes his thinking visible for other students, supported with the pictures, his ideas transform into concepts accessible by his peers. Diagrams assist and shape students' discourse and hence, peer collaboration.

Summing up, Extract 1a highlights the role of the teacher as a facilitator of students' learning in the orientation phase that establishes grounds for the use of mediational tools and reveals their potential as support components. Extract 1b reveals the dialectical interplay of the task design, and peer collaboration in the phases of a materialised action and communicated thinking. Digital tools are present indirectly in this extract as a source of scientific knowledge, which students acquired during the whole-class teaching session and which they elicit through interactions with the diagrams provided in the task sheet. This intertwines the diagrams as mediational tools into the interplay of peer collaboration and task design in the support of students' acquisition of substantive and syntactic knowledge (Schwab, 1982).

3.2. Analysis of Students' Interactions in Group 3 and the Teacher's Interventions in this Group

In Extract 2a, the students are in the middle of their discussion of the process of meiosis using the animation from Viten.no. In the phase of a materialised action (Galperin, 2002) the girls Mira and

Helena have already looked through the stages of the animation of meiosis, however, they struggle to understand why chromosomes produced in meiosis are different. At this point Chris joins the conversation. We enter when Chris turns to the textbook and supports his explanation by pointing at the picture showing 23 pairs of chromosomes present in a human cell.

Extract 2a:

1.	Chris:	Let me show you. I've got a diagram. Here is a picture of all the chromosomes ((*shows in the textbook* Eureka)). In a normal cell division [mitosis], for example, they make only two, they copy themselves. In the next stage, they copy themselves up to four – two of each. So, each of these chromosomes goes to one of the cells. At the end both of the cells have both of those two. But here [in meiosis] they make copies of themselves, so they double, two of them go here, to one cell and two of them go there, to another cell.
2.	Helene:	And they divide again.
3.	Chris:	And they divide again, so some of the cells get one of these and some of the cells get one of these. So, one cell gets 23 chromosomes that come randomly, they can be one of these and one of these and one of these ((*points at the diagram in Eureka*)). They are randomly important here. So for each pair of chromosomes, you get one of these chromosomes.
4.	Helene:	Yes.
5.	Mira:	((*looks at the screen – animation stage E*)) Do you get one of these? Are you thinking of these? ((*points at the screen on the single chromosomes that appear in each of the daughter cells*)). And they don't divide any more. I still do not understand is it just me, or–
6.	Chris:	Go back to C. What is important here: think about this as one chromosome ((*points at the screen at the copied chromosomes*)). This is only a copy, so this is one chromosome and this is one chromosome. And these two is a pair of chromosomes – go to the start.
7.	Mira:	Is this, for example, a copy of this? ((*points at the blue and the red chromosomes on the screen*))
8.	Chris:	No! These two blue are just one chromosome with two identical – This is a copy of that one ((*points at the blue chromosomes*)).
9.	Mira:	Yes, this is a copy of that one ((*points at the blue chromosomes*)).
10.	Chris:	Yes, in fact, it's just one blue and one red that make a pair of chromosomes.
11.	Helene:	In a normal process of mitosis.
12.	Chris:	Yes. So, now in E – If this was a normal process of cell division, this part would have replaced that part and this part would have replaced that part ((*points at the red and blue stripes on the chromosomes*)), so you would have had two similar chromosomes.
13.	Mira:	Now I understand what you mean.
14.	Chris:	So, now you have one pair of chromosomes and another pair of chromosomes, they are not similar. And they divide again, so each half turns into a full chromosome, but they are a bit different now, they have mixed with each other.
15.	Mira:	Yes, there are red and blue lines here and there.

Using a diagram in the textbook that shows a photo of 23 pairs of chromosomes, Chris describes the stages of mitosis and points out that in meiosis, an extra division occurs (line 3). He turns to the animation to explain the difference between the copied chromosomes and the homologue pairs (line 6). Helene adds that these chromosomes would have been of the same colour in the process of mitosis (line 11) and Chris emphasises the different structure of the chromosomes in mitosis and meiosis (line 12). Mira provides more details that show her understanding – she mentions the red and blue lines on the chromosomes that reflect these differences (line 15).

According to Galperin's phases of a teaching-learning process, the students interacting with material resources supported by group discussions are making the transition from the phase of a materialised action to the phase of communicated thinking (Galperin, 2002). A more knowledgeable student, Chris, joins the conversation and emphasises that at the first stage the chromosomes copy, whereas recombination happens at the second stage of meiosis (lines 12, 14). He explains that this makes one of the fundamental differences between meiosis and mitosis and gives an answer to the problem stated in the assignment.

The steps of the task are important components that allow students to form their understanding of mitosis and meiosis. The compare-and-contrast task draws students' attention to identifying the differences between the scientific phenomena, which enhances students' attention to detail and promotes development of their conceptual understanding. The way the students conduct their discourse is of particular interest: Chris builds his explanation of the stages of meiosis, comparing them with the stages of mitosis (lines 1, 12). In this way he helps other students to shape their understanding of meiosis and at the same time solve the task. Chris explains the differences between the processes and the structure of the chromosomes (lines 1, 6, 8, 10, 12, and 14), Mira poses critical questions (lines 5, 7), Helene follows

Chris's explanation attentively and appears to echo his thoughts on various occasions, as in lines 2 and 11. In this way the compare-and-contrast task does not only promote analytical thinking, but it affects the whole discourse among the students and, hence, peer collaboration.

In the phases of a materialised action and communicated thinking (Galperin, 2002), Chris draws on the digital animations presenting the stages of meiosis to compare them with mitosis, which allows other members of the group to visualise the processes and follow the explanation he gives. Chris refers to stage E of the animation to emphasise when the differences between the processes start to occur (line 13). Supported by the animations, the words of Chris offer a particular meaning and there is evidence of conceptual grasp on the part of Mira and Helene. This grasp is expressed in words as Mira confirms her understanding in line 15.

Chris, Helene, and Mira contribute to solving the task, their conversation is shaped by the assignment, and the digital animations help the students to elicit any (mis)understandings. The compare-and-contrast task shapes the way the digital tools are used, while peer collaboration in the phases of a materialised action and communicated thinking (Galperin, 2002) establishes a connection between the digital tools and the task design. This interplay of the digital animations, task, and peer collaboration promotes the development of students' substantive and syntactic knowledge (Schwab, 1982).

In Extract 2b, the students of group 3 are in the middle of writing the differences between mitosis and meiosis in their answer sheets, they are in the transfer from communicative to dialogical thinking (Galperin, 2002). The teacher approaches the group and intervenes in their work:

Extract 2b:

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? What is the result?
4.	Helene:	Well, I think the main point is that they divide one extra time comparing to the previous process.
5.	Teacher:	Yes.
6.	Helene:	And DNA–
7.	Chris:	It 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.
8.	Teacher:	Yes, it looks quite easy, what happens here ((*points at the diagram of mitosis*))? How many chromosomes are there?
9.	Helene:	22? 26? No, 23?
10.	Teacher:	23 (.) pairs?
11.	Helene:	Yes.
12.	Teacher:	Are these daughter cells similar to those ((*points at the mother cells*))? Are there 23 pairs too ((*points at the diagram of meiosis*))?
13.	Helene:	Here, we've got 23 pairs, right ((*points at the mother cell*))? And here we've got 23 pairs divided by 2, haven't we?
14.	Teacher:	Here are 46 single chromosomes.
15.	Mira:	And there will be 23 single chromosomes.
16.	Helene:	23 in each of them, right ((*points at the diagram*))?
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 twice. 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:	Are they different sex cells' chromosomes?
21.	Teacher:	This too. They 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?
22.	Mira:	Can you repeat it?
23.	Teacher:	OK, how many cells have you got here ((*points at the daughter cells in mitosis*))? One cell divides up to two. Here ((*points at meiosis*)) one cell divides up to–
24.	Helene:	Four.
25.	Teacher:	Right! Do you see the difference?
26.	Mira:	Yes.
27.	Helene:	Yes.
28.	Teacher:	What about the similarities? ((*goes away from the group*))

Having received an account of students' progress and a summary of the reduction division, the teacher asks about the number of chromosomes in mitosis (line 8). He draws students' attention to the

number of chromosomes in the daughter and mother cell in mitosis and meiosis (line 12) and summarises students' ideas in the statement about 46 single chromosomes at the beginning (line 14). Mira and Helene extend the teacher's thought by reporting on the number of chromosomes in the daughter cells (lines 15, 16). The teacher concludes that the number of chromosomes in meiosis reduces by half (line 17), which is different in mitosis. In conclusion, he emphasises that the chromosomes are not similar in the daughter cells, which constitutes another difference in meiosis (line 21).

The teacher joins in when the students are in the middle of working on their task, they have employed the digital tools in the phase of a materialised action and have established collaboration within the group in the phase of communicated thinking (Galperin, 2002). Having received a detailed description of the stages of meiosis from Chris, he poses the question that requires comparing, by pinpointing the stages of the processes where the differences occur and, hence, promotes 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 at the number of chromosomes in the cells in mitosis (line 12) that prompts the students with the right answer (lines 13–18). In the phase of communicated thinking (Galperin, 2002), the students imitate their teacher, they use the pattern created and come up with the right answer. The pattern makes the teacher's thinking accessible to the learners.

Summing up, the analysis of interactions in Group 3 suggests that the teacher intervention in the phase of communicated thinking establishes a dialectical link with the peer collaboration, task design, and digital tools, which in turn interplay and determine each other. In this interplay, the teacher has a guiding function, helping the students to structure their knowledge and complete the task. Extracts 2a and 2b therefore demonstrate the dialectical interplay of social and material mediational tools supporting students' acquisition of substantive and syntactic knowledge (Schwab, 1982) in the phases of a materialised action and communicated thinking (Galperin, 2002).

4. Discussion

This study has attempted to conceptualise the interplay of mediational means in supporting students' learning in a group setting in Science. Taking a cultural -historical perspective and employing Galperin's pedagogic phases, it has examined student involvement in classroom interactions in order to identify whether and how students engage in and with an array of mediational tools comprising digital tools, task design, peer collaborations, and teacher interventions. The analysis of the interactions revealed a dialectical interplay between these mediational tools to the extent that they shape how each is used to support student learning. In this section, the findings are discussed in relation to previous research. The practical implications for teachers' design of learning situations with digital tools are then outlined.

First, the analyses discussed above have shown that the compare-and-contrast task in the phases of a materialised action and communicated thinking (Galperin, 2002) was not simply a matter of improving student collaboration (Cohen, 1994). Rather, the compare-and-contrast design drew students' attention to the details between the scientific phenomena and promoted development of conceptual understanding. The compare-and-contrast design shaped the discourse in both of the groups, where peer collaboration was directed at solving the task. The task design presupposed the development of students' discussions in the phase of communicated thinking, establishing a dialectical link between the task design and the peer collaboration.

Second, the task design offered possibilities for the way the digital tools were utilised. Extract 2a served as a good example of this process. In the phase of a materialised action (Galperin, 2002) the students turned to the programme Viten.no, as advised in the task sheet, to build their understanding of mitosis and meiosis. Digital tools assisted Chris, Helene, and Mira in eliciting their misunderstandings in the phase of communicated thinking, the tools helped them to visualise abstract scientific phenomena, identify the differences between the processes, and, hence, build their conceptual

understanding. In Extract 2b, digital tools were present indirectly as a source of information for the students during the whole-class teaching session. The learners relied on this information when solving the task and making sense of the diagrams presented in the task sheet. Indeed, in the phase of communicated thinking (Galperin, 2002), the students of Group 5 used the diagrams to co-construct their knowledge.

With this, the task design dialectically contributed to the way the digital tools were utilised by Group 3 and the diagrams were used in Group 5. While the task design was interacting with the use of visual displays, peer discourse in the phase of communicated thinking was evidenced as an arena to discuss these visualisations, display ideas, make thinking visible, and contribute to the joint construction of knowledge (Linn & Eylon, 2011; Mercer, 2010; Mercer & Wegerif, 1999; Scardamalia & Bereiter, 2006). The use of digital tools and the pictorial diagrams in the phase of a materialised action stimulated peer discourse in the phase of communicated thinking. Hence, peer collaboration was shaped by the digital tools, the diagrams in the task sheet, and the task design, allowing us to trace a dialectical link between these mediational means.

Third, the analysis performed in this study indicates the contributions of the teacher's interventions (Chin & Hortin, 1993; Collins, 2001; David, 1991; Hancock & Betts, 1994), where the teacher, as a mediational mean, fulfils a range of different functions at different points in students' sense-making. Extract 1a showed how the teacher worked at building a common recognition of the mediational support tools available to the students, exemplifying the orientation phase of the teaching and learning process (Galperin, 2002). By clarifying the details of the task design and emphasising the digital tools, the teacher ensured the presence of these mediational means in students' learning. In doing so, he helped to promote peer collaboration within the group and students' engagement with the available mediational means.

Extract 2b demonstrated the role of the teacher's intervention in the phase of communicated thinking (Galperin, 2002). The teacher created a pattern for analysis that students followed when outlining the differences between the processes of mitosis and meiosis. In doing so, the teacher helped the students to organise and structure their knowledge and complete the task. The teacher's intervention was shaped by the task design and hence, dialectically linked with it. At the same time, the teacher's intervention influenced the student discourse, affecting peer collaboration. The teacher supported his explanations with the diagrams in the task sheet and relied on the understandings the students gained in the phase of a materialised action when working with digital animations. In this way, the teacher's intervention was integrated into the interplay of the task design, digital tools, and peer collaboration, and established a dialectical link with them. However, the analysis has shown that the teacher's interventions appeared to be important for different reasons at different stages in students' sense-making. It therefore suggests the need for further research scrutinising the role of the teacher at different phases of students' learning with digital tools.

5. Conclusion and Implications

Our attempt to conceptualise the complexity of group learning with digital tools offers an account of the dialectical interplay of the meditational means of task design, peer collaboration, teacher interventions, and digital tools to create a structure that supports and guides students' engagement with the curriculum. The analysis has shown that the dialectical interplay of the mediational means allows for students acquiring the relevant substantive knowledge of the concepts of mitosis and meiosis and their relations to each other, together with the syntactic knowledge (Schwab, 1982) of scientific thinking in the form of analytical comparing and contrasting.

There are several implications arising from the study for how we approach classroom pedagogy. First, understanding the dialectic nature of learning alerts one to some of the challenges of teaching in digital environments. The analysis performed in this study revealed the structure created by the interplay of the material digital tools and task design and social peer collaboration and teacher's intervention that supported and guided students' learning. This structure appeared to be sensitive

to the learners' needs. For example, other mediational tools may enter the system and replace some of the components permanently or stay in the system for a period of time, providing temporary support. This happened in Extract 1b, where students used diagrams in the task sheet to build their understanding of mitosis and meiosis.

The second, and perhaps more profound, implication of the dialectical link between material and social mediational tools in supporting and guiding students' learning is the emphasis the analysis places on the system created through the dialectical interplay of the different meditational means. These dialectical links give rise to how each of the mediational tools assists learning: (1) the digital tools were used as depictive resources that enabled students to explicate their (mis)understandings; (2) the compare-and-contrast task guided students' attention towards the similarities and differences in mitosis and meiosis and promoted learners' scientific thinking; (3) peers elicited mutual ideas and understandings and presented themselves as resources, which promoted development of students' conceptual understanding; (4) the teacher guided learners' attention towards the potential of the mediational resources, elicited, organized, and structured students' knowledge.

The recognition of the dialectical relationships in the system of interplaying mediational means both draws on and gives support to Galperin's detailed attention to the dialectically linked phases involved in learning in formal settings. In particular, the analysis here has shown that in the phases of orientation, materialised action, and communicative thinking, the dialectical interplay of material and social mediational tools shapes how each of them is used by learners.

The third implication, which is only tentatively indicated in the present study, is the role of the teacher at different points in the teaching-learning process: in guiding the students towards the potential offered by the material resources and enabling peer collaboration in the orientation phase, in and organising students' conceptual understanding in the phase of communicated thinking (Galperin, 2002).

The fourth implication arises from the employment of Galperin's theory in this study. It appeared to be useful as a tool for the analysis of students' learning processes. Galperin's dialectically linked pedagogical phases were a helpful addition to the method inspired by interaction analysis to understand what students did at different times as they progressed in their learning. We suggest that this approach may offer new pathways for the use of Galperin's conceptual contribution in further research exploring teaching-learning process and designing of learning activities.

These findings therefore have implications for learning designs with digital tools, suggesting the importance of accommodating material and social support components. They also suggest that further research is needed to examine the role of the teacher at different phases of learning with digital tools.

Acknowledgements

We thank Anniken Furberg and Ingvill Rasmussen for their comments on the early drafts of this study.

Funding

This study was funded by the Faculty of Educational Sciences, University of Oslo, Norway. The collection of the data was conducted in the frame of the project Ark&App funded by the Ministry of Education of Norway.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Table A1. 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

Article 2

Engeness, I., & Mørch, A. (2016) Developing Writing Skills in English Using Content-Specific Computer-Generated Feedback with EssayCritic.
Nordic Journal of Digital Literacy, 11(2), p.118–135*,*
DOI: 10.18261/issn.1891-943x-2016-02-03

Nordic Journal of Digital Literacy,
volume 11, no 2-2016 p. 118–135
ISSN online: 1891-943X

DOI: 10.18261/issn.1891-943x-2016-02-03

PEER REVIEWED ARTICLE

Developing Writing Skills in English Using Content-Specific Computer-Generated Feedback with EssayCritic

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ABSTRACT

This paper presents a study of Norwegian Upper Secondary School students' writing process in English with: 1) feedback from an essay critiquing system (EssayCritic) (target class) and 2) feedback from collaborating peers (comparison class). The students in both classes significantly improved their grades. In the target class, the feedback from EssayCritic gave content-specific cues and the students included more ideas in their essays than the students in the comparison class who struggled when giving feedback to each other.

Keywords

Developing Writing Skills in English, Computer Generated Feedback, Cultural Historical Theory, Galperin

ACKNOWLEDGEMENTS

This study was funded by the Department of Education, University of Oslo, Norway. The collection of the data was conducted in the frame of the project Ark&App funded by the Ministry of Education of Norway. We thank Øystein Gilje and Anne Edwards for their constructive comments on the early drafts of this study and Victor Cheng, William Cheung and Kelvin Wong, Hong Kong Baptist University for creating the machine learning algorithms for the Essay-Critic system.

UNIVERSITETSFORLAGET

INTRODUCTION

Development of written communication is one of the competence aims of the Upper Secondary School English subject curriculum in Norway[1] and in common with other countries feedback and assessment for learning (AfL) have been encouraged in Norwegian schools[2] (Bueie, 2015; Gamlem & Smith, 2013; Røyeng, 2010). Feedback has been employed in formative assessment to promote the development of students' writing skills (Black & Wiliam, 2009; Hattie, 1999) and AfL has been defined as a classroom practice that involves dialogue and feedback loops between teachers and peers during subject specific problem solving (Gamlem & Munthe, 2014). New digital technologies open up opportunities by providing automated feedback (Dikli, 2006; Kukich, 2000; Sireci & Rizavi, 2000) and specifically for enhancing the development of students' writing skills in English (Lee, 2007; Mørch et al., 2005; Winerip, 2012).

Although several studies have explored the types and the role of feedback teachers and peers give on students' writing (Yang, et al., 2006; Zhao, 2010), to the best of our knowledge none has examined and compared the writing process in English with computer-generated feedback and peer feedback from collaborating peers. By taking a cultural-historical perspective (Edwards, 2005; Galperin, 1969; Vygotsky, 1980), this study aims to fill this gap. The study was undertaken in an Upper Secondary School in Norway, involving one hundred and twenty five students aged 16–17 who wrote essays on the topic *English as a Global Language*. We examined students' writing processes under two conditions of mediation: with the feedback from EssayCritic (target class) and with the feedback from collaborating peers using a set of available (non-computerized) support tools (comparison class).

Feedback in the writing process

The complexity of writing as a process of discovery, learning and communication through language has been emphasized by several researchers (Graves, 1975, 1994; Murray, 1999). Over forty years ago, Murray identified three phases in the classroom writing process: prewriting, writing and rewriting. Prewriting is everything that takes place before the first draft, writing is the act of producing the first draft and rewriting includes reconsideration of subject, form and audience (Murray, 1972). Along the same lines, Hayes and Flower observed that writers employ the following processes: planning, translating (or sentence generation) and revising (Hayes & Flower, 1986). Later the model was revised (Hayes, 1996) where planning was replaced by reflection, translating by text production and revising by text interpretation. In general, learn-

1. See: http://www.udir.no/kl06/eng1-03/Hele/Kompetansemaal/kompetansemal-etter-vg1--studieforberedende-utdanningsprogram-og-vg2---yrkesfaglige-utdanningsprogram/?lplang=eng
2. See: http://www.udir.no/Vurdering-for-laring/4-prinsipper/Viktige-prinsipper-for-vudering/fire-prinsipper/

ing to write has been defined as a complex developmental process (Graves, 1983) where feedback as active intervention mediates learning within the activity of writing (Graves, 1982; Thompson, 2013).

Previous research (Black & Wiliam, 2009) has conceptualized feedback consisting of five key strategies: clarifying and sharing learning intentions and criteria for success; engineering effective classroom discussions and learning tasks that elicit evidence of student understanding; providing feedback that moves learners forward; activating students as instructional resources for one another and as owners of their own learning. According to Hattie and Timperley (2007), effective feedback must answer three major questions: Where am I going? How am I going? and Where to next? These questions correspond to the notions of feed up, feedback and feed forward (Hattie & Timperley, 2007). Four levels of feedback have been identified: feedback about the task, about the processing of the task, about self-regulation and about the self as a person. It has been argued that feedback on how to complete a task is the most effective, whereas feedback related to praise, reward and punishment is the least effective (Hattie & Timperley, 2007). However, research shows that in English writing classes assessment *of* learning often dominates over assessment *for* learning (Lee, 2007).

Echoing international research, Norwegian studies reveal that feedback on students' writing tends to be general and unspecific, consisting mainly of praise, and consequently lacking information on what to do next (Danielsen, et al., 2009; Furre, et al., 2006; Klette & Hertzberg, 2002).

Previous research in computer-based feedback systems includes automated essays scoring (AES). AES systems assign scores to essays written for educational purposes. The score is dynamically determined by machine learning and statistical techniques based on a set of training examples, which typically range from about twenty to several hundred, dependent on the learning algorithms and the desired precision of the feedback (Dikli, 2006). On the one hand, proponents argue for the success of AES systems in terms of how well they compare with the accuracy and reliability of human evaluation (Chung & O'Neil Jr, 1997; Sireci & Rizavi, 2000). On the other hand, critics have pointed out that AES systems can often be fooled by intentionally gibberish essays giving them higher scores (Kukich, 2000; Winerip, 2012). Our version of AES adopts a "qualitative" approach to presenting feedback by asking the students for specified content to be elaborated in their essays instead of the more common "quantitative" approach of presenting scores along a numerical scale.

Despite the considerable improvement of automated formative feedback systems (Shermis & Burstein, 2003), developers acknowledge that it is infeasible for computers to measure every aesthetic property of writing (Landauer, et al., 2003). In addition, classroom teachers express worries that the type of writing being measured with these systems is mechanistic, formulaic in nature and divorced from real-world contexts. Hence, more research is needed to examine

the context in which the system is used, the content of what is written, and the impact on key stakeholders as part of its integration (Ware, 2011).

Early studies of EssayCritic (Mørch et al., 2005) showed that it is a useful tool to facilitate writing in English, as it supplements teachers' feedback. A study in Hong Kong found no significant difference between the grades achieved by students who used EssayCritic and those who revised their texts themselves (Lee, et al., 2009). A later study of the same system (Lee, et al., 2013) compared two conditions: one group that received feedback from EssayCritic and from the teacher, and another group that received feedback from the teacher only. The essays of the group that received two types of feedback were richer in content than the essays of the other group.

Research in peer assessment indicates its summative and quantitative nature, with a strong reliance on scoring and grading (Falchikov & Goldfinch, 2000); and an emphasis on grammar mistakes and other writing errors (Hansman & Wilson, 1998). Despite peer assessment being increasingly used during group work, the link between peer assessment and collaborative learning has not been the subject of much research (Sluijsmans & Strijbos, 2010). To the best of our knowledge, no studies have compared peer feedback and computer-generated feedback in formative assessment in English composition.

Cultural-historical perspective on the development of writing skills

In exploring feedback in writing processes that include both collaborative (discussion) and individual (text processing) activities, we draw on Vygotskian cultural-historical theory. Vygotsky distinguished between social learning and individual development (Vygotsky, 1981), where the latter requires changes in the psychological functions of the learner (Chaiklin, 2003).

Development according to cultural-historical theory (Claxton, 2007; Edwards, 2015) requires employing the cultural tools central to practices. In the case of writing, learning that leads to such development involves feedback to be used by students in their development as writers. However, Vygotsky did not specify how the particular content of instruction (feedback) is related to development, and how specific qualities of the tools acquired by the child affect development. A cultural-historical scholar Galperin (Galperin, 1969; Haenen, 2001) 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 & Arievitch, 2002). Galperin proposed six phases of socially meaningful activity that have implications for pedagogy (Edwards, 1995) and more specifically for the development of writing skills: (1) *motivation*, (2) *orientation*, (3) *materialized action*, (4) *communicated thinking*, (5) *dialogical thinking*, and (6) *acting mentally* (Haenen, 2001; Rambusch, 2006).

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: (a) incomplete, where mediational means are identified by learners through trial and error; (b) complete, where learners are informed about all the mediational means necessary to solve a particular problem; and (c) complete, but being constructed by learners based on a general approach. In the third phase of a materialized action, learners interact with material or materialized 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 first carried out externally on material objects is being transformed mentally. In the final phase of acting mentally, an action has become a pure mental act with the focus on the outcome of the action (Haenen, 2001; Rambusch, 2006).

According to Galperin, the orientation phase is of particular importance as it introduces mediational tools to learners that will assist and guide further learning process. Two different types of feedback as meditational tools are in the focus of our study: automated and peer. Galperin's pedagogical phases may inform teachers and researchers about the complexity of the processes involved in a learner's move from, for example, orientation to the potential of advice on how to write, to the ability to act as a writer. Therefore, the quality and appropriateness of the feedback guiding students' writing process would seem to be crucial. From this perspective we address the following research question:

How do different types of feedback assist students in their writing process?

METHOD

Participants and setting

Data was collected during the autumn term 2014 in an upper secondary school in Norway that had AfL as a focal area. One hundred and twenty-five students (aged 16–17) from five classes, five teachers and four researchers participated in the project. The teaching plans that preceded the essay writing activity had been discussed and standardized with the teachers who were involved in the project. Previous to the writing activity, the students had covered the same study topics from the textbook *Passage* (Burgess & Sørhus 2009) as sources of information for their essays. The text of the assignment of the essay had been created in collaboration between five teachers and two researchers (the authors): *"Write an essay on the topic of English as a Global Language: Explore how English was spread around the globe, and present the most important reasons for this development"* (300–400 words).

In the first round, the students in five classes wrote the first version of the essay using only a laptop as a writing tool. The learners did not have access to any source materials. Eleven best essays from three classes were selected to code

for the subthemes of the topic "English as a Global Language" and to train EssayCritic (see section EssayCritic System).

The remaining two classes (48 students) were assigned as the target and comparison class. The students of the target class uploaded the first draft to EssayCritic and after they had discussed the feedback received from the system with their peers, they produced the second draft. The students of the comparison class read each other's essays and gave advice on how to create the second draft. All the students repeated the process of receiving feedback and revising their essays one more time, which resulted in the production of the third draft handed in to the teachers for final evaluation.

During the interventions, the teachers circulated among the groups and responded to questions. The researchers did not interfere in the group work.

EssayCritic System

EssayCritic (EC3) is a web application that analyzes uploaded essays with the help of a Decision Tree machine-learning algorithm (Quinlan, 1986), synonyms from dictionaries and a lexical database for English WordNet (Fellbaum, 1998) and generates feedback based on the content of the essays. Before using the system, a concept tree representing the essay topic was created. The teachers identified eleven subthemes for the topic by using a chapter in *Passage* (Burgess & Sørhus 2009), and the researchers decomposed each subtheme into simpler concepts, represented by a few phrases or word expressions taken from the students' essays that were selected to train the system, together with the synonyms from the dictionaries and the WordNet lexical database. In doing this, a "model" was created and the process of training the system took approximately one month.

Once a new essay was written and uploaded by a student, the system computed a score for the uploaded essay's similarity with the model for each of the subthemes. If this score was below a threshold value, "critique" was given for missing the corresponding subtheme, and if above the threshold, the subtheme was considered to be a part of the essay, and was highlighted in the essay as a phrase or sentence. Figure 1 shows the screen pictures of EC3 in the praise (leftmost picture) and critique (rightmost picture) modes.

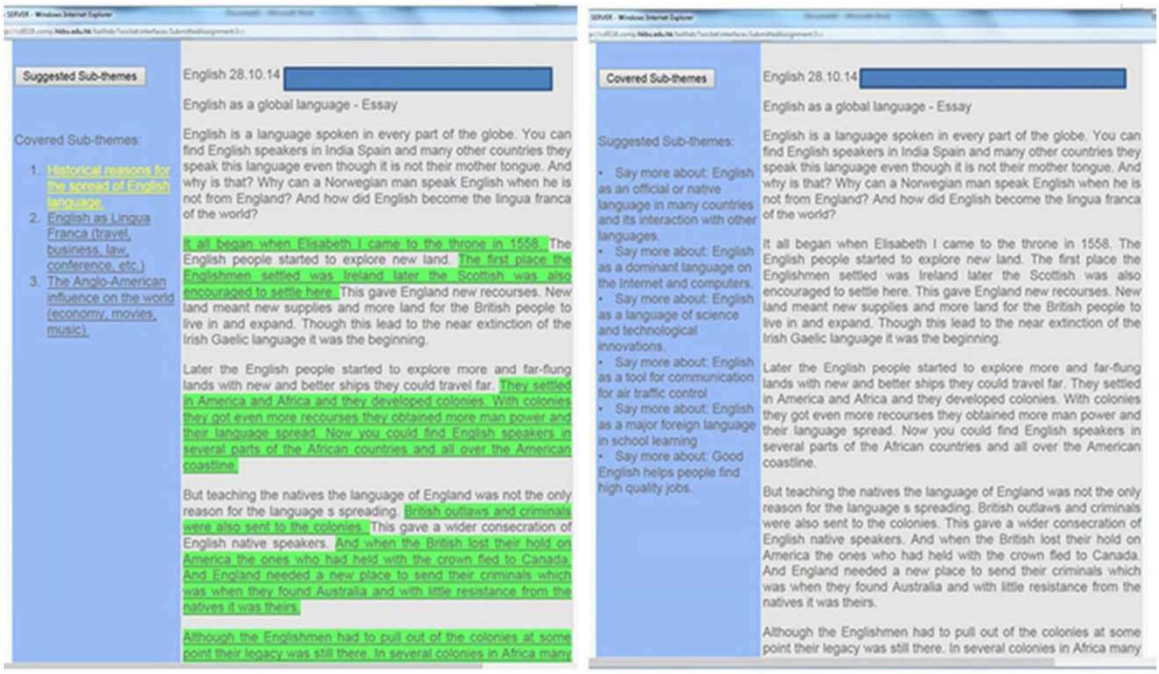

Figure 1. The user interface of EC3: Covered subthemes (left) and suggested sub-themes (right)

Data analysis

Three groups of four students in both classes were video recorded. Another camera followed the teachers. Nine hours of video recordings were transcribed according to the Jeffersonian transcription notations (Atkinson & Heritage, 1999) (Appendix A). Field notes taken during class observations were used to contextualize the data collected (Derry et al., 2010). In total 96 essays, including 24 pre-tests (the first draft) and 24 post-tests (the third drafts) from both classes, were marked on the scale 1–6 by the classroom teachers and an independent English teacher.

To analyze the data we applied *mixed methods* (Creswell, 2012). The paired t-test was used to analyze the improvement between pre- and post-tests and the number of subthemes included in the pre- and post-tests. Cohen's *d* (Cohen, 1992; Field, 2013) was calculated to evaluate the effect size of this improvement. We used the independent t-test (Cohen, et al., 2011; Field, 2013) to calculate: a) statistical difference between the results of the pre- and post-tests and b) statistical difference between the number of subthemes included in the pre- and post-tests.

Two interaction extracts from the target and comparison classes analyzed qualitatively are presented. The groups were selected because the students were verbally active and the chosen extracts represent typical discussions that happened in the observed groups. The analytical procedure was inspired by inter-

action analysis (Jordan & Henderson, 1995). The primary unit of analysis were sequences and turns rather than isolated utterances (Linell, 2009). Once the interaction analysis was completed, the interactions were examined through the analytic lens offered by Galperin's types of orientation and pedagogical phases.

RESULTS

Analysis of pre-test and post-test data

In order to evaluate the writing process, we compare the results of the first (pre-test) and the last (post-test) drafts of students' essays. Forty-eight pre- and post-tests from both classes marked on the scale 1–6 constitute the quantitative data. Our analysis is based on the grades awarded by the independent teacher. The results of the pre- and post-tests are presented in Table 1.

TABLE 1. AVERAGE PRE- AND POST- TEST GRADES IN THE TARGET AND COMPARISON CLASSES AND THE OBSERVED GROUPS.

	Average grade pre-test (essay v.1)	**Average grade post-test (essay v.3)**	**Difference**	**Paired t-test**	**Cohen's d**
Target class	2.79 M = 2.79 SD = 0.88	4.79 M = 4.49 SD = 1.41	2	t (24) = –7.62 p < .000	d = 2.26
Observed target group	2.75	4.5	1.75		
Comparison class	2.88 M = 2.86 SD = 0.74	4.83 M = 4.83 SD = 0.87	1.95	t (24) = –8.86 p < .000	d = 2.64
Observed comparison group	3.5	4.5	1		
Independent t-test, p	p = .725	p = .903			

The paired t-test (Cohen et al., 2011) shows a significant difference between the average grades of the pre- and post-tests in both classes. Cohen's *d* (Cohen, 1992; Field, 2013) indicates large effect[3] in both classes. The independent t-test (Field, 2013) shows no significant statistical difference[4] between the grades of the pre-tests in the target and comparison classes and no significant statistical difference between the grades of the post-tests in the correspondent classes.

These results triggered our interest to do further analysis and in Table 2 we present the average number of subthemes in the essays in both classes.

3. Effect size Cohen's d>0.2 – little effect, Cohen's d>0.5 – middle effect, Cohen's d>0.8 large effect (Cohen, 1992; Field, 2013)
4. p> .05 indicates no significant statistical difference between the means of two samples (Field, 2013)

The paired t-test indicates a significant difference between the number of subthemes included in the pre- and post-tests in both classes. Cohen's d reflects large effect achieved in both classes. The independent t-test shows significant statistical difference between the number of subthemes in the pre- and post-tests: p= .000. The students in the target class included significantly more subthemes (almost twice as many) in their post-tests than the students in the comparison class.

TABLE 2. AVERAGE NUMBER OF SUBTHEMES IN THE PRE- AND POST-TESTS IN THE TARGET AND COMPARISON CLASSES AND THE OBSERVED GROUPS

	Average number of subthemes in the pre-tests (essay v.1)	**Average number of subthemes in the post-tests (essay v.3)**	**Difference between the average number of subthemes in the pre- and post-tests**	**Paired t-test**	**Cohen's d**
Target class	3.25 M = 3.25 SD = 0.79	7 M = 7 SD = 1.89	3.75	t (24) = –9.70 p < .000	d = 4.72
Observed target group	4	8.25	4.25		
Comparison class	4.04 M = 4.04 SD = 0.91	5.92 M = 5.92 SD = 1.14	1.88	t (24) = –6.91 p < .000	d = 2.07
Observed comparison group	4.5	6	1.5		
Independent t-test, p			p = .000		

The students in both classes achieved similar grades on their final drafts. However, the students in the target class included significantly more subthemes than the students in the comparison class. This encouraged us to take a closer look at the learning process and analyze student-student interactions qualitatively.

Analysis of the interactions of the students of the target class

In extract 1, four students are sitting around the table with open laptops. They have uploaded version 1 essays to EC3 and received feedback on the missing subthemes: in Galperin's terms, the learners are in the phase of communicated thinking. The group has just finished discussing the feedback Silje received. It is Thea's turn to share her feedback with the group. The names of the students have been changed for anonymity.

EXTRACT 1

1.	Thea:	We can mention where English is used today. And then I have an air traffic control thing and English as a major foreign language in school.
2.	Silje:	Yes. I have covered that. ((*reading from the screen*)) To be able to read the Internet pages and study, you require at least basic knowledge of English.
3.	Thea:	And to get a job. I think that is why you have to learn English at school or get to know it somehow.
4.	Ida:	I think they speak English in any store. If you go to Spain, for example, and you don't know Spanish and you go to a store and they don't speak English, you can't communicate then.
5.	Thea:	Yes, you have to know English to communicate with others. I was in Germany last summer with the school band and we were at the amusement park and there was a lady behind the counter in the souvenir shop, she hardly knew any English and that was so annoying!
6.	Ida:	The official language, like in France it's like: where can I find the passport desk? Er, er, er ((*making pointing gestures*)) They don't speak a word of English.
7.	Thea:	OK and then I have to say about how English helps people to find high quality jobs. Well, I think high quality jobs are international, in business and in companies. Many companies deal outside the country. My dad, he works with furniture, he has to travel to Asia and Europe. He knows what furniture we are going to sell in Norway and he has to know English very well because he talks to Chinese and Japanese people. And if you are going to be a doctor, many things should be learnt in English.
8.	Ida:	Well, I went to chiropractor, and only the secretary was Norwegian, all the doctors there spoke English; they were Australians and British and Americans.
9.	Thea:	So, if you are going to have a job, you have to have some knowledge.
10.	Ida:	Yes, basically you don't get a good job if you don't speak English.
11.	Thea:	Yes, you have to know some basic English.
12.	Ida:	Yes, at least.
13.	Thea:	Yes, at least.

The extract emphasizes the role of the generated feedback: two subthemes prompted by EC3 trigger a conversation and one of the feedback messages relates to the sentence in Silje's essay (line 2) extended by Thea (line 3). The students engage in the discussion by giving examples from their personal experience, which might serve as a way of making brief feedback more meaningful (lines 4–8). Summarizing their discussion, the girls draw a conclusion that English is very important for working life (lines 9–13).

The discussion may enable the learners to incorporate new ideas in their essays and hence, promote the development of their writing skills. In fact, Thea included the following in her final draft:

> "Today we find English all over the globe. In today's society you have to have some basic language to get around. You almost can't visit a website without some knowledge of English, and you can't watch TV without knowing English. We use English everywhere, we are surrounded with it. We use English in science and technological innovations and to get a good

> job. We even use English to communicate in air traffic control. English is used all the time and everywhere because the majority of the world's population knows some English."

This shows that the ideas EC3 had prompted appeared twice: 1) when talked about in groups and 2) incorporated as a new text in the essays.

Analysis of the interactions of the students of the comparison class

In extract 2, four students are sitting around the table with open laptops. They have received their first drafts from the teacher who graded them, without giving any feedback: the learners are in Galperin's phase of communicated thinking. Jonas and Tobias have read each other's essays and Jonas is in the middle of giving feedback to Tobias.

EXTRACT 2

1.	Jonas:	If you want, you can write about the upper class situation with learning English.
2.	Tobias:	It isn't coming naturally here, that's the point. And that's about history and I don't want more history.
3.	Jonas:	No, you need other things.
4.	Tobias:	Because ((*takes the assessment rubric*)) I have already five or six sentences about history, I don't think I need more.
5.	Jonas:	It's so difficult not to talk about history because the whole book is about history. Have you talked about music?
6.	Tobias:	Music? I say media, perhaps I should mention music. I say media and entertainment.
7.	Jonas:	You can specify, but that's not needed really.
8.	Tobias:	Then there will be producing of media, music and films and TV series ((*laughing*)) I feel like I want to write entertainment. It feels like it's easier.
9.	Jonas:	Yes, that's more descriptive.
10.	Tobias:	OK. But I feel if I want a better grade, there is something more I have to change.
11.	Jonas:	You decide.
12.	Tobias:	And I don't know what it is. That's kind of annoying.

Having looked through the assessment rubric, Tobias realizes that he has covered the historical reasons for the spread of English, but he is lacking other ideas (line 4). Jonas mentions music (line 5) and Tobias interprets this as "media, music, films and TV series" and generalizes it to "entertainment" (line 8). By eliciting each other's thoughts, the two peers attempt to develop their understanding of how to improve their essays. However, the students are somewhat unsure if they are moving in the right direction (line 12). Tobias includes the following in his final draft:

> " …the US has taken the role of a mass producer of media and entertainment in the world. After the Second World War, Europe was in ruins. The

> European industry and prosperity was dramatically slowed down, while in the US, the economy grew. Making the US the first and the only international superpower. Now, new Hollywood movies are displayed on the big screen all over the world."

Jonas writes:

> " With all new smartphones and streaming possibilities of films and music, we are hearing English more than we used to. With streaming programs like Netflix and Spotify, you can watch Titanic or listen to The Beatles on the bus. The massive information we receive from international news pages also influences us".

These paragraphs reflect the extent to which the two students are able to incorporate the spoken dialogs in their writing. Tobias chooses to write about the Unites States' role in the production of the world's media and entertainment from a historical perspective, whereas Jonas refers to the opportunities offered by streaming. The students' uncertainty about the type of feedback that should be given results in different interpretations of the ideas discussed when transferring them from speech to writing.

The analysis of extract 2 reflects that giving feedback can be difficult for learners. Nevertheless, by using the assessment rubric and exchanging personal ideas, the students are able to provide feedback suggesting potential improvements for their essays.

DISCUSSION

By adopting a cultural-historical perspective, this study explored students' writing processes in English through the exposure to two different types of orientation (see section Cultural-historical perspective on the development of writing skills). In this section we discuss the main findings in relation to Galperin's theory and previous research.

Target class

Galperin's types of orientation (Haenen, 2001; Rambusch, 2006) suggest that the students in the target class were exposed to so-called complete orientation. In other words, the mediational means needed for the learners to receive individual feedback (EC3), elaborate on it (group discussions) and improve their drafts were available and contributed to the significant improvement the students achieved from the pre- to post-tests. The analysis of students' interactions revealed that the discussions in the target group were triggered by the feedback generated by EC3, then elaborated and made sense of by referring to the learners' personal experiences. In this way, collaboration might have contributed to the development of students' understanding of the automated feed-

back, which might have resulted in a greater variety of subthemes included in the final drafts. This potentially indicates the need for incorporating group discussions when students' writing is supported with computer-generated feedback.

These findings reflect the role of EC3 in constantly assisting the students during the writing process by providing individual feedback to all learners simultaneously on multiple occasions and drafts. In doing this, EC3 supplements the teacher's facilitating of students' writing process (Lee et al., 2013). In addition, EC3 assisted the students in their analysis of essays by identifying the missing and covered subthemes, which was challenging for the learners in the comparison class. In this respect, the feedback from EC3 coincides with the five key strategies of formative assessment (Black & Wiliam, 2009): it clarifies and shares learning intentions and criteria for success (feedback on covered and suggested subthemes); engineers effective classroom discussions that elicit evidence of student understanding (initiated group discussions); provides feedback that moves learners forward (suggested subthemes); activates students as instructional resources for one another (initiated group discussions), and as owners of their own learning (individual feedback on multiple drafts and occasions).

On the one hand, EssayCritic is unique in two respects: 1) it utilizes semantic matching using Decision Tree learning algorithms to compute feedback on text-based artifacts and 2) it provides formative feedback which is dynamically computed based on the best essays produced by the community of learners and used to compare individual essays against it, suggesting further improvements in a cycle of write/rewrite activities.

On the other hand, the feedback given by EC3 was framed by the contextual constraints of the textbook Passage (Burgess & Sørhus 2009) and the pedagogical choices of the teachers made when identifying eleven subthemes to train the system (Landauer, et al., 2003; Ware, 2011), which might have narrowed the choice of the subthemes included in the essays. Consequently, the study raises the question of the need for teachers to critically analyze the cost-benefits of using computer-generated feedback as formative assessment in the writing process. In addition, reflecting on the four levels of feedback (Hattie & Timperley, 2007), EssayCritic provides only feedback about the task, but not about the processing of the task. This may be addressed as potential improvements of EssayCritic in further research.

Comparison class

The learners in the comparison class also achieved significant improvement from pre- to post-tests. However, the students' discussions showed that giving feedback was challenging. The learners were unsure about what kind of feedback to give and what tools could assist them. The peers had to identify useful resources when giving feedback, which indicates that they were exposed to the

orientation of the third type (Haenen, 2001; Rambusch, 2006): complete but created by learners based on a general approach. The assessment rubric with the list of the subthemes, the students' essays, the peers and the teacher were the resources available and the students' previous experience in the AfL practice served as a general approach they were to pursue. The learners struggled in their attempt to give feedback: the analysis revealed that the students relied on their general understanding of what had to be improved (Hansman & Wilson, 1998). The assessment rubric, however, was occasionally used as a guiding tool. By reading each other's drafts, the students might have acquired another insight, as one source for ideas to write about. However, students' uncertainty about the type of the feedback that would improve their drafts resulted in different interpretations of the mutually discussed ideas. The quantitative analysis showed that the students in the comparison class included fewer subthemes in their final drafts.

Directions for further research

Our findings suggest that further research is needed to explore: 1) whether EC3 can be modified so that it would provide feedback both on the task and on the processing of the task (Hattie & Timperley, 2007); 2) whether the students exposed to the complete orientation are able to transfer their feedback-giving skills gained working with EC3 to other learning situations without access to EC3, 3) the role of the teacher facilitating students' writing with EC3; and 4) our tentative hypothesis that group discussions based on the feedback given by EC3 are more likely to be incorporated in the text compared to other conditions.

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
Courier	`Courier  Verbatim reading from screen (typed text)`

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Article 3

Engeness, I. (accepted for publication) What Teachers Do: Facilitating the Writing Process with the Feedback from EssayCritic and Collaborating Peers.
Technology, Pedagogy and Education

ERRATA LIST

Pages vi and 123

Article 3 has been published in a slightly revised version in Technology, Pedagogy and Education journal:

Engeness, I. (2018). What teachers do: facilitating the writing process with feedback from EssayCritic and collaborating peers, *Technology, Pedagogy and Education*, 1-15
DOI:10.1080/1475939X.2017.1421259