Juho Oikarinen

TECHNOLOGY-ENHANCED STATISTICS LEARNING EXPERIMENT

A CASE STUDY AT UPPER SECONDARY LEVEL
JUHO OIKARINEN

TECHNOLOGY-ENHANCED STATISTICS LEARNING EXPERIMENT
A case study at upper secondary level

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Abstract

The aim of this study was to examine and develop statistics education by implementing computer supported collaborative learning (CSCL). This study has been influenced by design-based research, and it focuses on describing the statistical learning of upper secondary school students (N=138) in a CSCL environment, both quantitative and qualitative methods have been utilised. The present study is filling a gaping void in classroom study and disseminates new knowledge with a novel approach in combining CSCL, mathematics education at secondary level and statistical literacy.

First, the students’ starting level in statistical literacy was assessed in the pre-test in which students’ perceptions and knowledge of statistics was evaluated. The results showed that students had a severe lack of understanding of basic statistical concepts.

Second, CSCL supports students in collaborating asynchronously in different small-groups by using technology. Results suggest that studying in a group fostered their learning and the electronic and interactive material clarified learned topics which was designed by integrating the principles of cognitive theory of multimedia learning.

Third, the shift from traditional didactic instruction towards student-centred CSCL learning was challenging for students. According to the results, students had only a few earlier experiences in learning CSCL environments. The quality of the students’ conversational acts varied considerably. It seems that learning how to collaborate productively needs practice. According to the results, the articulation and quality of mathematical discussion increased as students’ acquaintance with their teammates improved.

Students’ collaboration in small groups was examined by using video analyses and content analyses. Contact summary sheet -instrument used in analyses facilitated observation of the magnitude and quality in student’s inter-subjective phenomena in collaborative learning.

Fourth, students in the treatment group had better learning outcomes than students in the control group. The results suggest a statistically significant difference between treatment and control groups only in the delayed post-test and the effect size indicates a medium effect. The interactive material and CSCL seemed to foster and facilitate the development of statistical literacy. Nevertheless, students were critical of studying in the CSCL environment.

Keywords: collaborative learning, computer supported collaborative learning, design-based research, statistics learning
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Oulun yliopiston tutkijakoulu; Oulun yliopisto, Kasvatustieteiden tiedekunta
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Tiivistelmä

Tutkimuksen tarkoituksena oli tutkia ja kehittää tilastojen opetusta hyödyntäen tietokoneavustetta ja yhteisöllistä oppimista (CSCL). Tutkimus on saanut vaikutteita design-perustaisesta tutkimuksesta ja se keskitty nykyisä aikaan lukio-opiskelijoiden (N=138) tilastojen oppimista CSCL- ympäristössä ja tutkimuksessa on hyödynnetty kvantitatiivisia ja kvalitatiivisia menetelmiä. 

Tämä tutkimus lisää tietämystä luokkahuoneetutkimuksesta ja yhdistää CSCL:n ja tilastollisen lukutaidon opetuksen toisella asteella.

Ensimmäiseksi oppilaiden tilastollisen lukutaidon lähtötaso mitattiin alkutestissä, missä arvioitiin heidän ennakkokäsityksiään ja tietoa tilastoista. Tutkimustulokset osoittivat, että oppilailla oli suuria vaikeuksia ymmärtää tilastollisia peruskäsitteitä.

Toiseksi CSCL-teknologia tukee asynkronisesti pienryhmätyöskentelyä. Tulosten mukaan opiskelu ryhmissä tuki opiskelijoiden oppimista ja sähköinen ja interaktiivinen oppimateriaali selkiytti opeteltavia asioita, joka oli suunniteltu kognitiivisen multimedia oppimisteorian periaatteiden mukaisesti.


Opiskelijoiden pienryhmätyöskentelyä tutkittiin video- ja sisällönanalysen avulla. Analysoinnissa käytetty contact summary sheet -instrumentti auttoi havainnoimaan opiskelijoiden yhteistoiminnallisen oppimisen laatua ja määrittämistä.

Figuroiksi opiskelutestin ja laantu lopputulokset ovat merkittävät eri osissa hyödyntäen opetuskokeiluun osallistuneiden tilastollisen oppimisen tarkemman selvityksen. Interaktiivinen oppimistilanne ja CSCL näyttävät edistävän tilastollisen oppimisen kehittymistä. Tästä huolimatta, opiskelijat suhtautuivat kriittisesti CSCL-ympäristöön.

Asiainmat: design-perustainen tutkimus, tietokoneavustelun yhteisöllinen oppiminen, tilastojen oppiminen, yhteisöllinen oppiminen
Preface

As a senior lecturer in mathematics in upper secondary school, it has been a great opportunity to have an experience as a part-time researcher. It has enabled me to contemplate learning design, processes and evaluation in scientific and versatile ways. In the age of information technology, we have to peel sweet temptations from learning environments and show and provide students with the most constructive opportunities and strategies in learning.

The premise in my study was to improve and enrich teaching and practices in lessons. My endeavour was to combine information and communication technology (ICT), collaboration and mathematics education. After spending these fruitful moments and having these experiences in postgraduate studies, I have enlarged my proficiency as a teacher as well as a researcher. My postgraduate studies have also enabled my participation in several international events.

This study has been carried out in an upper secondary school in the eastern part of Finland. This design-based and technology-enhanced teaching experiment study concentrates on students’ collaboration in statistical problem-solving in the compulsory advanced mathematic course probability and statistics.
Acknowledgements

It has been a great opportunity to spend these years as a postgraduate student mainly as a part-time researcher. The completion of this dissertation process would not have been possible without the support of a number of talented individuals and academic communities. This dissertation has been completed in the University of Oulu in Finland under the direction of Professor Sanna Järvelä and Professor Raimo Kaasila. Many thanks to my supervisors for their useful advice and support.

This study has been carried out in real-world educational contexts. Hence, I thank the principal who granted the dissertation and my workmates as well as students who participated in the sub-studies of dissertation. I appreciate particularly and thank my workmate Dr Antti Savinainen who gave me additional support in writing this dissertation.

This study has been also supported by the Finnish Cultural Foundation, the Finnish Cultural Foundation – North Savo Regional Fund, the Foundation of the University of Oulu, the OKKA Foundation, the Finnish Graduate School and the Nordic Society for Research in Mathematics Education (NoRME).

It has been a great pleasure during this process to participate in different kind of events in Mathematics Education. Participating in the international conferences, seminars and summer-schools have given me a fruitful input into the dissertation in order to comprehend the nature of this domain.

The dissertation has also benefitted enormously from the useful feedback I have received in a revision seminar from Dr Essi Vuopala and fellow PhD student Marjut Sulkakoski. I have made use of all of the valuable comments and advice provided by the entire Learning & Educational Technology research unit (LET). In addition referees Tarja-Riitta Hurme and Markus Hähkiöniemi have given me most useful feedback and ideas to refine the present study. In the last meter of publication process editor Veli-Matti Ulvinen and Vesa Komulainen have given useful feedback to finalise this dissertation to the format of the series Acta Universitatis Ouluensis. In the age of information and smart technology, it has been a fruitful and illuminated experience to travel this path in mathematics education.

Finally, I would like to thank my family – my patient wife Maarit and my vibrant and spirited children: Roosa, Heta, Akseli and Linnea for all their love, support and forbearance. In loving memory of my mother,

Kuopio, September 2016

Juho Oikarinen
Abbreviations

CL       Collaborative Learning
CTML     Cognitive Theory of Multimedia Learning
CSCL     Computer-Supported Collaborative Learning
CSS      Contact Summary Sheet
DBR      Design-Based Research
GAISE    Guidelines for Assessment and Instruction in Statistics Education
IASE     International Association for Statistical Education
ICMI     International Commission on Mathematical Instruction
ICT      Information and Communication Technology
ILD      Integrative Learning Design
LT       Learning Task
NCTM     National Council of Teachers of Mathematics
PISA     Programme for International Student Assessment
SL       Statistical Literacy
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1 Introduction

The growing movement to expand and include statistics at all educational levels has created an interest in employing effective instructional methods to teach abstract and difficult statistical concepts. Nevertheless, little empirical research exists on this subject (Mills 2002). There has been lack of studies about teaching and learning statistics in online courses (Mills & Raju 2011). Studies are needed combining collaboration, technology enhanced teaching experiment and statistics education in upper secondary school. This design-based research focuses on documenting upper secondary school students’ statistical learning in a CSCL environment.

According to the PISA results, the Finnish school-system has been ranked very high (Kupari et al. 2013), but there is no sense in being too satisfied with the results. In our modern and sophisticated school system there are still severe problems and obstacles in students’ learning processes, and so development in education is needed. Also, the first steps in the current trend in the age of information is a great challenge to educators. Luckily, there are some opportunities to improve our education methods in general. For example, teachers in schools have an important role to teach both statistical literature and collaboration skills to students. Often, statistical numbers and graphics are utilized in the media for brief and explicit expressions. In most major newspapers, statistical studies are featured prominently on a daily or weekly basis (Utts 2003) even if most citizens as well as many reporters do not have the knowledge required to read them critically.

It is important to be critical about how to read and interpret the statistical information. Many personal and political decisions are made based on statistical interpretations and, at worst, misuse of the results from statistical studies by policy-makers, physicians and others leads to misunderstandings (Utts 2003). Based on recent research, it seems that statistical literacy is unfamiliar and hard to understand to most people (Gal 2002). Educators are in a key-role in underpinning the development of students’ statistical learning processes. In this study and teaching experiment, learning happens via electronic learning material and collaboration. Especially if there are any differences in students’ achievements in statistics when compared with traditional mathematics instruction.

Ross (1995) has stated that the most important achievement in graduate school education is that students comprehend the power of team and know-how to communicate in team settings. These future and especially teamwork skills should also be taken seriously in education at a lower level. This exploratory study is an
excellent example of the usefulness of implementing collaborative learning (CL) and CSCL in statistics education. When students are instructed in teamwork skills and they have internalized CL, the conversation acts become remarkably productive in group settings (cf. Ben-Zvi & Garfield 2007). Productive conversation acts seem to facilitate statistical learning. In this study, students’ conversational acts are under review when we study their learning processes. Also, students’ opinions on the contribution of CSCL environment in learning statistics are studied.

There is a large number of studies concerning collaboration and technology as well as learning outcomes and growing numbers of studies in contributing the successes and failures of these domains. This study can be seen as an example of how the teaching of statistical literacy or mathematics education could be developed in our schools. The dissemination of this design-based research is in reporting the technology-enhanced teaching experiment in statistics at the secondary level. Most studies of statistical literature have been done in comprehensive school or at the graduate level. One emergent value of this study is to present results in this dissertation where these elements have been combined. In the statistical literature, upper secondary schools provide new knowledge of this research area.

1.1 Rationale

Finnish comprehensive school students have been successful in the Programme for International Student Assessment (PISA) in the 21st century (Kupari et al. 2013, Sahlberg 2009, Thomson & De Bortoli 2008). But still the novel results suggest that proficiency in mathematics has declined considerably from the level in 2003 as well as literacy and proficiency in the natural sciences (Kupari et al. 2013). This should be a good starting point to implement this knowledge and contemporary technologies and feasible approaches in pedagogy in education. One aim of this study is to investigate how collaboration and technology-enhanced learning settings could contribute or obstruct students’ adaptation of statistics in mathematics education.

The financial crisis in Europe and worldwide has shown the power of misleading and manipulated statistical information (Paulos 1991). The policy makers have made wrong or hasty interpretations in decision-making based on misleading statistics. In reading and interpreting statistics one should always bear in mind from whose perspective the statistics have been constructed. Statistical
teaching can have a significant role in promoting future citizens and policy makers’ ability to comprehend surrounding statistical information in real-life demanding situations.

The National Council of Teachers of Mathematics (NCTM) (2000) stresses an understanding of probability and the related areas of statistics as an essential feature of an informed citizen. Knowledge of statistics is crucial to students’ development into critical and intelligent data consumers (Schied 2004). From the perspective of mathematical education, in order to develop students’ statistical outcomes from basic literacy to critical thinking, a variety of educational approaches is needed. Students and even professionals often misunderstand statistical ideas (delMas et al. 1999). Students need to construct a deeper understanding of fundamental concepts in order to develop better statistical reasoning skills.

In the last 25 years, worldwide, but especially in the United States, attention has been paid to teaching probability and statistics in our schools (Shaughnessy 2006). However, until the 1990s, teaching probabilities and statistics has had a poor status in school mathematics. Probability and statistics have been used merely to enrich and colour the teaching of other subjects. In 2000, NCTM has included probability and statistics among the five most important subjects within school mathematics. This has increased interest in studying students’ patterns of statistical thinking and how statistical learning and teaching could be developed. After this study, there more studies on teaching probability and statistics have appeared. There have been findings in this study that statistics education has a poor status in the Finnish comprehensive school.

Furthermore, it is urgent to educate students to be sensitive and vigilant in reading and understanding new data and to give them enough challenging and secure learning situations in learning statistics. In order to achieve statistical reasoning and thinking in the upper secondary school, statistical literacy should also be developed in the comprehensive school. Basic literacy is the framework of statistical education, but basic statistical literacy cannot develop without good statistical teaching in our schools.

The present study concerns upper secondary school students’ statistical learning outcomes in CSCL learning environment context. The purpose of this study is to create a technology-enhanced environment which enables students to learn asynchronously in small-groups as active and collaborative participants. Before the actual teaching experiment, a pilot study has been carried out in the first year advanced mathematics course of analytical geometry. The pilot study has
provided relevant information about the feasibility of learning technology and collaboration.

In the first stage of the present study, the authors assess students’ starting level of statistical literacy before the students begin the course in probability and statistics at the start of the second school-year in upper secondary school in Finland. This study examines how well students have adapted to the statistical tasks in the comprehensive school curriculum. It aims to provide an understanding of Finnish upper secondary school students’ statistical literacy and their conceptions of statistics before taking the aforementioned probability and statistics course. Such knowledge is valuable from the viewpoints of designing and refining the curriculum, textbooks, and learning and teaching materials.

In the second stage of the present study, the authors document students’ collaboration when learning statistics in a CSCL environment in the current teaching experiment. In addition, this stage portrays the emergent value of this study in reporting the shift from teacher-led teaching in mathematics to autonomous student-centred small-group learning. Students’ collaboration in learning statistics in the CSCL environment has been examined, and the related learning tasks are depicted. There are a few studies on CSCL Finnish schools, but few of them are relevant to the upper secondary level. This study provides new information about CSCL in upper secondary maths.

In the third stage of the present study, the authors characterize students’ collaboration in statistical problem solving and students’ statistical learning processes. A contact summary sheet -instrument (CSS) was developed for analysing selected video episodes and the conversations. This novel instrument for analysing students’ conversational acts in collaboration can be used in other studies too.

In the last stage of the present study, the authors depict learning outcomes via a technology-enhanced teaching experiment involving learning statistics at the secondary school level. In addition, the authors investigate possible differences between the statistical learning outcomes of the treatment and the control groups. The essential part of this study is reporting how the CSCL environment can potentially be employed in teaching experiments to foster the learning of statistics. The present study examines upper secondary school students’ achievements in statistics and the feasibility of electronic testing in mathematics. The results provide valuable knowledge with regard to electronic reform of the matriculation examination.
In this study, a CSCL environment is applied to mathematics learning, in which students could collaborate asynchronously in small groups, which enabled statistical learning and the shared learning experiences, as well as collaboration. This is because computer tools provide opportunities for students to converge and display their shared learning (Hmelo-Silver 2003). The pedagogical design is tested in the pilot phase in order to implement the improved pedagogical model that is characteristic of design-based research (DBR) (Bannan-Ritland 2003). The foundation for the design of the group work supporting software is in understanding the nature of group interaction and group meaning making (Stahl 2010). Integrative learning design (ILD) has been another premise that is used in designing material for this teaching experiment.

In this teaching experiment, the materials enable small groups to work asynchronously. Students are also needed to be directed in their hands-on experience with simulations in order to develop a good understanding of the underlying statistical concepts (Lunsford et al. 2006, Mun 2011). An extension of his teaching experiment is to implement computer-supported test environment in mathematics education by using knowledge of Mathematics Education, Research, Software-background and the experience of the electronic-test. It can be utilized in the matriculation examination with broader impact.

1.2 Objectives and research questions

This study investigates upper secondary school students’ statistical learning in a CSCL context. The aim is also to delineate students’ knowledge of statistics in order to adjust learning material in a pedagogically useful manner. In the core of this study, students’ collaboration, learning processes and learning outcomes as well as students’ adaptation of the use of statistical software was investigated.

In the first section of this study, Finnish upper secondary school students’ starting level in statistical literacy is assessed. Students’ own perceptions of their proficiency in statistics as well as students’ opinions about statistical teaching in comprehensive school are examined. Research questions are:

1. What is the starting level of statistical literacy and attitudes towards statistics among students before the course of probability and statistics in upper secondary level?

   a) What are students’ own conceptions of statistics teaching in comprehensive school?
The aim in the second section of this study is to present students’ opinions about the teaching experiment in CSCL environment. The research questions is:

2. What is the contribution of the CSCL environment in learning statistics in students’ opinions?

The major objective of this section of the study is to indicate the nature of statistical learning processes in terms of the form of collaboration in the CSCL environment. In this study, students’ conversational acts of using the CSCL in learning statistics are evaluated through the following research question:

3. What kind of differences can be found in learning processes among different small groups during collaboration in a CSCL environment in statistics?

In the fourth section of this study, students learning outcomes are evaluated through a course exam and delayed post-test. The purpose of the course exam and delayed post-test is to point out the equalities as well as differences in deeper learning between students in the teaching experiment and a comparison class. Students learning outcomes in the teaching experiment in the year 2012 are evaluated through an immediate test after the teaching experiment. There is an electronic test after the teaching experiment. The main aim of the electronic test is to evaluate how students have adapted utilization of the computer in statistics in the topics of the course. The research questions is:

4. What is the difference in student achievement in statistics when compared CSCL and traditional mathematics instruction?

   a) How students have adapted utilization of the computer in statistics?
2 Theoretical background

Over the past few decades, many studies focused on teaching and learning statistics have been reported (Garfield 1993, Garfield & Ben-Zvi 2007). Statistics educational studies can be divided into three categories based on various perspectives such as teaching and learning methods, implementation of technology in statistics education, and evaluation of teaching and learning methods (Tishkovskaya & Lancaster 2012). The International Association for Statistical Education (IASE) is the international umbrella organization for statistics education. This organization aims to promote, support, and improve statistical education at all levels worldwide. According to IASE’s data (2016), 93 doctoral dissertations related to statistics education have been published worldwide in this millennium.

Finnish upper secondary school students’ attitudes towards statistics and their own conceptions of statistics teaching in comprehensive school provides a point of reference from the viewpoint of international research. Based on international research, students have traditionally studied statistics individually. The importance of studying the quality of social interaction among students is more evident when the majority of students are not familiar with collaboration. Mutually shared understanding seems to foster active learning (Van den Bossche et al. 2006). In the present study, the contribution of CSCL in learning statistics is examined through this perspective as well.

In recent years CSCL has been pursued as one possible method in fostering education in general (Brandon & Hollingshead 1999, Lehtinen et al. 1999). According to Lehtinen et al. (1999), a computer environment can improve the magnitude and quality of social interaction among students and between teachers and students. Deliberate use and implementation of the technology is crucial to having a direct impact on student learning (Chance et al. 2007). A reasonable number of positive learning effects occur when CSCL systems have been implemented in classroom learning (Lehtinen et al. 1999).

Students’ statistical learning outcomes are examined by dividing them into two groups, namely, CSCL treatment group and traditional mathematics instruction group. In the teaching experiment conducted herein, different levels of statistical learning processes are analysed. The theoretical background portrays the versatility of technology-enhanced mathematics learning. Achieving the desired impact of technology as an inherent part of teaching and learning mathematics requires the appropriate use of technology. In spite of the preponderance of CSCL, it is not a recipe for promoting learning outcomes: “its results depend upon the extent to
which groups actually engage in productive interactions” (Dillenbourg et al. 2009: 4).

In the chapters that follow, the theoretical background of this study is reviewed. It reviews mathematical education and statistical learning, technology-enhanced learning in mathematics and statistical learning in small-group activities. The theoretical background concentrates on the main domains of this study: statistical literacy (SL), statistical reasoning, statistical thinking, CL, CSCL, functional roles and cognitive theory of multimedia learning (CTML). At the end of the theoretical background, a taxonomy of collaborative conversation acts in statistical learning processes is given.

2.1 Mathematical education and statistical learning

There are different kind of approaches to teaching and learning in mathematics education. Improvement of mathematics learning in classrooms is fundamentally related to development in teaching which requires engagement both teachers and students to grow into the practices through a learning process (Jaworski 2006). In a traditional, didactic instruction learning setting, the teacher often conveys the textbook’s curriculum-saturated knowledge in a strict and rather learner-passive manner (Röj-Lindberg 2001).

Probability and statistics are among the five most important subjects within school mathematics, and they are not only to be used merely to enrich and colour the teaching of other subjects (The National Council of Teachers of Mathematics 2000). The underlying standards of content and process include statistical literacy, data analysis, and probability. Learning statistics is an essential part of being an informed citizen and data consumer. Mathematical communication enables students to share ideas and clarify understanding: “Listening to others’ explanations gives students opportunities to develop their own understanding. Conversations in which mathematical ideas are explored from multiple perspectives help the participants sharpen their thinking and make connections” (The National Council of Teachers of Mathematics 2000: 60).

According to the Guidelines for Assessment and Instruction in Statistics Education (GAISE), the curriculum framework for PreK-12 has stated recommendations for statistics education (Franklin & Garfield 2006). These recommendations are to: 1. Emphasize statistical literacy and develop statistical thinking, 2. Use real data, 3. Stress conceptual understanding, rather than a mere knowledge of procedures, 4. Foster active learning in the classroom, 5. Use
technology for developing concepts and analysing data, and 6. Use assessments to improve and evaluate student learning.

Nowadays, many different learning and teaching approaches can be implemented in education. It is not clear what teaching should or might involve: “thus, we learn about teaching with the possibility to develop teaching” (Jaworski 2006: 189). Mathematics teaching is developed through the work of mathematics teachers. Thus, pre-service teacher education and additional in-service mathematics teacher education are important.

2.1.1 Trends in mathematics education research in Finland

In the last decades of 20th century, first cognitive psychology and later constructivism has characterized a strong emphasis on mathematics education. Later, new trends such as teacher education and professional development, algebra and algebraic thinking, affect, emotion, beliefs and attitudes, etc., have taken a place in the domain of mathematics education (Hannula 2009).

Trends in mathematics education research in Finland can be categorised into five main streams: mathematics teaching, mathematics learning and study, affects, professional development as a teacher, and the educational system (Krzywacki et al. 2012). A second distinction is to categorise studies into empirical or non-empirical. Presumably, the volume of research in mathematics education in Finland is quite low, and it is focused more on themes such as affects in mathematics learning and study rather than on study of classrooms. Table 1 summarizes the distribution of mathematics education research including national articles, national dissertations, scientific articles, and conference articles over the past two decades in Finland.

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In Table 1, the conference articles are selected from the annual conference proceedings of the International Group for the Psychology of Mathematics Education (PME). The international scientific articles are ranked by using the Scopus database in years 2000–2009. The national articles are assembled from the sources of: The Finnish Journal of Education, conference proceedings of mathematic didactic symposiums, conference proceedings of the Finnish Mathematics and Science Education Research Association (FMSERA) and dissertations. Some of publications are calculated more than once in Table 1, because they are located in different domains of interest (Krzywacki et al. 2012). During the last two decades¹, Krzywacki et al. (2012) have

found 214 national articles including 34 dissertations and 84 peer-reviewed conference or scientific journal articles at the international level.

Table 1. Mathematics education research in Finland 1990–2009, Krzywacki et al. 2012.

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<th>Themes</th>
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<td>Learning</td>
<td>66</td>
<td>21.64%</td>
</tr>
<tr>
<td>studying</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=92) 30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affects</td>
<td></td>
<td>14</td>
<td>4.59%</td>
</tr>
<tr>
<td>(n=100) 33%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional development as a</td>
<td></td>
<td>28</td>
<td>9.18%</td>
</tr>
<tr>
<td>teacher</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=31) 10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational system</td>
<td></td>
<td>7</td>
<td>2.30%</td>
</tr>
<tr>
<td>(n=17) 6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=305)</td>
<td></td>
<td>241</td>
<td>79.02%</td>
</tr>
</tbody>
</table>

1 AF = all frequency,  
2 RF = relative frequency

The most essential themes in mathematics education research in Finland are affects and mathematics learning and study. Studies of teaching experiments in mathematics education research are needed. Only a few studies have employed a mixed-methods approach. Research on pre-service teacher education, mathematics teaching, and in-service mathematics teachers has increased to 15% of all studies on mathematics education in Finland (Krzywacki et al. 2012).

Dissertations of statistics education in Finland (e.g. Murtenon 2005, Rautopuro 2010) focus on to examine the state of statistical research and the problems of teaching and learning statistical methods in tertiary level. In this study, we perform an empirical
and multidisciplinary teaching experiment involving Finnish mathematics education in secondary level.

2.1.2 Statistical literacy

At the end of 20th century many researchers have been concerned about difficulties in learning basic concepts in probability and statistics (Garfield & Ahlgren 1988). The development of different types of understanding and cognitive outcomes in statistics promotion in education is needed (Cobb 1992). One of the first definitions of statistical literacy is Wallman’s definition as the ability to understand and critically evaluate statistical results that might appear in daily life (Wallman 1993).

It was crucial for the development of statistical literacy when The National Council of Teachers of Mathematics (2000) stated that statistical competence is a prerequisite to being an informed citizen and data consumer. Basic statistical competence involves data awareness, an understanding of certain basic statistical concepts and terminology, knowledge of the basics of collecting data and generating descriptive statistics, as well as basic interpretation and communication skills (Rumsey 2002). These specific concepts and skills will be needed in the context of specific jobs in future. In today’s world, statistical skills should be thought of as “civics”. The curriculum of comprehensive schools in Finland includes a similar basic statistical competence definition.

Statistical teaching should lead students to become good statistical citizens (Rumsey 2002). A good statistical citizen understands statistics well enough to be able to consume the information that they are inundated with on a daily basis. Gal (2002) also stresses citizens’ ability to interpret and critically evaluate statistical information by using data-based arguments in discussing their opinions regarding such statistical information in diverse and different kind of media channels. In the pre-test students’ basic statistical literacy and competence are reviewed by using the criteria of the final assessment of mathematics used in comprehensive schools (Opetushallitus 2004).

The definition of statistical literacy is the fundamental understanding of statistics (Ben-Zvi & Garfield 2004, Chance 2002). It includes knowledge of basic statistical concepts, statistical methods and the understanding of results. It also includes the interpretation of various figures and distributions, statistical parameters, etc. In identifying the learning outcomes in statistical literacy, Garfield and Ben-Zvi (2004) state a premise. It involves an understanding of statistical language: words, symbols, and terms. It also comprises an ability to interpret graphs.
and tables as well as the ability to read and make sense of statistics in the news, media, polls, etc.

Garfield and Ben-Zvi (2007) have stated that statistical literacy is an expected key ability of citizens in information-laden societies as well as an expected outcome of schooling and as a necessary component of adults’ numeracy and literacy. Hayden (2004) defines that a person who is statistically literate is able to deal with issues of probability and statistics that arise in everyday life. Statistical literacy can serve individuals and their communities by allowing them to make choices when confronted with chance-based situations (Gal 2002). The lack of statistical literacy causes difficulty in distinguishing the correct statistical information and may even lead to making incorrect decisions (Utts 2003).

Watson (1997) has also identified three tiers of development of statistical thinking: the first tier is the basic understanding of terminology. The second tier is embedding of language and concepts in a wider context. The third tier is the questioning of claims. When Watson has outlined statistical thinking, she has also defined statistical literacy. For example, Rumsey (2002) interpreted Watson's' statistical thinking as statistical literacy – because the concept of statistical literacy was so novel in the late 20th century. Many researchers used the term statistical thinking as a synonym for statistical literacy. The terms statistical literacy, statistical reasoning and statistical thinking are often used interchangeably and used in different ways by different authors (Garfield & Ben-Zvi 2007, Schied 2004, Wild & Pfannkuch 1999).

According to Watson (1997), a basic understanding of statistical terminology is needed for understanding statistical language and concepts. It enables us to distinguish contradictions in claims that are processed without proper statistical foundation. Thus, statistical literacy requires the ability to respect statistical thinking in general, private, professional, and personal decisions (Wallman 1993). A student who has the ability to correctly understand and interpret tables, graphs, figures, distributions, and percentages has solid statistical literacy.

2.1.3 Statistical literacy, statistical reasoning, and statistical thinking

The first definitions of statistical literature emerged late in the 20th century. There has been inconsistency in the use of the terms statistical literacy, reasoning, and thinking (delMas 2002a, Mooney 2002). In the present study, the definition of statistical literacy that describes statistical literacy, reasoning, and thinking as independent and hierarchical domains that may overlap is used to describe students’
statistical literacy (see Fig. 1). Watson’s and Callingham’s (2003) framework is used to analyse students’ levels of statistical literacy.

Some researchers in the field of statistical education use the terms statistical literacy, reasoning, and thinking interchangeably and even use them in different ways (delMas 2002, Mooney 2002). From the statistics educator’s point of view, statistics should be taught as statistics, and the distinctions between those three domains should be given greater consideration (Ben-Zvi & Garfield 2004, Cobb & Moore 1997). A certain level of statistical literacy should be achieved during comprehensive school in order to give students the ability to achieve an acceptable level of statistical reasoning and thinking at upper secondary level.

There are three different levels of statistical learning (Chance 2002). The development of statistical learning begins with statistical literacy. At this first level, the knowledge of basic statistical concepts and methods will increase. Statistical literacy implies the understanding and use of the basic language and tools of statistics (Rumsey 2002). It also refers to acquiring knowledge of the meanings of statistical terms, understanding the use of statistical symbols, and the capability to interpret representations of data (Rumsey 2002).

At the second level, which is statistical reasoning, students are able to produce statistical information and material and find the key issues within the given data (Garfield 2002). Statistical reasoning refers to the ability to use statistics in decision-making (Garfield 2002). Statistical reasoning can be seen as an understanding of and capability to explain statistical processes as well as the capability to fully interpret statistical results (Ben-Zvi & Garfield 2007). When using statistical reasoning, people reason with statistical ideas and comprehend statistical information (Garfield 2002).

The third level is statistical thinking, in which students’ creativity, individual thinking and methodological expertise increase. Students are able to apply previously learned theoretical structures to new situations (Chance 2002). Statistical thinking is the interpretation of given or formulated statistics as well as their use and decision-making based on them. Statistical thinking is a commonly used term that is understood in general terms, but the scientific definition of statistical thinking is inaccurate and incomplete (Chance 2002). Statistical thinking is an independent, creative and applied activity. In statistical thinking, basic statistical concepts and theoretical structures that were learned earlier can be utilized in new situations. At the statistical thinking level, students are able independently to use the information learned in methodological courses while formulating new research problems (Wild & Pfannkuch 1999).
The taxonomy of Bloom et al. (1956) in Table 2 is ordered in six increasingly difficult levels as follows: knowledge, comprehension, application, analysis, synthesis, and evaluation. The basic idea in proceeding in the levels of the taxonomy of Bloom et al. (1956) is that one level must be mastered before the transition to the next. It is useful to educators to know when it is fruitful timing to proceed to the next level of the learning topic.

Table 2. Taxonomy of Bloom et al. (1956).

<table>
<thead>
<tr>
<th>No.</th>
<th>Level</th>
<th>Sample verbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Knowledge</td>
<td>arrange, define, duplicate, label, list, memorize, name, order, recognize,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>relate, recall, repeat, reproduce, state</td>
</tr>
<tr>
<td>2</td>
<td>Comprehension</td>
<td>classify, describe, discuss, explain, express, identify, indicate, locate,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recognize, report, restate, review, select, translate</td>
</tr>
<tr>
<td>3</td>
<td>Application</td>
<td>apply, choose, demonstrate, dramatize, employ, illustrate, interpret,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>operate, practice, schedule, sketch, solve, use, write</td>
</tr>
<tr>
<td>4</td>
<td>Analysis</td>
<td>analyse, appraise, calculate, categorize, compare, contrast, criticize,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>differentiate, discriminate, distinguish, examine, experiment, question, test</td>
</tr>
<tr>
<td>5</td>
<td>Synthesis</td>
<td>arrange, assemble, collect, compose, construct, create, design, develop,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>formulate, manage, organize, plan, prepare, propose, set up, write</td>
</tr>
<tr>
<td>6</td>
<td>Evaluation</td>
<td>appraise, argue, assess, attach, choose compare, defend estimate, judge,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>predict, rate, score, select, support, value, evaluate</td>
</tr>
</tbody>
</table>

In the middle of 20th century, there was an intention to classify educational goals and objectives. The classification system developed defines three domains: the cognitive, the affective, and the psychomotor. The cognitive domain is commonly referred to as the taxonomy of Bloom et al. (1956). The basic idea of the taxonomy is in arranging and classifying students’ educational outcomes in a hierarchy from less to more complex outcomes (Huitt 2014).

According to the Bloom et al. taxonomy (1956), it can be much more beneficial to educators to divide the topics of learning issues into several learning phases. This contains the same basic idea that statistical learning issues can be ordered into increasingly difficult levels in statistical literacy, statistical reasoning and statistical thinking before proceeding to the more complex level (Ben-Zvi & Garfield 2004, Cobb & Moore 1997).

There is similarity between the categorisation of the three aforementioned learning outcomes and Bloom’s more general categories of cognitive educational outcomes (Garfield et al. 2010). Statistical literacy is consistent with the knowing category, statistical reasoning is consistent with the comprehension category and
with some aspects of the application and analysis category, and statistical thinking encompasses many elements of the three levels of Bloom’s sophisticated taxonomy: analysis, synthesis, and evaluation. Statistical literacy, statistical reasoning, and statistical thinking are the three general categories of statistical learning outcomes (Ben-Zvi & Garfield 2004, Chance 2002). The categorization of learning outcomes in statistics is more useful than the six general categories of cognitive processes in Bloom’s taxonomy (Garfield et al. 2010). In the last century, Bloom’s taxonomy was used to assess a variety of levels of cognitive objectives. In the present study, learning outcomes in statistics are categorised based on the three general categories of statistical learning outcomes: statistical literacy, statistical reasoning, and statistical thinking.

### 2.1.4 Levels of statistical learning

Levels of statistical learning are: statistical literacy, statistical reasoning and statistical thinking (Chance 2002). Statistical learning happens through these three partially hierarchical domains (Chance 2002). Statistical literacy as the first level increases the students’ knowledge of basic statistical concepts and methods. During statistical reasoning, the second level, students are able to produce statistical information and materials and find the key issues within the given data (Garfield 2002). During statistical thinking as the third level, students’ creativity, individual thinking and methodological expertise are enhanced. At the third level, students’ ability to apply previously learned theoretical structures to new situations increases (Chance 2002).

There seem to be two different perspectives (see Fig. 1, Fig. 2) on how the three cognitive outcomes of instructional statistical activities are related. If the goal is to distinguish among the three types of cognitive outcomes, the inherent overlap may appear problematic. The true distinction between literacy, reasoning, and thinking as cognitive outcomes is not clear owing to the considerable overlap among the domains; the definition of one area includes abilities from one or both of the other areas (delMas 2002b). In the present study, the cognitive domain in statistical learning is constructed such that one level must be mastered before transitioning to the next. Students’ educational outcomes are arranged and classified in a hierarchy from less to more complex outcomes (see Table 2, Taxonomy of Bloom et al. 1956).
Figure 1 shows the ways in which the overlap and hierarchy of the independent domains of statistical literacy, reasoning, and thinking can be seen (delMas 2002b, Garfield & Ben-Zvi 2007). Moreover, the hierarchy of these three statistical domains is easy to distinguish. It shows how basic literacy is the framework of statistical education. As instructors of statistics, it is important to acknowledge the overlap of these three statistical outcomes to develop each domain independently of the other two (Chance 2002, delMas 2002b).

The outcomes of statistical literacy, reasoning, and thinking have also been distinguished by examining the types of words used in assessment tasks (delMas 2002b). Table 3 shows words that characterize assessment items.

<table>
<thead>
<tr>
<th>Basic literacy</th>
<th>Reasoning</th>
<th>Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify</td>
<td>Why?</td>
<td>Apply</td>
</tr>
<tr>
<td>Describe</td>
<td>How?</td>
<td>Critique</td>
</tr>
<tr>
<td>Rephrase</td>
<td>Explain</td>
<td>Evaluate</td>
</tr>
<tr>
<td>Translate</td>
<td>(The process)</td>
<td>Generalise</td>
</tr>
<tr>
<td>Interpret</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Read</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Tasks that may distinguish the three instructional domains by delMas (2002b).
In Figure 2, statistical reasoning and thinking are seen within statistical literacy. From this perspective, statistical reasoning and thinking no longer have content independent of literacy, and statistical literacy is the all-encompassing goal of instruction (delMas 2002b). Statistical reasoning and thinking are treated as sub-goals in the development of statistically competent citizens (Ben-Zvi & Garfield 2004, delMas 2002b).

The overlap between the three domains of instruction can be seen from both perspectives. For almost all topics in statistics, if any cognitive outcome can be described in one domain, there is a companion outcome in one or both of the other domains. In Figure 2, the larger overlap across the three domains implies the treatment of statistical literacy as an all-encompassing goal of instruction, but it still may over-represent the separation of literacy from the other two (delMas 2002b). Statistical reasoning and thinking within statistical literacy do not demonstrate construction of the cognitive domain in statistical learning in a hierarchy from less to more complex outcomes.

A statistical learning framework is useful information for educators in terms of being able to distinguish students’ statistical competence and being aware of where errors and misconceptions might occur when learning particular topics. It will help in developing the right kind of instructional statistical activities and teaching in all three domains (Ben-Zvi & Garfield 2004, Cobb & Moore 1997).
2.1.5 Levels of statistical literacy

Levels of the statistical literacy construct have been depicted through brief characterization of the step levels of tasks (Watson & Callingham 2003). The basic idea of identifying the levels of statistical literacy is summarized in Table 4. Watson’s and Callingham’s (2003) framework is based on a six-level hierarchy starting from the idiosyncratic level through increasingly sophisticated thinking to the critical mathematical level. Statistical literacy as a hierarchical construct supports the hierarchy of the independent domains of statistical literacy, reasoning, and thinking (see Fig. 1).

<table>
<thead>
<tr>
<th>No.</th>
<th>Level</th>
<th>Brief characterization of step levels of tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Idiosyncratic</td>
<td>Task-steps at this level suggest idiosyncratic engagement with context, tautological use of terminology, and basic mathematical skills associated with one-to-one counting and reading cell values in tables.</td>
</tr>
<tr>
<td>2</td>
<td>Informal</td>
<td>Task-steps require only colloquial or informal engagement with context often reflecting intuitive non-statistical beliefs, single elements of complex terminology and settings, and basic n-step straightforward table, graph, and chance calculations.</td>
</tr>
<tr>
<td>3</td>
<td>Inconsistent</td>
<td>Task-steps at this level, often in supportive formats, expect selective engagement with context, appropriate recognition of conclusions but without justification, and qualitative rather than quantitative use of statistical ideas.</td>
</tr>
<tr>
<td>4</td>
<td>Consistent</td>
<td>Task-steps require appropriate but non-critical engagement with context, multiple aspects of terminology usage, appreciation of variation in chance settings only, and statistical skills associated with the mean, simple probabilities, and graph characteristics.</td>
</tr>
<tr>
<td></td>
<td>Non-critical</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Critical</td>
<td>Task-steps require critical, questioning engagement in familiar and unfamiliar contexts that do not involve proportional reasoning, but which do involve appropriate use of terminology, qualitative interpretation of chance, and appreciation of variation.</td>
</tr>
<tr>
<td>6</td>
<td>Critical</td>
<td>Task-steps at this level demand critical, questioning engagement with context, using proportional reasoning particularly in media or chance contexts, showing appreciation of the need for uncertainty in making predictions, and interpreting subtle aspects of language.</td>
</tr>
<tr>
<td></td>
<td>Mathematical</td>
<td></td>
</tr>
</tbody>
</table>

At the idiosyncratic level (Level 1), statistical concepts do not appear, and this indicates a lack of engagement with their associated ideas and contexts. Students have severe problems with using terminology such as average. In addition, personal beliefs and experience dominate.
Students’ engagement with statistical contexts increases at the informal level (Level 2). The engagement is still intuitive, non-statistical and includes irrelevant aspects of the task context. Task steps require only colloquial engagement with the underlying context. At the informal level, students’ engagement in task steps reflects individual elements of complex terminology.

Task steps at the inconsistent level (Level 3) require selective engagement with the underlying context. At the Inconsistent level, selective engagement with context includes appropriate recognition of conclusions, but it is without justification, and statistical ideas are used qualitatively rather than quantitatively.

At the consistent non-critical level (Level 4), students have solid engagement and understanding with the context. They are able to master multiple aspects of statistics terminology. Nevertheless, students’ engagement with the context is non-critical.

Finally, at the critical (Level 5) and critical mathematical (Level 6) levels, students’ critical statistical skills are sophisticated. According to Watson and Callingham (2003), in the last two levels of the statistical literacy construct, students’ engagement in terms of criticality and questioning both in familiar and unfamiliar contexts, and their use of terminology are developed. The distinction between the critical and critical mathematical levels is the level of mathematical skill required to engage in critical questioning. At the critical mathematical level, sophisticated use of proportional reasoning is accomplished. In addition, according to Watson and Callingham (2003: 3): “these levels could be used by teachers and curriculum developers to incorporate appropriate aspects of statistical literacy into the existing curriculum”2. The statistical literacy construct can be used to classify students’ educational outcomes in a hierarchical from less to more complex outcomes.

2.1.6 Previous research findings on learning statistical literacy

Statistical literacy includes the idea that the student is a maker of decisions and is a citizen who respects the value of statistics in everyday life (Rumsey, 2002). Statistical literacy is also the ability to read and interpret data and the ability to use statistics as evidence (Ben-Zvi & Garfield 2004, Gal 2002, Rumsey 2002, Schied 1999, Watson & Callingham 2003). Statistical literacy is useful for data consumers. Data or information consumers utilize existing statistical data sets from the media (Gal 2002, Schied 2004, Watson & Callingham 2003) and can make critical and

2 In Australia.
informed decisions based on statistical data (The National Council of Teachers of Mathematics 2000).

After the recommendations of NCTM and GAISE there has been more impact on research into statistical literacy as well as statistical reasoning and statistical thinking. Studies of statistics education have depicted the difficulties related to statistical literacy. In this chapter some previous findings on learning statistical literacy are presented. Some studies have exposed various difficulties students have with concepts and interpretations that were assumed to be frankly elementary such as: histogram, bar chart, mean, principles of the pie chart and distributions.

Students’ difficulty in reading and interpreting graphical representations of distributions has been reported in several studies (delMas et al. 2005, delMas et al. 2007, Kaplan et al. 2014). Students’ ability to understand the information presented in typical statistical graphs of distributions such as dot plot, histogram, and box plot has been assessed at the graduate level. Students have severe problems in interpreting histograms before and after instruction. Misconceptions seemed to persist after instruction too.

Four common misconceptions about histograms have been identified in the literature. The first is the difference between a bar chart and a histogram. The second misconception occurs when students change frequency and data values and get confused between the horizontal and the vertical axes. The third misconception is students’ belief that flatter histograms show less variability. The fourth misconception occurs when students read a histogram as a time plot (Kaplan et al. 2014).

Students are often confused about the differences between bar graphs and histograms, and they seem to have difficulty in constructing bar charts (Garcia-Mila et al. 2014, Humphrey et al. 2014). Humphrey et al. (2014: 74) discussed some reasons behind this confusion and offered suggestions that help clarify thinking: “If statisticians can assemble and reach a consensus on curriculum issues, they should consider the importance of providing guidance on teaching bar graphs and histograms (and other topics) so that teachers in the field are clear on how to teach them. This will help students reach competence in stated goals of being able to critically evaluate newspaper and magazine accounts of statistics, and graphs of data”.

Humphrey et al. (2014) have found inconsistency in textbooks and websites which seems to be one reason why some students might have had problems with bar graphs and histograms. They also discovered some textbooks and websites that defined a histogram as a connected bar graph. Humphrey et al. (2014) have
suggested more accurate distinction between bar charts and histograms for proper use of them. In general, the distinction between bar graphs and histograms is that bar graphs are for categorical data and histograms are for numerical data. For improving the distinction, they also suggest that nominal and ordinal data should be represented with bar graphs. Interval and ratio data should be represented with histograms (Humphrey et al. 2014).

It is very common for people to encounter histograms, for example, in the media and elsewhere, even if they do not understand them. The transformation of raw data into graphical representations such as histograms and bar graphs is challenging, and statistics instruction is needed to comprehend this transformation (Meletiou & Lee 2002).

Watson’s (1997) study Assessing Statistical Thinking Using the Media examines students understanding of statistics presented in social contexts. It was carried out at the end of 20th century with students (N = 670) in grades 6 and 9 in Tasmania. The basic idea of this study was to assess students’ outcomes at a variety of levels of cognitive objectives in presentation such as a pie chart in an economic context and sampling in a social science context. A manipulated pie chart was been shown to students (Watson 1997). The intention of the pie chart items was to discover whether students understand the principle that a pie chart represents 100% of the quantity. One great interest was whether students would notice that there is something wrong with the pie chart. Graphs such as pie charts can easily mislead students (Watson 1997). Only a few students have understood the principle that a pie chart represents 100% of some quantity. Similarly, a manipulated pie chart has been used in the present study.

In-service teachers’ difficulties in identifying different types of graphs were investigated by Cooper and Shore (2010). 28% of in-service teachers failed to identify a histogram as a histogram, preferring to call it a bar graph, while 51% referred to all non-histogram graphs that use bars as simply bar graphs. Being able to differentiate among the underlying structures of different graph types is an essential step in perceiving variability graphically. Teachers’ misconceptions in identifying different types of graphs may reflect a lack of statistical literature in general.

Graphs such as histograms and pie charts can easily mislead people (Watson 1997). If the statistical graphics ”seem to be all right”, basic statistical skills are forgotten, such understanding the use of statistical symbols. Students’ statistical literacy needs to be developed by practice and solid instruction. Distinguishing students’ statistical difficulties is needed to improve statistical teaching.
2.1.7 Summary of previous research findings on learning statistical literacy

Previous studies on learning statistical literacy evidence students’ severe problems in coping with basic statistical concepts. Students’ difficulty in reading and interpreting graphical representations of distributions such as histograms, bar charts, pie charts, and dot plots have been reported in several studies (delMas et al. 2005, delMas et al. 2007, Kaplan et al. 2014). The present study concentrates on evaluating students’ knowledge of basic statistical concepts, statistical methods, and their understanding of results by using different instruments. The key theme in the present study is to investigate students’ statistical literacy of histograms, bar charts, mean, principles of pie charts and distributions at the secondary level.

Especially bar chart and histograms seem to be the most difficult methods for students (see delMas et al. 2005, delMas et al. 2007, Kaplan et al. 2014). Very often, people encounter histograms in different context even if they do not understand them (Meletiou & Lee 2002). There is evidence that students’ misconceptions seem to persist after instruction (Kaplan et al. 2014). Teachers also have some difficulties in identifying different types of graphs (Cooper & Shore 2010). Teachers’ misconceptions in identifying different types of graphs may reflect a lack of statistical literature in general.

Reasons for students’ difficulties in interpreting and reading graphical representations of distributions seem to be the lack of statistical literacy and inconsistency in textbooks and websites (Humphrey et al. 2014). More accurate distinction between bar charts and histograms is needed.

Based on studies of statistical education, difficulties related to statistical literature can be made visible and relevant. More impactful research on statistical literacy is required to expose the various difficulties faced by students and teachers in reading and interpreting graphical representations of distributions.

2.2 Technology enhanced learning in mathematics

In the 21st century, different kinds of technological tools for teaching probability and statistics have emerged: statistical software packages, educational software, spreadsheets, applets or stand-alone applications, graphics calculators, multimedia materials and data and materials repositories (cf. Chance et al. 2007). In this chapter, some earlier research findings on the current domain are presented. It seems that collaboration and technology have a potential to facilitate learning processes. In the
first years of the third millennium we have entered to the technology-orientated society. In the age of information and smart technology diginatives as well as ordinary citizens are expected to exploit 21st citizen skills as a civic necessity.

The National Council of Teachers of Mathematics (2000) outlines the essential components of a high-quality school mathematics programme and has stated principles for school mathematics concerning equity, curriculum, teaching, learning, assessment, and technology. The impact of technology is an inherent part of teaching and learning mathematics, where students can develop deeper comprehension of mathematics with the appropriate use of technology: “The existence, versatility, and power of technology make it possible and necessary to re-examine what mathematics students should learn as well as how they can best learn it” (The National Council of Teachers of Mathematics 2000: 25).

The use of technology for enhancing mathematics learning has been debated regularly in conferences organized by the International Commission on Mathematical Instruction (ICMI). Early interest (1986 at ICMI 5) in the potential benefits of technology “painted a picture of a future classroom in which teachers would be supported by a digital teaching assistant, who would assume a substantial part of a teacher’s load of explaining and managing task setting, thus freeing teachers to assist students with less directed activities such as problem-solving” (Gadanidis & Geiger 2010: 98). The use of technology to facilitate productive interactions between teachers and students or between students and their peers has not been discussed at all. The use of technology to enhance collaborative classroom practices has not yet been discussed either (Gadanidis & Geiger 2010).

The passage toward intentional use of technology in mathematics teaching and learning from a social perspective in education can has attracted research interest in recent ICMI conferences. Topics such as collaborative interaction, collective argumentation, and cooperative meaning making have clearly been emphasised (Gadanidis & Geiger 2010). In the present study, the main streams are technology and collaboration for enhancing mathematics learning.

Technology plays an important role, particularly in statistics education, in terms of changing legacy views on statistical knowledge, pedagogy, and learning (Schuyten & Thas 2007). It enables us to contribute to statistics education in terms of statistical knowledge, pedagogy, and learning. Technology should be used to analyse data, allowing students to focus on interpreting results and testing conditions, rather than on computational mechanics (Franklin & Garfield 2006).
2.2.1 Review of research on technology-enhanced mathematics learning

Technology-enhanced mathematics studies using several types of technological tools and resources have been performed in many countries. The results of the use of technology and multimedia materials have been encouraging. Technology-enhanced mathematics learning and student-centred approaches should be in praxis in classroom settings. Tools used in technology-enhanced classrooms should be taken into praxis by focusing on the inherent mathematical and pedagogical principles. Internationally, as well as in the Nordic countries, the importance of studies for implementing the use of tools and artefacts in mathematics teaching and learning has been noticed (Grevholm 2009).

There are many types of technological tools and resources to support the learning and teaching of statistics. According to Biehler et al. (2013), the tools and resources used for promoting learning and teaching in statistics include statistical software packages, spreadsheets, applets/stand-alone applications, graphic calculators, multimedia materials, data repositories, and other educational software. The tools used in the present study include graphic calculators, multimedia materials, data repositories, and educational software.

In technology-enhanced classrooms, the focus should be on inherent mathematical and pedagogical challenges (Goos et al. 2003). Technological tools and artefacts are not passive or neutral objects because they can reshape interactions among teachers, students, and the technology itself. In their teaching experiment, Goos et al. (2003) examined technology-mediated learning in secondary school mathematics classrooms and implemented graphic calculators, computers, and projection devices.

Goos et al. (2003) focused on investigating students’ and teachers’ use of technology in specific classroom environments. Their study suggests that calculators and computers can reshape interactions, especially when technology is treated as a partner or extension of the self. Metaphors used in their study such as master, servant, partner, and extension of self, describe precisely the interaction with technology. Technology as a master reflects a limited and narrow range of technical competence, whereas as extension of self, it is in its most sophisticated mode of functioning.

Graphic calculators and computers can facilitate communication and the sharing of knowledge, especially when technology is treated as a partner or as an extension of the self (Goos et al. 2003), especially when orchestrating collaborative
learning in classrooms, where technology regulates collaboration, interactions, and shared mathematical knowledge.

One type of implementation of technology in education is simulation, and it is often used for demonstration in a statistics classroom setting. In the present study, the use of simulation was tested in the teaching experiment material. Lane and Peres (2006) used an online textbook containing multimedia simulations and presentations in statistics education at the graduate level. They used the "query-first" method. They concluded that technology-enhanced mathematics has the potential to make learning statistics easier and more fun, but these resources should be used with care. According to Lane and Peres (2006), these types of common simulations can lead to passive learning, because they do not ensure active learning given that students can become passive observers.

A constructivist view of learning and hands-on interaction in adopting new knowledge is more effective than direct instruction, which can even deactivate students. Students learn by actively building or constructing their own knowledge, and teachers should facilitate students to make sense of this knowledge learning process. Interaction and discussion are crucial components in the learning process (Cobb 1994, Mills 2003).

Another type of technology implementation is multimedia group. Milovanovic et al. (2011) discovered that students showed better theoretical, practical, and visual knowledge learning in a multimedia group. The use of multimedia in mathematics classes refers to software-based visualization possibilities, animations, and illustrations. The survey also showed that the students from a multimedia group are highly interested in this way of learning. The findings of previous studies support the benefits of using multimedia materials and the collaborative approach in learning mathematics.

Computer simulations have been devised and trialled as carefully designed, specific trajectories for learning inferential reasoning in statistics education (Arnold et al. 2011). In their teaching experiment, it was found that visual animations regulate students’ learning trajectories. Speed and Hardin (2001) have recorded instructions and online manual tutorials, which capture all of the computer screen movements as well as the narration. They found that captured animated tutorials are an excellent substitute for attendance in a computer lab and a more effective use of resources than printing large detailed documents filled with static screen shots. These findings suggest that it is beneficial to implement verbal, visual, and sensory information in statistics education. Such an implementation follows the triple-coding theory. In the present study, learning material has been
implemented according to the dual-coding theory, and cognition is divided into two systems, namely, verbal and visual (see Clark & Paivio 1991).

Students in traditional statistics course seem to be more confident of learning, whereas students in online course had lower expectations of learning statistics. Nevertheless, students in their online course were “satisfied that the course provided them with a sound basis in statistics” (Katz & Yablon 2002).

As an artefact for promoting the learning and teaching of statistics, Hammerman and Rubin (2004) used interactive software data visualization tools. The creation of novel representations of data opens new possibilities for interpreting data and visualising reasoning. Moreover, according to delMas et al. (1999): “software can provide the means for a rich classroom experience, computer simulations alone do not guarantee conceptual change”. Constructivism-based computer simulations may help develop students’ understanding of statistical concepts (Mills 2003). In the present study, technology-enhanced statistics learning has been implemented in a pedagogically devised manner.

Flipped or inverted classroom is a new approach to learning in which the usual classroom paradigm is inverted. The traditional lecture style of teaching is flipped outside of the classroom. Students learn initial course concepts by watching screencasts prepared by instructors or by reading a textbook (Herreid & Schiller 2013). We have used a similar approach to provide learning materials beforehand via the Internet. Flipped-classroom students’ understanding of the content increased significantly compared to that of students in the traditional lecture setting, as evidenced by the results of subsequent exams. Students in the flipped-classroom environment have been very positive about their course experience, especially about the collaboration and instructional video components (Love et al. 2014).

The role of mathematical practices is important factor for promoting greater enjoyment in learning. In student-driven conditions, students have been significantly more positive about learning and have used discussions for questioning peers and aligning outcomes with prior experiences. The design of learning opportunities that promote mathematical practices does not only promote proficiency but also promotes greater enjoyment of learning. Similar results of the positive impact of student-driven conditions were obtained in the present study. In deciding how to vary teaching approaches, varied instructional designs should be prepared with the aim of influencing interest, emotion, affect, and enjoyment (Sengupta-Irving & Enyedy 2015).
2.2.2 Summary of previous research findings on technology enhanced mathematics learning

According to previous research findings, plenty of feasible technology-enhanced possibilities can be implemented in education. The findings reveal the benefits of the constructivist view of learning, use of graphic calculators and computers (Goos et al. 2003), and the dual- and triple-coding theories (Arnold et al. 2011, Cobb 1994, Mills 2003). Technology-enhanced mathematics learning is not a recipe for promoting learning outcomes, but it can provide the means for a rich classroom experience (delMas et al. 1999). Technological tools should be used with care because they can also retard students’ activity in learning, and students may become passive observers (Lane & Peres 2006). The inverted classroom idea is aimed at motivating students to learn new topics and share learning materials in advance (Herreid & Schiller 2013). In the present study, these findings are used as a premise in the design of learning environments.

2.3 Computer-supported collaborative learning

In promoting 21st century skills such as critical thinking, information and media literacy, creativity, communication skills, collaboration, and contextual learning, the CSCL approach in classroom learning is needed (Lambert & Cuper 2008). Three general and overlapping theoretical perspectives: learner-centred instruction, constructivism, and socio-cultural theory scaffold CL (Bonk & Cunningham 1998). Seatter (2003) portrays constructivist teaching as a focused elicitation of student’s prior and present knowledge and experiences. A process of shared meaning construction conceptualizes the nature of CL (Stahl et al. 2006). It can be seen as collaborative knowledge building (Stahl 2006) or classical collaboration where learning happens via social interaction in group settings (Dillenbourg 1999).

Collaborative learning and CSCL play important roles because these learning approaches are implemented in our teaching experiment. Collaboration is a skill for future citizens’ civic duties, and students are expected to be familiar with collaboration in problem solving (Lambert & Cuper 2008). Nevertheless, the majority of students are not familiar with collaboration (Lehtinen et al. 1999), and traditionally, students have studied statistics individually (Garfield & Ben-Zvi 2007). This design-based research (DBR) focuses on documenting upper secondary school students’ statistical learning in a CSCL environment and examines the
impact of CSCL on promoting students’ learning in a mathematics education classroom.

CSCL promotes active learning and collaboration in classroom settings, which allows students to learn from each other (Hmelo-Silver & Barrows 2008, Stahl 2005). Collaborative learning enables students to discover, construct, understand, and share important statistical ideas and to model statistical thinking (Chance et al. 2007, Garfield 1993). As a learning skill, collaboration should be promoted by schools to prepare students for the 21st century learning society.

Collaborative Learning is an umbrella term for various educational approaches (Johnson et al. 1998, Smith & MacGregor 1992). These educational approaches involve students’ joint intellectual effort or students and teachers joint intellectual effort together. CL activities vary widely, but usually students are working in groups of two or more students (Dillenbourg 1999, Smith & MacGregor 1992) and students are mutually searching for understanding, solutions, meaning or creating a product. The main aim in this study is to examine students’ collaborations in statistical problem solving.

The lecturing, listening and note-taking process may not totally disappear in collaborative classrooms, but Collaborative Learning embodies a significant shift away from the typical lecture-centred milieu (Smith & MacGregor 1992). Students’ discussions and collaboration with the course material is an essential part of the CL process. In a CL environment, students can identify knowledge processing and improve their ideas collectively. In this context, the atmosphere is open for discussion which enables students’ thinking to become visible. The teacher’s role is to instruct learning and maintain the student’s thinking processes into productive discourse (Hmelo-Silver & Barrows 2008).

Typical lecture-centred and oriented classrooms are criticised for not supporting students social skills which they need to interact effectively in a team (Soller 2001). Effective collaboration with peers involves students being encouraged to ask questions, explain and justify their opinions, articulate their reasoning, elaborate and reflect upon their knowledge. Working together productively has proved itself to be a successful and powerful learning method, but these benefits can be achieved only in active and well-functioning learning teams (Hmelo-Silver & Barrows 2008). According to Nussbaum et al. (2009) working in small-groups may contribute common understanding and develop verbal and social abilities.

Students and teachers generally tend to comprehend learning as an individual matter, and CL can be seen as an unproductive nuisance (Stahl 2005). The role is
one variable in the social interaction (Hare 1994), and roles can promote responsibility and cohesion in the group (Mudrack & Farrell 1995). In the present study, students utilise electronic and interactive material in learning statistics by using novel strategies that enabled the thought process, intuition and experience of demanding data analysis (Nolan & Lang 2007).

In the learning sciences, CSCL is a unique pedagogical approach (Stahl 2010). In CSCL, learning takes place via social interaction in a classroom with the aid of computers for online activities. On a theoretical level, the orientation stresses social and intersubjective learning and other higher psychological processes (Vygotsky 1978). It is not useful to theorize individuals’ mental models during CL, because it does not help to capture the shared meaning making during collaborative interactions (Stahl et al. 2006). Empirical studies should systematically investigate the intersubjective phenomena of small-group interaction (Stahl 2010).

To delineate and comprehend the nature of interaction and meaning making should be the foundation of CSCL (Stahl 2010). The purpose of CSCL is to support group interactions in a CL context. It scaffolds and supports students’ effective learning together (Hurme et al. 2009). Technology is used to control interactions, regulate tasks, rules, and roles and to inform new knowledge (Järvelä et al. 2004). CSCL as a learning environment leads to the increase learning effectiveness of the activity and an increase in the student’s motivation (Stahl et al. 2006). CSCL learning may be implemented both online and in a classroom by using social interaction (Stahl et al. 2006). CSCL environment design requires careful orchestration of various components and deliberate implementation (Strijbos et al. 2004).

Slavin (1996) has stated four major theoretical perspectives and explanations for the predicted efficacy behind CL: motivational perspectives, social cohesion perspectives, cognitive elaboration perspectives and developmental perspectives. These elements should be taken account in design to maximize success in CL (Gubera & Aruguete 2013).

Lehtinen (2003) emphasises the importance of carefully collaborative incentives which reward group members from a motivational perspective. According to Lehtinen (2003), the social cohesion perspective emphasises the idea that students share their expertise in groups because they care about the group.

Based on cognitive elaboration perspectives, group interaction gives individuals a platform to test their ideas (Gubera & Aruguete 2013). The benefits of CL are seen as dependent upon students’ elaborative rehearsal of the content material from a cognitive elaboration perspective (Gubera & Aruguete 2013).
CL should be implemented in the statistics classroom in order to result in higher learning outcomes (Garfield 2013, Keeler & Steinhorst 1995, Roseth et al. 2008). Despite an input to adopt more student-centred approaches in learning strategies, collaborative learning activities have not frequently been examined in college statistics courses (Garfield 1993). The utility of CSCL in mathematics education signals enhanced higher order skills such as critical thinking and conceptual understanding (Roseth et al. 2008). The use of technology fosters and extends in-class collaboration and facilitates work on group projects outside of class as well as supporting team performance. Students’ experience of collaboration, teamwork and communication skills can be seen as a useful achievement in education (Garfield et al. 2008, Ross 1995). Conceptual and the procedural conditions improve during the collaboration in terms of successful knowledge acquisition in mathematics (Giraud 1997, Mullins et al. 2011).

The use of technology-based tools enables teachers to monitor students learning activities, and it also provides an opportunity to give effective feedback to the students. The experimental sections, visual representations, numerical summaries and graphs engage students in statistical course material in a favourable way (Ben-Zvi 2007, Ben-Zvi & Garfield 2007, Keeler & Steinhorst 1995, Magel 1998). Collaborative learning activities increase students’ attendance, class participation and understanding of statistical methods in statistics education (Dietz 1993, Garfield 1993, Jones 1991), and an intelligent collaborative learning system can actively support the students during their learning activities (Soller 2001). It is essential to understand and interpret a group’s conversations by monitoring, understanding, and facilitating collaborative learning activities which characterize effective collaborative learning interaction (Soller 2001).

Ben-Zvi’s (2007) study suggest that collaboration can improve learning of individuals in the group and the whole class. Wiki has been used to promote CL in statistics education, because it allowed all users to add and edit content with relative simplicity. He has written that: "Wiki and other emergent technologies are filling a gaping void in existing teaching and learning practices." (Ben-Zvi 2007: 15).

The use of technology fostered and extent in-class collaboration and facilitated work on group projects outside of class as well as supported team performance. In addition wiki enabled to circulate course materials, hand out syllabus, readings, provided access to supplementary material as well as distributed links to graphics, videos, and audio materials. Students are asked to work together in creating a
resources page for a collaborative questions and answers collection that points out useful web references related to the topics of the course. Wiki as a tool can be powerful in supporting statistics learning in classrooms through collaboration and communication (Ben-Zvi & Garfield 2007).

Efforts have been made to translate collaboration methods to the statistics classroom. Generally, statistical learning tends to be an individual endeavour. When starting to learn self-regulated problem-solving skills in mathematics, thus far, students have participated as submissive observers (Lazakidou & Retalis 2010). Students’ reluctance to exceed the collaboration rules during the first collaboration has improved in terms of successful knowledge acquisition in mathematics (Mullins et al. 2011). The shift from traditional instruction methods toward CSCL methods requires repetition.

### 2.4 Statistical learning in small-group activities

To incorporate collaborative learning in classes can be an opportunity for students to work in small-groups (Garfield 1993). The use of small-groups appears to have reduced some misconceptions about probability and facilitated student learning of statistical concepts (Shaughnessy 1977). An opportunity to work in small groups may contribute common understanding, as well as developing verbal and social abilities. In small-groups, students can share their knowledge and learning (Nussbaum et al. 2009).

Statistical learning can emerge in various type of collaboration and communication. The conversational acts among the individual participants and group cognition can result from cognitive processes occurring through small-group interactions (Stahl 2005). Vygotsky (1981) and Piaget (1985) suggest several mechanisms for how students learn together in collaborative settings. Vygotsky’s theory describes the zone of proximal development as the difference in acquisition of knowledge between what the same learner can independently achieve and what he can acquire with the help of more experienced peers (Wertsch 1985). More experienced peers in small groups enable a scaffolding of explanations with which to correct misconceptions, fill gaps in understanding and strengthen connections between new information and previous learning (Bonk & Cunningham 1998, Wittrock 1990).

Collaborative learning methods seem to improve students’ achievements in learning statistics (e.g. Giraud 1997, Kalaian & Kasim 2014, Ragasa 2008). The previous studies suggest large effect in the effectiveness of the small-group learning
methods in improving students’ achievement in statistics. It can be concluded that collaborative learning method in small-groups is beneficial approach in learning statistics.

The externalisation of individual mental representations such as planning, thinking aloud, explanation, support, evaluation, and idea generation are interpreted as statistical learning (see Fig. 3) in the present study. All of these individual mental representations such as planning tasks or generating ideas related to knowledge-building are task-related interactions. The taxonomy in Figure 3 reflects research data and is derived from the studies of Veerman and Veldhuis-Diermanse (2001), Scardamalia and Bereiter (1994), and Soller (2001). The most visible and available small-group unit of analysis is the shared knowledge-building of meaning-making (Stahl et al., 2006). The term building implies that a small group works to produce knowledge or a collective product of collaboration (Scardamalia & Bereiter 1994).

Students’ conversational acts are divided into non-task-related and task-related categories to depict students’ levels of collaboration (Veerman & Veldhuis-Diermanse 2001). In this context, task-related functional roles include collaboration and statistical learning. If we focus on statistical learning processes as the orientation, context and role, a diagram such as the one presented in Figure 3 can be an appropriate framework for collaborative conversation taxonomy in data analysis (Oikarinen et al. 2014).
2.4.1 Functional roles in small groups

In the present study, students’ intersubjective statistical learning processes are evaluated from the perspective of functional roles. The aim is to explore what kind of composition of functional roles in small-group work are productive and how these roles in small-group activities should be revitalized or instructed.

In collaborative small-group settings, functional roles in group processes can be divided into three main categories (Mudrack & Farrell 1995) which describe related behaviours: task roles, maintenance roles and individual roles. Task roles promote and coordinate group problem-solving activities whereas maintenance roles maintain group-centred attitudes and orientation with other group members by strengthening and regulating the group (Mudrack & Farrell 1995). The individual roles include dysfunctional behaviours which are not relevant to the task at hand. These role descriptions can guide the pedagogical purposes to illustrate the...
design of roles, nevertheless participant performs several roles simultaneously (Strijbos et al. 2004). Task, maintenance and individual roles can be used to reveal the nature of collaborative conversations in statistical problem-solving.

2.4.2 Cognitive theory of multimedia learning

In this study, a multimedia approach to CSCL has been implemented in mathematics education. Cognitive theory of multimedia learning (CTML) has been a premise in devising the learning material in the teaching experiment. The multimedia principle has been taken account in the creation process of learning material. In this chapter the basic theory of CTML is reviewed.

The CTML has emerged in the 21st century and it states the multimedia principle that students learn more deeply from words and pictures than from words alone (Mayer & Moreno 2002a). According to Mayer and Moreno (2002a), multimedia supports the way that the human brain learns. In the teaching experiment, the interactive .pdf learning material is designed by using CTML.

There is evidence that carefully designed learning trajectories including the perspective of multimedia learning can stimulate students to gain inferential concepts and reasoning processes (Arnold et al. 2011). By dual coding theory, cognition can be divided into two processing systems, verbal and visual (Clark & Paivio 1991). In multimedia learning, cognition can be divided into two processing system as in dual coding theory (Clark & Paivio 1991) or like in CTML (Mayer & Moreno 2002a). Dual coding theory means that learning is enhanced when information is coded in verbal and visual systems and connected between them. Although Clark and Paivio (1991) divide cognition into two systems, verbal and visual, Mayer and Moreno (2002a) had proposed that animation can foster learners’ comprehension when used in ways that are consistent with the CTML.

The CTML in Figure 4 assumes that cognitive learning goes through three domains: dual-channel, limited capacity of information and active processing (Mayer & Moreno 2002a, 2002b). Dual-channel assumption means that humans have separate channels for processing visual/pictorial representations and auditory/verbal representations (Baddeley 1997, Clark & Paivio 1991). Limited capacity assumption means that only a few pieces of information can be actively processed at any one time in each channel (Baddeley 1997, Mayer & Moreno 2002a, Sweller 2005).
According to the multimedia principle, the combination of animation and narration is more effective than narration alone (Mayer & Moreno 2002a). This supports limited capacity assumption, which means that only a few pieces of information can be actively processed at a time in each channel. At the core of the CTML is the active processing assumption. According to this assumption, meaningful learning occurs when the learner engages in cognitive processes such as selecting relevant material, organizing it into a coherent representation, and integrating it with existing knowledge (Mayer 2005).

According to CTML, the cognitive process of integrating is most likely to occur when the learner has supporting pictorial and verbal representations in working memory at the same time (Mayer & Moreno 2002a, Clark & Paivio 1991). In addition, Arnold et al. (2011) have perceived that computer animations perform a crucial role in learning trajectories. They conjecture that, for learning inferential reasoning in statistics at school level, a triple-coding theory should be considered: verbal, visual and sensory.
3 Methodology

This chapter presents the methodology used in the study. The chapter begins with a discussion of the design-based research design, followed by subjects and context, research design, learning tasks, data analysis, validity and reliability. The chapter ends with ethics.

The main aim of this study and teaching experiment is to develop the teaching of mathematics and statistics in the upper secondary level in a CSCL context. The teaching experiment consists of five lessons of 75 minutes which are devised by the principles of design-based research.

In the first section of this study, juvenile 16–17 year-old Finnish upper secondary school students’ basic statistical concepts and statistical literacy are evaluated as a premise of broader design-based research. In the second section the cycle of creation of learning material and students’ opinions in learning statistics in a CSCL environment are described. The third section of the present study characterizes students’ statistical learning processes. The last section of this study focuses on delineating students’ statistical learning outcomes in the technology-enhanced teaching experiment.

3.1 Design-based research

The design-based research method is a relatively new and progressive research paradigm in the research into contextual learning. Design-based research can be seen as a research method as well as a methodological orientation. According to Collins, Joseph and Bielaczyc (2004), design-based research is needed to better meet the challenges of studying learning and teaching. The most important thing is the connection between the theory and the practice (Cobb et al. 2003, Juuti & Lavonen 2006, Mor 2010).

According to Bannan-Ritland (2003), DBR includes four different phases: informed exploration, enactment, local and broader impact from the ILD framework perspective. In the first phase it is characteristic to explore the target of the audience and to survey the literature as well as the development of theory. In the second phase, it is essential to make system design, formulate articulated prototype and detailed design. The third phase of ILD focuses on the local impact that includes formative testing, refinement of the theory and system, implementation and evaluation. Finally, in the fourth phase, the broader impact
consists in publishing the results, releasing the artefact to the broader stage and evaluation.

Bannan-Ritland (2003) describes the ILD framework as an attempt to provide a comprehensive, yet flexible, guiding framework. Design-based research as a socially constructed, contextualized process produces educationally effective interventions that can be utilized in practice. According to Bannan-Ritland (2003), the goal of the ILD framework is to engineer and construct effective learning environments by using software and other artefacts. These constructed propositions about learning and teaching allow teachers and learners to act more effectively in the learning environment.

Design-based research methodologies are used to develop many cognitively oriented technology innovations. Real classroom settings where researchers work closely with teachers and students to design, develop, implement, and evaluate an innovation have been a growing trend in educational research in the last decade (Fishman et al. 2004).

Reeves (2006) describes how the focus of the design-based approaches is in the process of developing innovative tools and activities. According to Reeves (2006: 101) design research can offer: "... a viable alternative approach to enhancing the integration of technology into teaching and learning and the ultimate improvement of education for all." In the following Figure 5 Mor (2010) illustrates the nature of design-based research. It shows the connection between practice and theory and present the endless cycles of design experiments.

![Fig. 5. Design experiment cycle by Mor (2010, published by permission of Creative Commons Attribution-Non Commercial-Share Alike 2.0 UK: England & Wales License).](image-url)
3.1.1 Implementation of DBR in this study

The design-based research method provides a great opportunity to promote learning and create useable knowledge in multiple learning environments and circumstances (Design-based research 2003, Lagemann 2003). A cycle of interventions and improved implementations are characteristic of design-based research (Bannan-Ritland 2003, Juuti & Lavonen 2006). Figure 6 describes design of this study from integrative learning design’s perspective.

Fig. 6. DBR in this study from integrative learning design’s perspective.

Students’ starting level of statistical literacy before they start the course on probability and statistics has been one premise in an implementation plan of the teaching experiment of technology-enhanced learning environment. An instrument of a pre-test in the present study has been devised to assess students’ starting level of statistical literacy. The instrument has been tested several times before the present study (see Appendix 1).

Another premise has been a pilot study before the actual teaching experiment which has given relevant and usable knowledge about viable learning technology and collaboration. The purpose of an artefact of this teaching experiment has been to create material that promotes statistical learning processes. The implementation plan has been based on essential statistical concepts in the Finnish mathematics
curriculum. A number of interventions are needed to complete cycle of entire design-based method and to develop CSCL-module in the present study.

The intention of the pilot phase is to test the pedagogical design in order to implement an improved pedagogical model into the teaching experiment. Several improvements were made in the first teaching experiment (in autumn 2011) based on the pilot phase testing. During the pilot phase, students’ feedback on the teaching material was gathered. Based on the gathered feedback, the interactive learning material was transferred to the Internet. New instructions for using different types of calculators in statistics were uploaded along with the learning material. Moreover, the technical solutions were improved after the pilot phase. Some small groups were situated in another classroom because of the disturbing background noise during videotaping.

In the second teaching experiment (in autumn 2012), the electronic test was incorporated into the teaching experiment. Different types of calculators or computer programs in statistics were included in the learning material. Questionnaire 1 was been refined and questionnaire 2 was included in the teaching experiment. In addition, new Internet-based homework material was developed to support students’ statistical learning.

The evaluation of students’ learning outcomes as well as students’ opinions of the feasibility of CSCL gives valuable information on how the CSCL-module should be refined. So, DBR can be seen as a continuous process of improving the education and the nature of design experiment cycle.

3.1.2 Technology-implementation to the teaching experiment

One important question in education policy is how technology should be implemented into education. It seems to be obvious that technology plays a particularly important role in statistics education in changing the views of statistical knowledge, pedagogy and learning (Schuyten & Thas 2007). There are also plenty of studies of the use of technology in classroom (Slavin & Lake 2007, Teo et al. 2008). There are some proposals on how to implement technology in statistics education (Arnold et al. 2011, Moore 1997, Nolan & Lang 2007).

How should a technology-enhanced teaching experiment be defined in this context? The contemporary techniques have great potential to implement technologically enhanced environments for students to collaborate asynchronously in different small-groups (Oikarinen et al. 2014). Interactive pdf-material has been designed by integrating CTML (Mayer & Moreno 2002a).
The interactive pdf-material supports dual-channel assumptions regarding learning (narrative/auditory and pictorial/visual), which is the most effective multimedia principle in the CTML (Clark & Paivio 1991, Mayer & Moreno 2002a). Dual-channel simulation also provides a constructive approach to the study of statistical concepts (Arnold et al. 2011, Nolan & Lang 2007).

CSCL-module is implemented by using a design-based research method. The module is based on design-based research with endless cycles of design (cf. Mor 2010), implementation, CSCL in in-service, questionnaire, course exam and evaluation. After each CSCL-module’s evaluation, students as well as the teacher are able to improve implementation. Evaluation works as an intervention in order to improve the implementation of CSCL-module. The following Figure 7 will present the cycle of design-based research in the present study.

**Fig. 7. The cycle of design-based research in this study.**

The pilot phase in the CSCL-module has been conducted in April 2011 in a course on analytical geometry. It offered valuable information to the actual CSCL-module in the course of probability and statistics. In the pilot phase, interactive .pdf files have been used in the course of analytic geometry. In this study, the framework of ILD has been done by using Bannan-Ritland’s (2003) model of an integrative learning design framework. The data collected from the pilot phase has formed the development of the next stage of intervention.

The development of the CSCL module was a long and iterative process. The CSCL module is an artefact of this process, and it has brought into play new aspects
in teaching statistics at the upper secondary level (cf. Cobb et al. 2003, Juuti & Lavonen 2006). In the pilot phase, the interactive material was uploaded to the school’s own domain on the school Intranet. In the present study and teaching experiment, the interactive material was uploaded to the internet. This improvement enabled students to access the learning material by using Internet-connected computers.

Based on DBR, there has been an implemented CSCL-module in this research. The actual CSCL-teaching experiment began in the ICT-class. During the CSCL-module, students have used interactive pdf-files where the main topics of statistics in the curriculum are presented, i.e. descriptive statistics. The students worked in groups of three or four and they could practice several exercises and improve their statistical literacy and collaboration as well as student-centred learning skills.

The interactive pdf-material includes hyperlinks for example: open shockwave flash objects, pictures and internet hyperlinks. Material also includes links to Youtube-videos and exercises to utilize Microsoft Word and Excel. The interactive pdf-material also includes tutorials on the use of calculators in statistics. Students practiced several exercises in order to improve their statistical proficiency and competence. During CSCL-teaching experiment students completed a statistical assignment. According to Dillenbourg et al. (1996), the asynchronous use of material provides time for reflection. In a group problem-solving process, the teacher’s role is to be a mentor, support learning processes when needed and guide in clear wording (Hurme et al. 2009).

3.1.3 Mixed methods

Many different methods of investigations promote scientific quality. Mixed methods are used in order to obtain multidisciplinary and comprehensive results. Interviews with documentary analysis, or multiple regression with inferential statistics combine qualitative and quantitative methods (Symonds & Gorard 2010).

In empirical research, the data can be collected by using versatile methods. In order to enhance the scientific quality of this study quantitative and qualitative methods are combined. Qualitative and quantitative methods can be seen as complementary methods (Hirsjärvi & Hurme 2000). Mixed methods can confirm, complete and enrich analyses of the data (Creswell & Plano Clark 2011).

In educational research, mixed methods enable us to link the various data sources and offer a much better opportunity to present the breadth and complexity of the data. It can be said that a good intervention study should use the variety of
data collection techniques in order to understand whether something works, how to improve it, or why it does not work (Gorard 2012). There should be consensus in using numbers, text, visual and sensory data synthetically (Gorard 2010).

3.2 Subjects and context

This design-based research focuses on describing upper secondary school students’ statistical learning in a CSCL environment. A premise of the present study has been to develop statistics teaching in upper secondary school. A major endeavour in this study has been to open ideas and perspectives for mathematic education by using CSCL in learning statistics and mathematics in upper secondary school in Finland.

The present design-based research has been carried out in an upper secondary school in the eastern part of Finland during 2009–2012. In the first two years, instruments and material used in this study have been tested and redesigned. The principal of upper secondary school of Kuopio Lyseo has granted permission to carry out this study. The teaching experiment has been carried out in the compulsory long mathematic course number 6, MAA06, Probability and statistics. It has been held in the first period of the second school-year. In addition, most students have been in the ICT-class during the current teaching experiment, because computers with internet-connection have been available.

The Finnish system is classless, periodic, and usually lasts 3 years. There are five or six periods during the school year, and one period lasts seven or six weeks. Students have to complete at least 75 courses and 55 are mandatory courses. During the course, there is an average of 18 lessons of 75 minutes each. Students can choose the advanced mathematics syllabus (10 mandatory courses) or the basic mathematics syllabus (6 mandatory courses). If they enrol for the matriculation examination in mathematics, they usually also complete from 3 to 6 advanced courses. The following subchapters present the core content of probability and statistics curriculum at both comprehensive school and upper secondary school. Participants are introduced after that.

3.2.1 Statistics curriculum in comprehensive school

In the curriculum of comprehensive schools in grades 7–9 produced by the Finnish National Board of Education (Opetushallitus 2004), the essential contents of probability and statistics have been defined in the following way: the concept of probability, frequency, relative frequency, mean, mode, and the definition of
median as well as the concept of deviation, the interpretation of diagrams, data collection and re-numeration, and data presentation in a usable form.

In the criteria of the final assessment of comprehensive schools (Finnish National Board of Education 2015, Opetushallitus 2004), a student who has received a grade of eight in mathematics is capable of performing the following probability and statistics tasks: determine the number of possible events and organize a simple empirical investigation of probability and randomness in everyday life situations, read various tables and diagrams, and determine frequencies, average, median and mode from the given data. In other words, the student has gained a basic understanding of statistical terminology.

3.2.2 Probability and statistics curriculum in upper secondary school

Upper secondary school education and other activities should be organized in the Government Decree (955/2002) according to the general national objectives (Finlex 2014). The national curriculum of upper secondary schools created by the Finnish National Board of Education (Opetushallitus 2003) outlines the essential contents of probability and statistics in the advanced mathematics syllabus. In the curriculum, the content of statistics is mainly descriptive statistics. According to the national curriculum, the course of probability and statistics is a mandatory course and it is graded numerically (4–10) (Kuopion kaupunki 2013).

1. The course objectives for students are (Kuopion kaupunki 2013)
   a) learn to illustrate discrete and continuous statistical distributions, as well as to define and interpret distribution parameters;
   b) familiarise themselves with combinatorial methods;
   c) familiarise themselves with the concept of probability and the probability calculation rules;
   d) understand the concept of a discrete probability distribution, and learn to define the expected value of a distribution and apply it;
   e) familiarise themselves with the concept of a continuous probability distribution, and learn how to apply the normal distribution.

2. Core contents (Kuopion kaupunki 2013)
   a) Statistical distributions and distribution parameters;
   b) Discrete and continuous statistical distributions;
c) Mathematical and statistical probability;
d) Combinatorial calculations;
e) Probability calculation rules;
f) Discrete and continuous probability distributions;
g) Expected values of discrete distributions;
h) Normal distribution.

3.2.3 Participants

The participants in the present study are adolescent 16–17 year-old Finnish upper secondary school students (N=138). The students who participated are from different comprehensive schools. They are second year students of advanced mathematics in the course of probability and statistics. The following Tables 5 and 6 present, show how many students have participated and the gender distribution in this study of each data collection unit.

From the set of participants (N = 138), 38 students participated in the pilot phase in spring 2011. Twenty-four students attended the CSCL teaching experiment in autumn 2011, and 13 students were in the control group in autumn 2011. In addition, one student attended a students’ exchange program and participated in the teaching experiment in autumn 2012. From the participants, 25 students have previous experience of studying in a CSCL environment. Forty-six students participated in the teaching experiment in autumn 2011, and 60 students participated in the teaching experiment in autumn 2012.

The participants in school year 2011, in Table 5, are juvenile 16–17 year-old Finnish upper secondary school students (N=78), 38 girls and 40 boys. All present students have participated: pre-test, course exam (N=74), and delayed post-test (N=68). Students are divided into three different classes. Treatment groups have been divided into two classes, and students participated in the CSCL-teaching experiment and they also completed a statistical assignment. The control group has been taught by using traditional, didactic instruction methods. The students in the comparison class did not make a statistical project nor utilise CSCL-environment in learning statistics. In addition, ten (N=10) students from the treatment group have participated in thematically organized interviews, and all students in the treatment group responded to questionnaire 1 (N=46).
Table 5. Participants in pre-test, questionnaire, course exam and delayed post-test in school year 2011.

<table>
<thead>
<tr>
<th>Participant groups</th>
<th>Pre-test (n=78)</th>
<th>Questionnaire 1 (n=46)</th>
<th>Course exam (n=74)</th>
<th>Delayed post-test (n=68)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>Treatment group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all</td>
<td>46</td>
<td>100.00%</td>
<td>46</td>
<td>100.00%</td>
</tr>
<tr>
<td>girls</td>
<td>24</td>
<td>52.17%</td>
<td>21</td>
<td>45.65%</td>
</tr>
<tr>
<td>boys</td>
<td>22</td>
<td>47.83%</td>
<td>22</td>
<td>47.83%</td>
</tr>
<tr>
<td>absent or rejected</td>
<td>0</td>
<td>0.00%</td>
<td>3</td>
<td>6.52%</td>
</tr>
<tr>
<td>Control group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all</td>
<td>32</td>
<td>100.00%</td>
<td>32</td>
<td>100.00%</td>
</tr>
<tr>
<td>girls</td>
<td>10</td>
<td>31.25%</td>
<td>10</td>
<td>31.25%</td>
</tr>
<tr>
<td>boys</td>
<td>18</td>
<td>56.25%</td>
<td>18</td>
<td>56.25%</td>
</tr>
<tr>
<td>absent or rejected</td>
<td>4</td>
<td>12.50%</td>
<td>4</td>
<td>12.50%</td>
</tr>
</tbody>
</table>
The teaching experiments consist of five lessons of 75 min each. The teaching experiment course design included more active problem-based learning and practice activities. Students were made to watch screencasts and instructional videos prepared by the instructor. This educational approach established a strong conceptual foundation in introductory technology and mathematics to keep the students interested in learning, so that they can advance to a higher level of statistical learning.

The first lesson began with a brief 15-min lecture by the instructor. The instructor is expected to engineer a learning environment that supports students in grappling with mathematical problems and constructing their own statistical understanding. Students were encouraged to work with their peers in groups of two to five teammates and to consult other students and the instructor when they had a question. The students worked in the same groups throughout the teaching experiments.

Collaboration among the students was stimulated by instructing them to help each other in problem solving. They were encouraged to think aloud in order to make their thinking and learning processes audible in their interactions during the teaching experiments. By encouraging students to construct and evaluate their own and each other’s mathematical discussions, students’ mathematical discourse practices can be developed.

The participants in school year 2012, in Table 6 are adolescent 16–17 year-old Finnish upper secondary school students (N=60), 29 girls and 31 boys. The treatment group has been divided into two classes and students have participated in the CSCL-teaching experiment and after this have completed the electronic test (N=60) and questionnaire 2 (N=58).

Table 6. Participants in the electronic test and questionnaire 2 in school year 2012.

<table>
<thead>
<tr>
<th>Category</th>
<th>Questionnaire 1 (n=58)</th>
<th>Electronic-test (n=60)</th>
<th>Questionnaire 2 (n=58)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
<td>all frequency</td>
</tr>
<tr>
<td>all</td>
<td>60</td>
<td>100.00%</td>
<td>60</td>
</tr>
<tr>
<td>girls</td>
<td>28</td>
<td>46.67%</td>
<td>29</td>
</tr>
<tr>
<td>boys</td>
<td>30</td>
<td>50.00%</td>
<td>31</td>
</tr>
<tr>
<td>absent or rejected</td>
<td>2</td>
<td>3.33%</td>
<td>0</td>
</tr>
</tbody>
</table>
3.3 Research design

To promote systematic management of data collection, research design has been planned according to Figure 8. In this study, both quantitative and qualitative methods have been used and combined. The data in the present study has been gathered from pre-test, classroom observation, videotaped material, questionnaire, interview, exam, delayed post-test, electronic test, and notes of the researcher.

The following cycle in Figure 8 presents the settings of this study and the timeline of data collection. In the following subchapters are presented different phases of data collection in the chronological order.

---

**Fig. 8. Timeline of data collection in research design.**

1. Assessment of students’ starting level in statistical literacy
2. Contribution of the CSCL environment in learning statistics
3. The nature of students’ statistical learning processes in a CSCL environment
4. Students’ achievements in statistics in course exam and delayed post-test

= Control group 2011, = Treatment group 2011 and = Treatment group 2012
In the first section of this study, the students’ starting level in statistical literacy is assessed. Data was collected by both quantitative and qualitative methods including pre-test, interviews, and delayed post-test. The pre-test was conducted in both years 2011 and 2012. In the interview and the delayed post-test, some clarifying questions pertaining to research question 1. (RQ1) and research question 1a. (RQ1a) were asked.

The second section of this study illustrates the contribution of the CSCL environment in statistics learning. Students’ collaboration and classroom working were monitored during the teaching experiment lessons. Data pertaining to research question 2. (RQ2) was collected by using questionnaires and interviews. Interviews were used for data collection only in the year 2011.

The third section of this study depicts students’ collaborative processes in learning statistics in a CSCL environment. Research question 3. (RQ3) was analysed by using qualitative data from classroom monitoring, videotaped material, and students’ assignments. The research data is from the year 2011.

The fourth section of this study examines students’ achievements and adaptation of computer programs in statistics. Research question 4. (RQ4) was analysed by using the data of the course exam, delayed post-test, electronic test, and questionnaire. The course exam and the delayed post-test are from the year 2011. The electronic test and questionnaire were administered in the year 2012 research question 4a. (RQ4a).

### 3.3.1 Pre-test

Before the teaching experiment, students in the course of statistics and probability were made to take pre-test (N = 78). Seventy-four students took the pre-test (40 boys, 34 girls). Four students were absent. They were given 30 min to complete the pre-test. The pre-test was administered to discover students’ perceptions and competence in statistical literacy in order to assess their starting level of statistical literacy before the course on probability and statistics (see RQ1). There were 15 questions in the pre-test (see Appendix 1). Some of the questions measured students’ knowledge of statistical terms and basic statistical calculations. Some of the questions investigated students’ presumptions about statistics. This instrument was further refined via revisions and redesign by Mathematics Education research group of the University of Oulu. This process also included pre-testing with three teaching groups before the final data collection. None of the students in the treatment or control groups participated in the pre-testing.
The pre-assumption has been that all participating students have been familiar with the essential contents of statistics in the curriculum of comprehensive school (Finnish National Board of Education 2015, Opetushallitus 2004). The pre-test of statistics has been designed to follow the mathematics curriculum in Finnish comprehensive schools. In other words, the basic statistical concepts, such as frequency, relative frequency, mean, mode and median, the concept of deviation, the interpretation of diagrams, data collection and re-numeration, and data presentation in a usable form would be at the operational level.

There are 15 questions in the pre-test in total (see Appendix 1). There were questions that measured students’ knowledge of statistical terms and basic statistical calculations. There was also a questionnaire section including 7 questions (Items 5–11) on the Likert scale. A short description of the questions follows.

**Item 1**: Students have been asked to mark at which level (I don’t know this concept, I know this concept, I know this concept and I’m capable of using it) they understood certain statistical terms and concepts: frequency, relative frequency, mean, type value, median, standard deviation, sample standard deviation, diagram, histogram, mode, linear regression, and correlation.

**Item 2**: Students have been asked to mark the correct definition for mode.

**Item 3**: Students have been asked to mark the correct definition for histogram.

**Item 4**: Students have been asked to describe some statistical concepts in this open question.

**Item 5**: In my opinion, I have solid abilities in terms of reading and interpreting statistical information.

**Item 6**: When I read newspapers and watch television programmes or other media, statistics and graphs are easy to understand.

**Item 7**: I am critical with regard to statistical data.

**Item 8**: I think that statistics is an important part of upper secondary school mathematics.

**Item 9**: I need statistics in my post-graduate studies.

**Item 10**: I think that the understanding and interpretation of statistics are important skills from a postgraduate studies point of view.

**Item 11**: I think that the interpretation and understanding of statistics is an important skill in life.

**Item 12**: The next diagram (pie chart) represents the most common causes of death among Finnish men in 2005. The purpose has been to interpret and reason the pie chart.
Item 13: The following diagram represents the number of plum-tomatoes in packages prepared for sale. Define the number of plum-tomatoes in the selling packages type value, median, mean and the length of the range.

Item 15: Students have been asked to describe practical situations in which statistical skills would be beneficial.

3.3.2 Questionnaire 1: Students’ opinions about teaching experiment in CSCL environment

The aims of the questionnaire 1 have been to gain knowledge of the contribution of CSCL environment in learning statistics (see RQ2). The current questionnaire 1 has been held about one week after the teaching experiment and has taken an average of \(\frac{1}{2}\) an hour. The questionnaire comprises 33 items, 14 of which have been open questions (see Appendix 2). To refine this instrument, it has revised and designed in the research-group of Learning & Educational Technology research unit (LET) in the University of Oulu.

In this questionnaire, students are asked several questions on themes such as: 
utility and constraints in collaboration, activity in interactions in conversational acts, success in collaborative learning and personal proficiency.

In the teaching experiment students are asked Likert-scale (1–4) \(^3\) questions [Q1, Q6, Q9, Q11, Q13, Q15, Q16, and Q18] on the theme: utility and constraints in collaboration. Questions [Q7, Q10, Q12, Q14, Q17, and Q19] are open question.

In the teaching experiment students are asked Likert-scale (1–4) \(^3\) questions [Q27, Q28, Q29, and Q31] on the theme: activity in interactions in conversational acts. Questions [Q30 and Q32] are open question.

In the teaching experiment students are asked Likert-scale (1–4) \(^3\) questions [Q2, Q4, Q5, and Q8] on the theme: success in collaborative learning. Questions [Q34, and Q35] are open question.

In the teaching experiment students are asked Likert-scale (1–4) \(^3\) questions [Q20, Q21, and Q23] on the theme: personal proficiency. Questions [Q22, Q25, and Q26] are open question.

\(^3\) 1=totally disagree, 2=disagree, 3=agree, and 4=totally agree.
3.3.3 Students’ videotaped small-group collaborations

During the teaching experiment, students’ small-group collaborations are videotaped. The aim of analysing videotaped small-group collaboration has been to investigate differences in collaborative learning processes among small-groups during collaboration in a CSCL environment (see RQ3).

The collected videotaped material in which the students worked in the same small groups of two to five teammates consists of the course’s first four lessons of 75 minutes each. The mean size of the small groups is 3.57 students. The small groups were organised based on students own free will, but the students were informed that at least one member should have some experience of using Microsoft Excel. In the small groups, students gathered information about statistical terms and methods. The main task was to solve statistical problems collaboratively.

There are 40 videotaped episodes. The episodes were recorded by using a video camera. Based on the data collected from the pilot phase, the small groups were situated as far from each other as possible to achieve better sound recording. Nevertheless, the sound quality of most the 40 videotaped episodes was not acceptable.

Four episodes were chosen from the students’ videotaped small group collaborations. The selection was based on three criteria. First, the quality of recordings was required to be applicable. Second, the contact summary sheet was to be tested in practice by using the episodes. Third, the episodes were required to be versatile in terms of the problems tackled in them.

The analysed episodes consist of the following small groups: one small group in which all students participated in the pilot phase, one in which no student participated in the pilot phase, one in which all participants are mathematically talented and did not participate in the pilot phase, and one in which some of the students participated in the pilot phase. A conjecture was that students who participated in the pilot phase are more familiar with the methods.

The students were encouraged to think aloud to make their thinking and learning processes audible in their interactions during this teaching experiment. Students’ collaboration was stimulated by instructing them to help each other in problem solving. In order to capture their thinking processes on video, they were persuaded to ask questions, explain learning processes, support one another, and justify themselves to one another. They were not given specific roles to play during these small group interactions or conversational acts. Moreover, the students in the small groups were given one statistical assignment.
3.3.4 Assignment

Student have generated assignments vs. artefacts during the teaching experiment which can also reveal valuable information on outcomes in small-group work (see RQ3). For further information, see the description of learning task eight (LT8) in Appendix 11. The quality of the assignment has been observed to complete comprehension of students’ collaboration in a specific episode, and this assignment has been one part of the evaluation of the course on probability and statistics. This assignment has been particularly useful in this study, because it allows us to ascertain differences in learning processes among small-groups during collaboration in a CSCL environment. This phase of the CSCL included four and a half 75-minute lessons.

3.3.5 Interview 1: Concerning students‘ opinions about teaching experiment in CSCL environment

Ten randomly chosen students’ (N=10, four girls and six boys) in the teaching experiment are interviewed (see Appendix 3) immediately after teaching experiment and about two weeks before the course exam. There are 30 questions in the present videotaped interview. Student responses to the interview questions are organized thematically. The purpose of the interview is to investigate students’ opinions about the teaching experiment in CSCL environment (see RQ2). Another purpose is to acquire insight into students’ opinions of secondary school statistics teaching (see RQ1a).

In this interview, students are asked several questions on themes such as: students’ opinions of secondary school statistics teaching, utility and constraints in collaboration, activity in interactions in conversational acts, success in collaborative learning and personal proficiency. In the students’ interview questions (see Appendix 3):

- [Q29] is about the students’ opinions the theme of secondary school statistics teaching.
- [Q3, Q5–Q9, Q12, Q13, Q21, and Q23–Q26] are about the theme utility and constraints in collaboration.
- [Q18–Q20] are about the theme activity in interactions in conversational acts.
- [Q2, Q4, and Q14] are about the theme success in collaborative learning.
- [Q10, Q11, Q16, Q17, and Q27] are about the theme personal proficiency.
3.3.6 Interview 2: With teachers in secondary school

Two experienced teachers who have long experience in teaching in secondary school are interviewed (see Appendix 4). They are chosen to be interviewed because of their expertise in the statistical issues in secondary school mathematics teaching. The purpose is to gain more insights on the statistics as well as mathematics education in secondary school (see RQ1). The teachers’ interview questions concern statistical teaching during comprehensive school from the teachers’ point of view, providing more information on the students starting level of statistics comprehension before the course of probability and statistics.

3.3.7 Course exam

At the end of the course in probability and statistics, all students sit a course exam. There is one extended item concerning statistics (see Appendix 5, Appendix 6, and Appendix 7). The purpose of the course exam is to discover the similarities as well as differences in student achievements in statistics between students in the treatment group and the control group (see RQ4). To improve this instrument, it has been revised by other mathematic teachers in the upper secondary school.

3.3.8 Delayed post-test

The probability and statistics course considered herein lasts two and half months. A delayed post-test was carried out about two months after the course exam (see Appendix 8) to identify the similarities and differences in student achievement in statistics, especially in deeper learning between students in the treatment and the control groups (see RQ4). In this context, deeper learning can be seen as a student’s ability to master given statistical problems after a time interval. To refine this instrument, it was revised and redesigned by the Mathematics Education research group in the University of Oulu. This process also included a pre-test with three teaching groups before the final data collection. None of the students in the treatment and control groups participated in the pre-test of the delayed post-test.

In the delayed post-test, two questions deal with students’ conceptions of statistics teaching in comprehensive school (Question 1 and Question 2), two self-assessment questions (Question 3 and Question 4) and four statistical problems (Question 5 up to Question 8).
**Question 1:** Students are asked to state whether statistics have been taught for more than two lessons.

**Question 2:** Students are asked to mention statistical topics taught in secondary school.

**Question 3:** Evaluate your own proficiency (I don’t know this concept, I know this concept, I know this concept and I’m capable to use it) in terms of the following concepts: binomial distribution, pie chart, multiplication rule, permutation, k-combination, standard deviation, correlation, frequency, density function, median, histogram, linear regression, mode, the conditional probability, variance and type value.

**Question 4:** Student are asked to describe situations in which they might utilize statistics they have learned in the course MAA06.

**Question 5:** The following diagram shows the most common causes of death among Finnish women in 2005. Students are asked to interpret the pie chart.

**Question 6:** The following table shows magazine revenues in 1999–2009. Students are asked to construct a histogram and interpret the given data.

**Question 7:** The following Statistics Finland diagram shows the orientation of religious individuals in the period from 2000 to 2010. Students are asked to calculate and estimate statistical parameters.

**Question 8:** From one fishing vessel there was a range of different weights of fish, according to the following statistical table. Students are asked to calculate statistical parameters and interpret them.

### 3.3.9 Electronic test and questionnaire 2

The purpose of the electronic-test (see Appendix 9) is to appraise students’ adaptation and utilization of computers in statistics (see RQ4a). It is held directly after collaboration in the CSCL-module and it lasts an average 60 minutes per student. The electronic-test indicates how well students are able to exploit the Microsoft Excel program themselves after their collaboration. The electronic-test contains two statistical problems. Most of students are unfamiliar with the program before the course on probability and statistics. All students use a laptop provided by the school in the electronic-test. The laptops are not connected to any data-net.

The major aim of questionnaire 2 (see Appendix 10) has been to gain knowledge-related students’ opinions of the utility of the electronic-test. It has been held directly after the current test in the next lesson. The questionnaire comprises 47 items, 19 of which are open questions.
3.4 Learning tasks

This teaching experiment was aimed to create material that enables students’ collaboration in all statistical tasks in the present mathematics curriculum. The learning tasks are presented in Appendices 12 and 13. Pedagogical innovations in the material include providing students with the correct solutions and the use of a calculator or computer in video-clips to support dual-channel learning. An intention of the use of interactive pdf-material and collaboration in small groups is to enrich statistical learning. During the teaching experiment, students were instructed to collaborate in groups by playing different roles in the learning tasks and to think aloud, question, explain, and justify. In the next paragraphs, the learning tasks (LT) are presented. The learning tasks in Appendix 12 were assigned as homework to the students.

In the first LT on pages one and two in the material (see Appendix 11), students are asked to discover the main concepts and definitions in statistics. They are informed to use Internet search engines and textbooks, and write or copy the knowledge gained to a file. They are required to cite the sources of their knowledge. The first LT included routine statistical tasks to find the main concepts and definitions in statistics. The students’ knowledge of basic statistical concepts and methods increased during the first LT, which is characteristic of statistical literacy. Statistical tasks in the first LT included dual-channel learning.

The second LT aims to make the students learn the use of the summation on page three (see Appendix 11). Actually, summation will be taught to them later in mathematics in course number nine, and summation is a completely new and fresh operation for them. In monitoring this teaching experiment, it was noticed how the students arrived at a solution to a task via collaboration. In the second LT, the students’ task is to get to know summation by using learning material that is important in statistical formulas.

The third LT aims to make the students recall the use of mean, standard deviation, mode, and median, especially by using their own calculators. There are three exercises on page four (see Appendix 11) in the material concerning these problems. In the last exercise, students are required to combine the frequencies in the contribution and understand how to use calculators. The fourth LT involves determining mean from classified data. The aim is to develop a student’s ability to produce statistical information and materials, and find the key issues within the given data, which is characteristic in statistical reasoning.
The purpose of the fifth LT (see Appendix 11) is to determine mean, median, mode and standard deviation from classified data. First, students calculate values by using their calculators, and then, they use MS Excel to perform the task. In the sixth LT (see Appendix 11), students calculate linear regression and correlation by using a calculator and MS-Excel. In the seventh LT, students are required to implement these concepts and calculation rules in the classified data. The purpose of the fifth and sixth LTs is to enrich student’s statistical learning by using multiple technological tools such as calculators and computer programs.

After these exercises, students are allowed to perform an assignment in a small group of three to four teammates, which is to be presented (see Appendix 11). This is a short assignment in which they are to analyse the data gathered in the class, namely, the relationship between the students’ shoe sizes and heights, as well as the development and relationship between men’s and women’s world records in the 100-metre race. In addition, there is electronic homework material (see Appendix 12). This statistical learning activity includes shared knowledge-building, in which the small groups work to produce knowledge and collective products of collaboration. During this task, students’ ability to apply previously learned theoretical structures to new situations increases.

### 3.5 Data analysis

Qualitative, quantitative and mixed methods have been used and combined in the data analysis. In the following subchapters, how these methods have been utilised in data analysis in this study are presented in detail. The complexity of research settings demands a multiplicity of methodologies in the analysis of CSCL in mathematics (see Hakkarainen 2009, Stahl 2011). Some of the research data has been re-coded and analysed by using Microsoft Access and Excel as well as SPSS4-analyses. In turn, part of the qualitative data has been analysed by using the Nvivo program and CSS -instrument.

In the first section of this study, students’ starting level in statistical literacy is assessed, as is students’ own perceptions about their proficiency in statistics as well as their opinions about statistical teaching in comprehensive school (see RQ1, and RQ1a). The following Figure 9 illustrates the analytical framework of this section.

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4 Statistical Package for the Social Sciences.
The second section of this study is to present students’ opinions about teaching experiment in CSCL environment (see RQ2). The following Figure 10 illustrates the analytical framework of this section.

The third section of this study indicates the nature of statistical learning processes in terms of the form of collaboration in CSCL environment (see RQ3). The following Figure 11 illustrates the analytical framework of this section.
The fourth section of this study examines students’ learning outcomes through course exam and delayed post-test (see RQ4). In the teaching experiment, students’ learning outcomes are also evaluated through an electronic-test (see RQ4a). The following Figure 12 illustrates the analytical framework of this section.

### 3.5.1 Data analysis of pre-test

As background information, students’ final grades in mathematics after comprehensive school and grades in mathematics in upper secondary school have been requested. The Mann-Whitney U-test is used to depict possible differences in samples of treatment and control groups.
Analyses of item 1: Students answers are evaluated in different ways: in values and in the level of Statistical Literacy (Informal level or Inconsistent level). Categories are: I don’t know this concept = 0p, I know this concept = 1p, I know this concept and I’m capable to use it = 2p. Concepts: sample standard deviation, linear regression, and correlation are rejected from the evaluation, because they are not essential in the curriculum of comprehensive school. The maximum score is 18 points. Summarized points are presented in a distribution. The purpose is to depict students’ competence in terms of their level of statistical literacy in their own opinions.

Analysis of item 2: There are two correct answers. One point is given for each correct answer, and the maximum score is two points. The purpose is to examine students’ capability to identify concept modes.

Analysis of item 3: There are two correct answers. One point is given for each correct answer, and the maximum score is two points. The purpose is to examine the students’ capability to identify concept histograms.

Analysis of item 4: In this item, there are three sub-questions for defining concepts: statistics, mathematics in statistics, and statistical literacy. The purpose is to examine students’ capability to define the concepts of statistics, mathematical statistics, and statistical literacy. Answers are classified in the categories:

1. Statistics
   - 0 point = no answer
   - 1 point = If there is written “there are some information” etc.
   - 2 points = if data-set, table is mentioned, if there is possibility to compare data in statistics or it is possible to construct a graph or chart etc.

2. Mathematical Statistics
   - 0 point = no answer
   - 2 points = if there is mention of mathematics in statics

3. Statistical literacy
   - 0 point = no answer
   - 1 point = ability to read statistics etc.
   - 2 points = ability to read and interpret or reason statistics

Analysis of Items 5–11: The answers to these questions are classified into the following categories: totally disagree, disagree, agree, and totally agree. In addition,
students’ responses on a Likert scale (1–4) are analysed by using the Mann-Whitney U test. The Mann-Whitney U test (Ranta et al. 1999) is used to indicate possible differences between the treatment and the control groups. The purpose is to investigate students’ attitudes towards statistics.

**Analysis of item 12:** One aspect in the analysis of this item is to ascertaint students’ statistical literacy levels according to Watson and Callingham’s (2003) method. Students’ responses are categorised from idiosyncratic to critical mathematical level to examine students’ statistical literature constructs.

**Analysis of item 13:** One point is given for each correct answer, and the maximum score is four points. The purpose is to indicate students’ competence in working out statistical problems.

**Analysis of item 14:** In the pre-test, students’ answers in the open-ended question are coded into three categories: statistics facilitates everyday life, statistics is needed in postgraduate studies and in occupations, and statistics is needed in research. The purpose is to investigate students’ attitudes towards statistics.

### 3.5.2 Data analysis of questionnaire 1: Students’ opinions about teaching experiment in CSCL environment

This instrument is designed to acquire both quantitative and qualitative data using mixed methods (Creswell & Plano Clark 2011, Tashakkori & Teddlie 1998) in order to merge them. According to the questionnaire, it has been possible to organize the data by themes such as: utility and constraints in collaboration, activity in interactions in conversational acts, success in collaborative learning and personal proficiency. The data is organized under these categorized themes to illustrate and deepen analyses.

**Analyses of the quantitative data has applied:**

-  [Q1, Q6, Q9, Q11, Q13, Q15, Q16, and Q18] in the theme: utility and constraints in collaboration
-  [Q27, Q28, Q29, and Q31] in the theme: activity in interactions in conversational acts
-  [Q2, Q4, Q5, and Q8] in the theme: success in collaborative learning
-  [Q20, Q21, and Q23] in the theme: personal proficiency.

In the first phase of data analysis, quantitative data was evaluated by using statistical methods. The quantitative data from questionnaire 1 was used to devise the Likert response format to accompany the graded (1–4) verbal statements to
attain efficiencies in measurements (Carifio & Perla 2007). Verbal statements in the scale are as follows: 1, totally disagree or does not describe me at all; 2, disagree or describes me just a little; 3, agree or describes me well; and 4, totally agree or describes me very well. The aim of the analysis is to calculate statistical numbers such as mean, standard deviation, and significance. Another aim is to indicate reliability between items when data is organized by combining and comparing questions under similar categorized themes.

The quantitative Likert-scale data was analysed by using the Mann-Whitney U-test (Ranta et al. 1999) to indicate possible differences between responses classified by treatment groups of years 2011 and 2012.

- Q1: In my opinion, I learned during the teaching experiment lessons as well as in standard mathematics lessons.
- Q2: In my opinion, I learned better during the teaching experiment lessons than in standard mathematics lessons.
- Q4: As a group, we learned the essential contents of statistics in upper secondary school mathematics.
- Q5: We managed to deal with the statistical problems.
- Q6: In my opinion, it was more difficult to work in a group than in a standard mathematics lesson.
- Q8: In my opinion, it was a good change to have mathematics lessons in small CSCL groups.
- Q9: Studying in a group fosters my learning.
- Q11: In my opinion, the electronic material supported my learning.
- Q13: Group cognition fosters learning.
- Q15: Teacher’s guidance was adequate in the group.
- Q16: In my opinion, the electronic material clarified the learned topics.
- Q18: Rate of study was adequate.
- Q20: I learned to use the calculator in statistics.
- Q21: Tutorial on using the calculator was beneficial.
- Q23: I learned the basics of using MS-Excel for statistics.
- Q27: Did you initiate conversations?
- Q28: Did you participate in conversations?
- Q29: Did you think aloud?
- Q31: Did you get ideas from other group-members’ thoughts?

The data was organized by combining questions under similar categorized themes. Cronbach’s alpha was used to indicate the reliability of data analyses with Likert-
type scales (Gilem & Gilem 2003). Cronbach’s alpha coefficient indicates possible internal consistency in Questionnaire 1. Moreover, Friedman's Chi-square test was used to indicate possible statistically significant differences between the combined items. The purpose is to indicate the reliability of data analysis by organizing and combining two or three questions from Questionnaire 1 under similar categorized themes.

- Q9: Studying in a group fosters my learning (Q13: Group cognition fosters learning.).
- Q11: In my opinion, the electronic material supported my learning (Q16: In my opinion, the electronic material clarified the learned topics.).
- Student's activity in conversational acts (Q27: Did you initiate conversations? Q28: Did you participate in conversations? Q29: Did you think aloud?).

In the second phase, the qualitative data, the contents of students’ utterances are coded for quantification by using verbal analysis (Chi 1997). The classification in verbal analyses trims down the subjectivity of qualitative data (Chi 1997), and the qualitative data is organized by characteristic themes. After these phases comes the synthesis phase, where interpretation of data is an essential part of analyses (Alasuutari 1999). Students’ responses have been analysed by using verbal analyses in order to find characteristic themes. Each open question has been interpreted and classified. To attain inter-rater reliability in the case of content analyses, two independent raters have to reach mutual agreement in quantification.

**Analyses of the qualitative data has applied:**

- [Q7, Q10, Q12, Q14, Q17, and Q19] in the theme: utility and constraints in collaboration
- [Q30 and Q32] in the theme: activity in interactions in conversational acts
- [Q34 and Q35] in the theme: success in collaborative learning
- [Q22, Q25, and Q26] in the theme: personal proficiency

### 3.5.3 Data analysis of students’ videotaped small-group collaborations

During the teaching experiment, students’ collaborative work in CSCL-module is observed and video-taped. The purpose is to analyse students’ collaborative conversation acts in learning statistics (see RQ3) by using CSS-instrument. The following subchapters present the procedure of the analysis.
Analysing collaborative learning conversations

In the present study, we designed a CSS instrument to aid in the analysis of students’ collaborative learning conversational acts. The qualitative analyses can be transcribed for coding, and the CSS instrument automates the process. The transcript is coded in terms of conversational acts. The data analysis comprises through four phases: data collection, data display, data reduction, and conclusion (Miles & Huberman 1994).

The nature and development of statistical learning processes were analysed through a sequence of seven interactive, non-linear phases: viewing video data attentively, describing videos, identifying critical events, transcribing, coding, constructing the storyline, and composing the narrative (Powell et al. 2003). The data analysis of the videotaped CSCL sessions from the teaching experiment is depicted in the following subchapters.

Categories in analysis of conversational acts

To indicate the nature of statistical learning processes in a CSCL environment, the quality of questions and explanations in conversational acts were analysed. Questions were coded by using a model developed by Walter and Maher (Powell et al. 2003), in which inductive or emergent codes focus on identifying themes and patterns within student-to-student discursive interactions (see Table 7). Students’ learning processes were analysed by stressing on the form of collaboration in a CSCL environment.

The attunement question checks for attunement between participants’ understandings. The purpose of the attunement question is to demonstrate mutual agreement. The interrogative question concerns information that is not procedural. The procedural question concerns mathematical operations and algorithms. The confirmation question requests a participant’s own conceptual understanding. The difference between the confirmation and the attunement question is that the former does not demonstrate concern for “the other’s” understanding. The speculative question posits potential. The rhetorical question has no expected response.
Table 7. Categories of student-to-student discursive interactions (Walter & Maher 2001, 2002).

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Category of question</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA</td>
<td>Attunement question</td>
<td>Question that checks the attunement between participants’ understanding and seeks demonstrated mutual agreement</td>
</tr>
<tr>
<td>QI</td>
<td>Interrogative question</td>
<td>Interrogative question for information that is not procedural</td>
</tr>
<tr>
<td>QP</td>
<td>Procedural question</td>
<td>Procedural question</td>
</tr>
<tr>
<td>QC</td>
<td>Confirmation question</td>
<td>Confirmation request by participant regarding his/her own conceptual understanding; differs from attunement by not demonstrating a concern for “the other’s” understanding</td>
</tr>
<tr>
<td>QS</td>
<td>Speculative question</td>
<td>Speculative question that posits potential</td>
</tr>
<tr>
<td>QR</td>
<td>Rhetorical question</td>
<td>Question that has no expected response</td>
</tr>
</tbody>
</table>

To understand the nature of statistical learning processes during the students’ conversational acts in selected episodes, a specific discourse analysis method was adapted from previous studies. According to Kaartinen and Kumpulainen (2002), specific categories are needed for describing students’ explanation building. The natures of explanation include formal, causal, descriptive, and everyday (see Table 8).

Table 8. Categories of students’ conversational acts (Kaartinen & Kumpulainen 2002).

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Category of explanation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>Formal explanation</td>
<td>Reflects the formal language and procedures of statistical issues</td>
</tr>
<tr>
<td>EC</td>
<td>Causal explanation</td>
<td>Includes informal reasoning in statistics</td>
</tr>
<tr>
<td>ED</td>
<td>Descriptive explanation</td>
<td>Describes statistical phenomena based on experimentation</td>
</tr>
<tr>
<td>EE</td>
<td>Everyday explanation</td>
<td>Reflects the construction of situational meanings based on everyday reasoning</td>
</tr>
</tbody>
</table>

**Content analysis of videotaped observations**

The videotaped observations in the present study were subjected to content analysis. The content analysis of the videotaped observations proceeded as follows: selection, analysis, technology, and ethics (Derry et al. 2010). In the content analysis,
interactions and utterances were coded into categories of non-task-related and task-related units for statistical testing.

The CSS instrument shown in Figure 13 was used in the data analysis of the videotaped CSCL sessions. The CSS instrument was designed based on previous research (Miles & Huberman 1994, Veerman & Veldhuis-Diermanse 2001), and it was tested in the pilot phase of the present study. The main purpose of the categorisation of the analysis is to make collaborative learning visible with two or more participants (Stahl 2002), and the basic unit of this data analysis is the small group event in a given statistical task.

Four episodes were chosen from the students’ videotaped small-group collaborations, based on the quality and the versatility of the episodes. The main aim was to test the effectiveness of the CSS instrument in content analysis of the videotaped observations. Four students’ CSCL sessions were analysed by using the CSS instrument. First, the small group event’s episodes were identified with contact numbers. Second, the students’ comments were divided into two categories: non-task-related and task-related. Third, the task-related conversational acts were divided into seven subsections: individual, planning or thinking aloud, question, explanation, support, evaluation, and new idea. The non-task-related conversational acts were divided into four subsections: no participation, nonsense, social, and technical.

Students’ comments were categorised by content, and each comment occupies one data line. Discourse features are presented in chronological order. By using verbal analysis of the content, utterances can be coded for quantification (Chi 1997). Coding of verbal utterances reduces the subjectivity of qualitative data via the tabulation, counting, and drawing out of the relationships among the occurrences of different types of utterances (Chi 1997).

A conversational act is represented by an “x” in the appropriate column. This identifies interaction in the group. The natures of the students’ comments are marked in column attitude as + to denote positive attitude and - to denote negative attitude. The columns calculator, computer or software, Cassy/YouTube, exercise, and assignment are for noting the exact category to which a current event belongs to.

One column indicates knowledge-building or conceptualisation in the episode. The conceptualisation of distributed or mutually shared cognition may occur in social statistical learning (Van den Bossche et al. 2006). The CSS instrument helps distinguish the nature of student collaboration in small groups and makes social statistical learning visible.
Fig. 13. Contact summary sheet.
3.5.4 Data analysis of interviews

The main aim of students’ interviews is to examine their experiences and opinions about the teaching experiment in the CSCL environment (see RQ2). The second addressed aim is to investigate the students’ own conceptions of statistics teaching in comprehensive school. One stream is to attain triangulation of the research data and results. In addition, the purpose in the teachers’ interview is to gain more insights into the secondary school statistics education in the (see RQ1).

Analyzing interview responses

First, students’ videotaped interviews are transcribed for analysis. The data of the interview is transcribed word for word. The qualitative data is organized by using open coding, creating categories and abstraction. The verbal data of students’ utterances (Chi 1997) are classified into categories. Classification of the data is the ground of the interpretation. With the help of classification different parts of the data can be compared, simplified and interpreted. Classification organises analysed phenomena, whereas combining helps to find similarities as well as regularities between classifications (Hirsjärvi & Hurme 2000).

Students’ responses in the interview questions are organized thematically such as: students’ opinions of secondary school statistics teaching, utility and constraints in collaboration, activity in interactions in conversational acts, success in collaborative learning and personal proficiency.

Teachers’ responses in the interview questions are transcribed word for word. The intention of the analyses of teachers’ interviews is to discover the consensus between teachers’ and students’ responses. By combining teachers’ responses, it is possible to find similarities, differences as well as regularities between aspects of secondary school’ statistics education.

Content analysis of students’ responses

In the content analyses, transcribed data is observed by itemizing, assimilating and conducting (Tuomi & Sarajärvi 2002). According to Chi (1997) qualitative data analyses assists the researcher in analysing structures and context of the particular phenomena. Different interviews and statements of participants in the present study are separated by using identified codes. Ten randomly chosen students in the
teaching experiment are interviewed (see Appendix 3). The names of the participants in the qualitative data have been changed.

A unit of analysis is one sentence, and these units are segmented based on the categories created that arose from the research data. In content analyses, both analysis and synthesis is combined: collected data is segmented in units and through synthesis units are combined in the scientific conclusions (Alasuutari 1999, Grönfors 1982). Classified data under the themes are quantified in supporting the numeric values of the data. Students’ responses are coded, and frequencies and percentages are used for comparisons for statistical testing. In order to achieve a good-level of inter-rater reliability in the case of content analyses, two independent raters have attained mutual agreement in quantification.

**Categories in analysis of themes in students’ responses**

The qualitative data from interviews is analysed by content analysis (Miles & Huberman 1994). The qualitative research approach can be theory-based, theory-bound or data-based (Tuomi & Sarajärvi 2002). In content analyses, linguistic data is categorized in an objective and quantifiable way (Chi 1997). Various content classifications facilitate analyses of context and structures of the particular phenomena. In general, qualitative content analyses go through the following phases: data textualization, development of classification, segmentation and coding and reporting of data (Chi 1997). Analyses of themes in students’ videotaped interviews have proceeded through data textualization, developing of classification, segmentation and coding and reporting of data.

Based on analysed data of the questionnaire 1, it has been possible to organize the data by themes such as: utility and constraints in collaboration, activity in interactions in conversational acts, success in collaborative learning and personal proficiency. In addition one theme concentrates on students’ opinions of secondary school statistics teaching. The data is organized under these categorized themes to illustrate and deepen analyses.

**Students opinions of secondary school statistics teaching**

During the teaching experiment, some students stated that they are not familiar with basic statistical concepts. The aim is to get the insight of the theme: students’ opinions of secondary school statistics teaching.
A) Students’ opinions of secondary school statistics teaching. [Q29]

Utility and constraints in collaboration

Questions: 3, 5–9, 12, 13, 21, and 23–26 (see Appendix 3) concern the theme utility and constraints in collaboration. The main aim of the analyses is to illustrate:

B) Students’ earlier experiences of CSCL in school. [Q21]
C) Students’ opinions of feasibility of CSCL in mathematics. [Q24]
D) Students’ opinions of function of technology during teaching experiment. [Q3]
E) Students’ opinions of utility of collaboration [Q5, and Q7]
F) Students’ opinions of teaching material [Q9, Q12, Q13, and Q23]
G) Students’ opinions of retarding factors in learning in a group [Q8]
H) Students’ opinions of future prospects of CSCL in learning [Q26]

Activity in interactions in conversational acts

Questions: 18–20 (see Appendix 3) concern the theme activity in interactions in conversational acts. The aim of the analyses is to illustrate:

I) Students’ opinions of context in which students discussed with other team members. [Q18]
J) Students’ opinions of context in which students thought aloud with other team members. [Q19]
K) Students’ opinions of getting ideas from other teammates’ thoughts. [Q20]

Success in collaborative learning

Questions: 2, 4 and 14 (see Appendix 3) concerning the theme success in collaborative learning. The aim of the analyses is to investigate:

L) Students’ opinions of their learning during the teaching experiment. [Q2]
M) Students’ opinions how they managed to solve statistical problems. [Q4, and Q14]
Personal proficiency

Questions: 10, 11, 16, 17, and 27 (see Appendix 3) concern the theme personal proficiency. The aim of the analyses is to illustrate:

N) Students’ opinions of adequacy and utility of calculators’ instructions. [Q10, and Q16]
O) Students’ opinions of the utility of MS-Excel. [Q11, and Q17]
P) Students’ best experience of the teaching experiment. [Q27]

The first step after transcription of the data analyses has been to categorise students’ responses into the main categories. Coded responses are presented in a summarized table of frequencies of certain main categories in results. Another aim is to merge data with the data in Questionnaire 1 and data in the delayed post-test. In addition, some selected students’ responses are presented as authentic expressions to illustrate their discourse. Finally, students are asked about their best experience of the teaching experiment. Some authentic answers are presented in the results.

3.5.5 Data analysis of assignment

In this teaching experiment, the material enabled small-groups to work asynchronously. In dealing with screencasts and instructional video-components, students also need to be directed to develop a good understanding of the underlying statistical concepts (Lunsford et al. 2006, Mun 2011). In addition, the students produced a short assignment, where they analysed the material gathered from the class: the relationship between the shoe-size and height of the students, and the development and relationship between world records of men’s and women’s 100-metre sprint times. A short overview of the students’ assignments is included in the results.

3.5.6 Analysing course exam and delayed post-test

In this study, deeper learning outcomes are evaluated by the influence of collaboration and technology utilization. In this section of this study, the differences in delayed post-test in learning outcomes between students in the teaching experiment and the comparison class is reported. There are two raters for gaining inter-rater reliability in the case of Course exam and in the case of the Delayed post-test for the level of agreement.
The statistical task in the course exam carries a maximum score of eight points, and each section in the exam is worth two points. [a]: If all the statistical variables are correct (2p), partially correct (1p). [b]: Statistical analyses of linear regression (2p). [c]: Statistical analyses of two linear regressions (2p). [d]: Plot of statistical chart (2p). In Appendices 6, 7, and 8, the course exams are presented. The delayed post-test is analysed in the following way.

**Analyses of Questions 1 and 2:** Students’ conceptions of statistics teaching in comprehensive school are analysed statistically.

**Analysis of Question 3:** Students answers are evaluated in terms of the level of statistical literacy (informal or inconsistent).

**Analysis of Question 5:** Analysis of this item involves ascertaining students’ levels of statistical literacy according to Watson and Callingham’s (2003) scheme. Students’ responses are categorised from idiosyncratic to critical mathematical to examine their statistical literature constructs (Maximum 5 points).

**Analysis of Question 6:** The aim is to measure students’ ability to construct a histogram and interpret the data (Maximum 4 points).

**Analysis of Question 7:** The aim is to measure students’ ability to construct a bar chart and the manner in which they calculate and estimate statistical parameters (Maximum 8 points).

**Analysis of Question 8:** The aim is to measure students’ ability to calculate statistical parameters and interpret them (Maximum 4 points).

The total number of points in the delayed post-test are counted from Question 5 to Question 8 (Maximum 21 points). The Mann-Whitney U-test (Ranta et al. 1999) is used to distinguish possible differences in learning outcomes in the course exam and in the delayed post-test between treatment and control groups. The effect size is also used to distinguish the differences in learning outcomes. The effect size is estimated by using the correlation coefficient effect size $r$ for a contingency table (Wilson 2013). The effect size limits are defined the following way: $0.10 = $ small effect, $0.24 = $ medium effect, and $0.37 = $ large effect (McGrath & Meyer 2006).

### 3.5.7 Analysing electronic course exam and questionnaire 2

The numerical research data from the questionnaires and the electronic-test is analysed by using statistical methods. Some open questions are classified and quantified in supporting the numeric values of the data. Students’ competence in the use of MS-Excel in the electronic-test is evaluated in value 1 (correct) or value 0 (false) in different sub-questions of two items.
3.6 Issues of validity and reliability of study

In this chapter, reliability and validity, as well as trustworthiness and authenticity, of the present study are discussed. To judge the quality and rigor of the present study, reliability and validity should be taken into consideration in the positivistic tradition (Klenke 2008). This DBR focuses on describing upper secondary school students’ statistical learning in a CSCL environment. The strategy of this study can be divided into four tiers: assessment of students’ starting level in statistical literacy, contribution of the CSCL environment in statistics learning, nature of students’ statistical learning processes in a CSCL environment, and students’ achievements in statistics in course exam and delayed post-test.

In this evaluation of the reliability and validity of the present study, it seems obvious that qualitative, quantitative and mixed methods used in different instruments such as pre-test, interviews, questionnaires, course exam and delayed post-test have been used in data analyses. Also, the approach of design-based research has been a fruitful premise in the creation-process of a technology-enhanced learning environment. Thus, the strategy to implement this study was feasible.

Validity can be described as an ability to measure what it is supposed to measure (Alasuutari 1999, Maxwell 1992, Tashakkori & Teddlie 1998). Maxwell (1992: 283) delineates: “Validity, in a broad sense, pertains to this relationship between an account and something outside of that account, whether this something is construed as objective reality, the constructions of actors, or a variety of other possible interpretations.” It is obvious that access between study and instruments as well as methods suggest perfect and saturated data related to the research question. After revealing the nature of validity in qualitative research, there is a need for a checklist of the kinds of threats in dimensions such as descriptive, interpretive, theoretical, generalizability and evaluative of validity (Maxwell 1992). In the positivistic tradition internal and external validity are the traditional criteria used for justifying knowledge production (Klenke 2008).

Each student has identification number in pre-test, questionnaires and post-test for the confidentiality of data. In the transcription of the interviews and video-material, participants’ names are fictional. In turn, the students’ names in the course exam are replaced and enumerated as: B1\(^5\), B2, ... and G1\(^6\), G2, ... for the

---

\(^5\) B1, boy 1; B2, boy 2; etc.

\(^6\) G1, girl 1; G2, girl 2; etc.
anonymous. Thus the confidentiality of data has been taken in the consideration in praxis.

To gain the \textit{internal validity} to the present study, the instruments used in this study are discussed, evaluated and improved of the impact of the research group and the supervisors. Furthermore, workmates of the researcher are reviewed instruments too in the process out of ascertaining the relation and appropriateness between curriculum in mathematics education and instruments.

\textit{Reliability} can be described as an ability to reproduce or replicate a study by using a specific procedure and consistency of analysis (Alasuutari 1999, Creswell & Plano Clark 2011). For gaining trustworthiness and authenticity in reliability, the research data should be presented in a form that all valuable information is offered to the reviewers of the study. Reliability is increased by expressing the agreement between two independent coders as a numerical value (Strijbos \textit{et al.} 2006).

The sample of this study consists of all advanced mathematics students, expect students who have been absent. All students are in the same year, and so the sample represents a reliable sample of the current conditions. The students interviewed are chosen randomly, that selection of different kind of students provides almost all kinds of opinions. Only the treatment groups participated in the questionnaire, interviews and electronic course exam.

The data in the present study is analysed by using appropriate quantitative and qualitative methods. The qualitative data from video-taped episodes and interviews are first transcribed and discussed by two independent coders in content analyses. The major aim of using two independent coders in the data analyses is to gain and build upon the reliability and validity of the data collected.

In data analyses using Likert-type scales, the consistency coefficient, or Cronbach’s alpha, is used to indicate the internal consistency of items. Cronbach’s alpha indicates the reliability of an instrument (Gilem & Gilem 2003). For attaining an acceptable level of reliability, the Cronbach’s alpha coefficient of a scale should be more than 0.7 (Pallant 2005). If a scale has a Cronbach’s alpha coefficient between 0.6 and 0.7, it can be interpreted as being questionable. A scale with a Cronbach’s alpha coefficient value between 0.5 and 0.6 can be construed as poor. A scale with a Cronbach’s alpha coefficient less than 0.5 is unacceptable.

In Table 9 inter-rater reliability is presented. The Cohen’s kappa is calculated by using equation (see Fig. 14). Two raters are classified by unit of analysis into the “+” and “-” categories according to whether the trait of agreement is found or not.
Table 9. The inter-rater reliability between the two independent coders.

<table>
<thead>
<tr>
<th>Method</th>
<th>Rater1 [+]</th>
<th>Rater1 [-]</th>
<th>Total</th>
<th>Cohen’s kappa [κ]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Questionnaire 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>598</td>
<td>20</td>
<td>618</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>17</td>
<td>601</td>
<td>618</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>611</td>
<td>625</td>
<td>1236</td>
<td>0.927</td>
</tr>
<tr>
<td><strong>Students’ interview</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>152</td>
<td>12</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>7</td>
<td>157</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>169</td>
<td>328</td>
<td>0.884</td>
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<tr>
<td><strong>Students’ videotaped small-group collaborations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>99</td>
<td>11</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>8</td>
<td>102</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>113</td>
<td>220</td>
<td>0.827</td>
</tr>
<tr>
<td><strong>The course exam</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>66</td>
<td>7</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>5</td>
<td>68</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>75</td>
<td>146</td>
<td>0.836</td>
</tr>
<tr>
<td><strong>The delayed post-test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>61</td>
<td>7</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>2</td>
<td>66</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>73</td>
<td>136</td>
<td>0.868</td>
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<tr>
<td><strong>The electronic test</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater2 [+]</td>
<td>60</td>
<td>0</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Rater2 [-]</td>
<td>1</td>
<td>59</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>59</td>
<td>120</td>
<td>0.983</td>
</tr>
</tbody>
</table>

Reliability of videotaped observations is increased by expressing the agreement between two independent coders as a numerical value (Strijbos et al. 2006). The inter-rater agreement values, Cohen’s kappa: $\kappa = .884$ in Students interviews, $\kappa = .836$ in Students’ videotaped small-group collaborations, $\kappa = .836$ in the Course exam and $\kappa = .868$ in the Delayed post-test, indicate an almost excellent concurrence (Gwet 2012). The Cohen’s kappa value is $\kappa = .927$ in Questionnaire and $\kappa = .983$ in the Electronic test indicate an excellent concurrence (Gwet, 2012). In addition, there are 1,236 units in the total analysis in the Questionnaire, 328 units in the total analysis in Students’ interviews, 220 units in the total analysis in Students’ videotaped small-group collaborations, 146 units in the total analysis in the Course exam, 136 units in the total analysis in the Delayed post-test and, 120 units in the
In data analyses with Likert-type scales, the consistency coefficient, or Cronbach’s alpha, is calculated to indicate internal consistency of items. Results of Questionnaire 1 for the teaching experiments conducted in the years 2011 and 2012 are considered herein. For the item “Studying in group fosters my learning”, the Cronbach’s alpha values for the years 2011 and 2012 are 0.798 and 0.641, respectively, suggesting acceptable level of reliability and questionable level of reliability.

For the item “In my opinion, the electronic material supported my learning”, Cronbach’s alpha value for the years 2011 and 2012 are 0.878 and 0.742, respectively, and both values indicate acceptable levels of reliability. For the item ‘Student's activity in conversational acts’, Cronbach’s alpha values for the years 2011 and 2012 are 0.714 and 0.796, respectively, and both values indicate acceptable levels of reliability.

Triangulation is a method where analysing a research question happens via multiple perspectives. This procedure is used to indicate that at least two methods are used in a study in order to confirm the results. Denzin (2006) has identified four basic types of triangulation: data triangulation, investigator triangulation, theory triangulation and methodological triangulation.

In this study, triangulation has been used based on the definition by Denzin (2006). Data has been collected from different time periods and combined after that. Data has been compared between different samples. Statistical literacy has been analysed as levels of statistical literacy by Watson and Callingham (2003). There have been two independent raters in analyses. The same phenomena have been studied with different instruments. These methods have been used in gathering and analysing data in this study.

3.7 Review of ethical issues in present study

In the present study, mixed methods are used in order to achieve multidisciplinary and comprehensive results. Many different methods such as interviews with documentary analysis and multiple regression with inferential statistics are combined (Symonds & Gorard 2010). Scientific quality is gained by using qualitative and quantitative methods. In the present study, recording and presenting results and judging research modes of action are endorsed by the research community.
Ethical issues have been taken into consideration. The present study is carried out in an upper secondary school in the eastern part of Finland, after the principal has granted permission. None of participants is given extra credits or payment for their participation. It is not possible to identify participants in the reporting of the results in this study (fictional names are used).

All participants have been informed of the aims of the study, data collection methods and methods of reporting. The guidelines of the Singapore statement on Research integrity and Finnish advisory board on research integrity (TENK\(^7\)) procedure are followed (Steneck et al. 2014, Varantola et al. 2012).

This study has been planned, conducted and analysed referred to with good scientific practice. From the perspective of ethical issues, the research group and supervisors as well as scientific communities have influenced the present study. The sources of financing and other associations relevant to the conduct of the present study are made known and reported.

\(^7\) Tutkimuseettinen neuvottelukunta.
4 Results

The present study investigates Finnish upper secondary school students’ statistical learning in a CSCL context. In the first section of this study students’ starting level in statistical literacy is assessed as well as their own perceptions about their proficiency in statistics as well as students’ opinions about statistical teaching in comprehensive school. The second section of the present study illustrates students’ opinions about the teaching experiment in CSCL environment. The third section of the present study indicates the nature of statistical learning processes in terms of the form of collaboration in the CSCL environment. Finally, in the last section of this study, students learning outcomes are evaluated. After each section the main results and findings are summarised.

4.1 Students’ starting level in statistical literacy

In this chapter, Finnish upper secondary school students’ starting level in statistical literacy at the beginning of the course probability and statistics is illustrated. In addition, students’ own perceptions about their proficiency in statistics as well as students’ opinions about statistical teaching in comprehensive school are measured. Research questions are:

1. What is the starting level of statistical literacy and attitudes towards statistics among students before the course of probability and statistics in upper secondary level?
   a) What are students’ own conceptions of statistics teaching in comprehensive school?

As background information, students are asked in the pre-test about their final grade in mathematics after comprehensive school as well as their grades in mathematics in upper secondary school. The mean of the final grade after comprehensive school has been 9.140 in the treatment group and 9.071 in the control group. In addition, the mean grade in upper secondary school has been 7.705 in the treatment group and 8.122 in the control group. Table 10 shows that participating students have rather good grades in mathematics. According to the p-value there are no significant differences between treatment and control groups in this study.
Table 10. Grades in mathematics among all students on a scale of 4 to 10.

<table>
<thead>
<tr>
<th>School level</th>
<th>Treatment group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>Comprehensive school</td>
<td>9.140</td>
<td>0.639</td>
</tr>
<tr>
<td>Upper secondary school</td>
<td>7.705</td>
<td>1.193</td>
</tr>
</tbody>
</table>

4.1.1 What is the starting level of statistical literacy and attitudes towards statistics among students before the course of probability and statistics in upper secondary level?

Students’ most well-known statistical concepts after comprehensive school are mean, diagram, and median; other statistical concepts such as standard deviation, type value, mode, histogram frequency and the relative frequency are unfamiliar to students after comprehensive school. Students’ own evaluation of their statistical literacy is shown in Table 11. It shows a rated distribution of students’ total points of Item 1. The majority of students (86.48%) get 9 points or less from the item1, 18 is maximum points.

Table 11. Evaluation of Students’ own opinions of their knowledge in basic statistical concepts in item 1 (N=74).

<table>
<thead>
<tr>
<th>Points</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–3</td>
<td>3</td>
<td>4.05%</td>
</tr>
<tr>
<td>4–6</td>
<td>39</td>
<td>52.70%</td>
</tr>
<tr>
<td>7–9</td>
<td>22</td>
<td>29.73%</td>
</tr>
<tr>
<td>10–12</td>
<td>7</td>
<td>9.46%</td>
</tr>
<tr>
<td>13–15</td>
<td>3</td>
<td>4.05%</td>
</tr>
<tr>
<td>16–18</td>
<td>0</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Table 12 illustrates students’ competence in basic statistical levels in their own opinion. Results show that students are familiar only with concepts diagram, mean and median. In other concepts there are severe problems. All those evaluated variables are essential contents of statistics according to the curriculum of the comprehensive school (Finnish National Board of Education 2015, Opetushallitus 2004).
Table 12. Evaluation of students’ own opinions of their level in basic statistical concepts (N=74).

<table>
<thead>
<tr>
<th>Concept</th>
<th>Informal level</th>
<th>Inconsistent level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>Frequency</td>
<td>14</td>
<td>18.92%</td>
</tr>
<tr>
<td>Relative frequency</td>
<td>10</td>
<td>13.51%</td>
</tr>
<tr>
<td>Mean</td>
<td>74</td>
<td>100.00%</td>
</tr>
<tr>
<td>Type value</td>
<td>16</td>
<td>21.62%</td>
</tr>
<tr>
<td>Median</td>
<td>65</td>
<td>87.84%</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>34</td>
<td>45.95%</td>
</tr>
<tr>
<td>Diagram</td>
<td>74</td>
<td>100.00%</td>
</tr>
<tr>
<td>Histogram</td>
<td>15</td>
<td>20.27%</td>
</tr>
<tr>
<td>Mode</td>
<td>15</td>
<td>20.27%</td>
</tr>
</tbody>
</table>

In addition, Table 12 shows students’ severe problems is using concepts mode and histogram (5.41% Inconsistent level, 20.27% Informal level). Table 13 shows similar findings in that it is quite demanding to discover two correct options of each question in concepts mode and histogram. Students’ own pre-conceptions or conceptions of statistics, statistical mathematics and statistical literacy are also asked for. The results expose the fact that student have rather good proficiency in these concepts. Less than 21% of students have no cognition of these concepts.

Table 13. Evaluation of students' proficiency in Items 2, 3 and 4 (N=74).

<table>
<thead>
<tr>
<th>Concept</th>
<th>0 point</th>
<th>1 point</th>
<th>2 points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
<td>all frequency</td>
</tr>
<tr>
<td>Mode</td>
<td>38</td>
<td>51.35%</td>
<td>31</td>
</tr>
<tr>
<td>Histogram</td>
<td>42</td>
<td>56.76%</td>
<td>32</td>
</tr>
<tr>
<td>Statistics</td>
<td>5</td>
<td>6.76%</td>
<td>24</td>
</tr>
<tr>
<td>Statistics in</td>
<td>15</td>
<td>20.27%</td>
<td>0</td>
</tr>
<tr>
<td>mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistical literacy</td>
<td>13</td>
<td>17.57%</td>
<td>33</td>
</tr>
</tbody>
</table>

Students’ attitudes to statistics and the importance of statistics seemed to be quite positive. Table 14 shows a consensus in attitudes between control and treatment groups. The Mann-Whitney U-test suggests perfect congruence between samples (p>0.1). Students’ attitudes to statistics before the course in probability and statistics at upper secondary level are classified by using the following statements:
**Item 5**: In my opinion, I have solid abilities in terms of reading and interpreting statistical information.

**Item 6**: When I read newspapers or watch television programs or other media, statistical numbers and graphs are easy to understand.

**Item 7**: I am critical with regard to statistical data.

**Item 8**: I think that statistics is an important part of upper secondary school mathematics.

**Item 9**: I need statistics in my post-graduate studies.

**Item 10**: I think that the understanding and interpretation of statistics are important skills from a postgraduate studies point of view.

**Item 11**: I think that the interpretation and understanding of statistics is an important skill in life.

| Table 14. Students’ opinion in items 5–11 on a Likert scale of 1 to 4 (N=74). |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Item            | Treatment group | Control group   | p, significance |
| Item 5          | 3.043           | 3.071           | 0.889           |
| Item 6          | 3.174           | 3.250           | 0.721           |
| Item 7          | 2.609           | 2.679           | 0.692           |
| Item 8          | 2.609           | 2.607           | 0.698           |
| Item 9          | 2.609           | 2.607           | 0.694           |
| Item 10         | 2.609           | 2.607           | 0.776           |
| Item 11         | 2.848           | 3.000           | 0.316           |

In self-assessment (see Table 12), 64.86% of the participants reported that they are familiar with concept diagram and are able to use it. The statistical problem in item 12 regarding diagrams measured how students interpret graphs. The diagram is a pie chart regarding the most common causes of death for Finnish men in 2005. The website in the statistical diagram problem is fictional, and the data is manipulated (see Appendix 1).

All students are able to interpret the pie chart and found the required information in order to choose the two most common causes of men’s deaths based on the diagram. In Table 15, all students agree that the diagram is easy to read and interpret (Item 12b). Two-thirds of students respond that they are critical concerning the pie chart (Item 12c). This criticality is not the same as the Critical level in statistical literacy, because many answers reflect inconsistent justifications like: “I can’t justify”, “I’m always critical”, “I don’t know the internet-site”, “There might be a human error”, etc. One student justified: “By using percentage...”
ratios it is easy to mislead, if the right numbers are missing…” Reasoning is rational, but she could not calculate the ratios, so she is just in a critical level in this context. Only 4.05% of participants comprehend and are critical of justifying mathematically the fact that the pie chart does not present 100% of the quantity (question 12d). In this data-manipulated statistical graphic, the total percentage is 116%. The pie chart is a basic statistical graphic and belongs to basic statistical literacy. The majority of students are at an Inconsistent level in statistical literacy. Students’ levels in statistical literacy are shown in Table 16.

**Table 15. Students’ answers in item 12 (N=74).**

<table>
<thead>
<tr>
<th>Item</th>
<th>all frequency</th>
<th>relative frequency</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 12 b</td>
<td>0</td>
<td>0.00%</td>
<td>74</td>
<td>100.00%</td>
</tr>
<tr>
<td>Item 12 c</td>
<td>25</td>
<td>33.78%</td>
<td>49</td>
<td>66.22%</td>
</tr>
</tbody>
</table>

**Table 16. Students’ levels in statistical literacy in Item 12 d (N=74).**

<table>
<thead>
<tr>
<th>Level of statistical literacy</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>No answer</td>
<td>6</td>
<td>8.11%</td>
</tr>
<tr>
<td>Idiosyncratic level</td>
<td>9</td>
<td>12.16%</td>
</tr>
<tr>
<td>Informal level</td>
<td>5</td>
<td>6.76%</td>
</tr>
<tr>
<td>Inconsistent level</td>
<td>44</td>
<td>59.46%</td>
</tr>
<tr>
<td>Consistent non-critical level</td>
<td>6</td>
<td>8.11%</td>
</tr>
<tr>
<td>Critical level</td>
<td>1</td>
<td>1.35%</td>
</tr>
<tr>
<td>Critical mathematical level</td>
<td>3</td>
<td>4.05%</td>
</tr>
</tbody>
</table>

Based on secondary level mathematics text books, item 13 is quite a typical statistical task. The diagram shows the number of plum-tomatoes in packages prepared for sale. The result shows in Table 17 that students have severe problems defining the required statistical values from a bar chart: type value, median, mean and the length of the range. The majority of students (91.89%) get 2 points or less from the item, maximum was 4 points.
Students’ own conceptions of their statistical literacy competence are examined in statistical problems they should have been able to use mode, median, mean, and the length of the range in order to solve. Based on the research data gathered, it could be assumed that mean and median would have been easy statistical problems for the participants.

Table 18 shows how students solved statistical problems in which they should have been able to use mode, median, mean, and the length of the range. Even if 98.65% of the participated students have felt that mean is a statistical concept with regard to which they said, “I know this concept and I am capable of using it,” only 24.32% solved the problem correctly (13c). In addition, median is a statistical concept regarding which 35.14% of the participating students said, “I know this concept, and I am capable of using it.” However, only 12.16% of participants solve this statistical problem correctly.

In addition, 5.41% of participants respond, “I know this concept and I am capable of using it,” in regard to defining mode and 32.43% were able to solve this statistical problem correctly. Also, the length of range is a difficult statistical problem to interpret from the given data.

Table 18. Students’ correct answers in item 13 (N=74).

<table>
<thead>
<tr>
<th>Concept</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type value</td>
<td>24</td>
<td>32.43%</td>
</tr>
<tr>
<td>Median</td>
<td>9</td>
<td>12.16%</td>
</tr>
<tr>
<td>Mean</td>
<td>18</td>
<td>24.32%</td>
</tr>
<tr>
<td>The length of the range</td>
<td>22</td>
<td>29.73%</td>
</tr>
</tbody>
</table>

One-third of students respond that statistics will facilitate everyday life. One-fifth of students respond that statistics are needed in postgraduate studies as well as in occupations. And less than one-tenth of students respond that statistics are needed in research. A quarter of students do not respond to the question. Table 19 shows the distribution of answers.
Table 19. Students' answers in item 15 (N=65).

<table>
<thead>
<tr>
<th>Description</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistics will facilitate everyday life.</td>
<td>25</td>
<td>38.46%</td>
</tr>
<tr>
<td>Statistics are needed in postgraduate studies as well as in occupations.</td>
<td>15</td>
<td>23.08%</td>
</tr>
<tr>
<td>Statistics are needed in research.</td>
<td>6</td>
<td>9.23%</td>
</tr>
<tr>
<td>No answer</td>
<td>19</td>
<td>29.23%</td>
</tr>
</tbody>
</table>

4.1.2 What are students’ own conceptions of statistics teaching in comprehensive school?

In the students interview was asked students’ own conceptions of statistics teaching in comprehensive school. A short overview is presented in the following chapters. This chapter also includes results of teachers’ interviews and students’ delayed post-test for gaining triangulation to this theme.

Students interview

Ten indiscriminately chosen students in the teaching experiment are interviewed. They are asked: “How and to what extent were statistics taught in comprehensive school?” The names of the participants in the following qualitative data have been changed. The intention in the categorization is to aggregate students’ responses in similar groups. Students’ responses are divided into three main categories:

1. Basic statistics had been taught during comprehensive school.
2. Extent of statistics teaching had been very narrow.
3. Statistics had not been taught at all.

Two students interviewed have stated that basic statistics such as modes, medians and frequencies are familiar to them after comprehensive school.

Brian: “We had some, at least. Quite a familiar thing for me. Modes, medians and frequencies.”

Rihanna: “There was quite a lot at some phase. I can’t remember whether it was in 9th grade or in some other phase. In our school, we had a different mathematics teacher than the others and a different book than the others, in which they went through (statistics), so I don’t know if the others in our school went through them (statistics) at all.”
Five students have expressed that in their opinion the extent of statistics teaching had been inadequate. The following selected authentic responses belong to category 2: extent of statistics teaching have been very narrow.

Ozzy: “I guess there wasn’t. Maybe as a part of some other course. There was a little, but not very much.”

Ines: “No, I mean, like, the mean we went through. I mean the counting. We didn’t go through any standard deviation.”

David: “I do remember that we went through some things, but it wasn’t very wide. For me, it was quite new – all these frequencies and the others. We didn’t actually have anything very wide.”

Three of the students interviewed did not recall statistics teaching in comprehensive school. Students stated that they are not familiar with basic statistical concepts after comprehensive school.

Andrew: “I don’t remember, at least. We hadn’t even heard about those things (mode and median).”

Rafael: “I don’t remember any. Would we have studied it at all? I don’t remember, at least.”

Rose-Marie: “We may not have had much, because I hadn’t even heard about mode or median or anything like that.”

Based on students’ interviews, it seems that the extent of statistics teaching in comprehensive school has limitations. Students’ ability to recall essential statistical concepts based on the criteria of the final assessment of comprehensive school, seems to be inadequate.

The delayed post-test

The delayed post-test reflects similarities in the extent of the statistics in comprehensive schools to the students’ interview. All the participants are asked about statistics teaching in comprehensive school. Students (16.18%) agreed that basic statistics had been taught during comprehensive school. Nevertheless 48.53% of students’ responses reflected that the extent of statistics teaching had been very narrow. Based on the delayed post-test 35.29% of students recall that statistics had
not been taught at all. It seems that the extent of statistics should be wider in order to ensure deeper learning in statistical literature.

**Teachers’ interviews**

Two long career secondary school teachers are interviewed in the present study. The intention of the interviews is to evaluate the present state of statistics teaching in the comprehensive school. There are seven open questions in the teachers’ interview (see Appendix 4). The themes in the teachers’ interview complement the students’ interview and depict statistical teaching in comprehensive school from the teacher’s point of view. According to the teachers’ responses, the next subchapters illustrate their opinions of the circumstances of statistics teaching in secondary school. The complete transcription of the teachers’ interviews is given in Appendix 13.

In secondary school mathematics, statistics is taught only in the 9th grade for a period of a few weeks. There are too many aims in the curriculum to teach all the contents thoroughly. It seems that the position of statistics and probability and the amount of teaching is very weak. The variation in the average number of statistics classes can be from 4 to 20. It depends on whether a student choose optional courses or not.

According to teachers interviewed, there is not enough time to go thoroughly the concepts and practicing that the curriculum includes: “…but I know that many of my colleagues do not deal with these issues. The textbook has major significance in this. Teaching the subject is easier with the help of a good textbook.”

In teachers’ opinions, students like statistics, because the subject is so different and easy to combine with real-life situations. According to the teachers’ interviews, students’ motivation does not always come naturally and teachers have to think of ways of selling their subject. It seems that real-life situations interest students. Statistics teaching could be developed by using better teaching materials, ICT, statistical programs, and integration with other subjects. Another teachers’ remark runs: “…Sometimes the analysis of the measured data and the designing a questionnaire and marking results by using tally and classification to the table interests them. We have to think of ways of selling our subject; motivation does not come naturally. I use newspapers and the internet, and the research subjects are often the students themselves. I told the students to measure one another’s heights, mark them for everyone to see, and build a table. Those tables are arranged in terms of girls and boys. The means of the genders are defined, and other
observations are made from the constructed sample. This always seems to interest them.” Both teachers’ interviews gave the impression that a feeling of inadequacy and haste reflect what extent statistics were taught in comprehensive school.

### 4.1.3 Summary of results (RQ1 and RQ1a)

The results and main findings of students’ starting level in statistical literacy are presented in this summary. 1. *What is the starting level of statistical literacy among students before the course of probability and statistics in upper secondary level? a. What are students’ own conceptions of statistics teaching in comprehensive school?*

Results mediate that students participating have rather good grades in mathematics from comprehensive school as well as from the upper secondary school. The most well-known statistical concepts after comprehensive school are mean, diagram, and median. Most essential contents of statistics according to the curriculum of the comprehensive school (Finnish National Board of Education 2015, Opetushallitus 2004) are unfamiliar to students, such as standard deviation, type value, mode, histogram frequency and the relative frequency. In general, students seem to be at the informal or inconsistent level in statistical literacy in concepts mean, diagram, and median. In other concepts, most of students are at the idiosyncratic level.

Based on measured proficiency, students’ capability to solve statistical problems was weaker than they had expected. For example, the majority of students felt that mean is a familiar statistical concept to them, but only one quarter solve the problem correctly. Measured proficiency in statistical literacy does not advocate students’ self-evaluation.

Students’ own attitudes towards statistics are quite positive. In students’ opinions, statistical skills are beneficial in the following way: statistics will facilitate everyday life, Statistics are needed in postgraduate studies as well as in occupations and statistics are needed in research. According to the students’ and teachers’ interviews, the present state of statistical literacy in the comprehensive school is weak. It seems that there is not enough time to teach statistics thoroughly.

### 4.2 Contribution of CSCL environment in learning statistics

The contemporary techniques have great potential to implement technologically enhanced environments for students to collaborate asynchronously in different small-groups. The major objective in this chapter of the present study is to illustrate
students’ opinions about teaching experiment in a CSCL environment. The research question is:

2. *What is the contribution of the CSCL environment in learning statistics in students’ opinions?*

The Mann-Whitney U-test in Table 20 with a p-value of > 0.1 indicates a perfect concurrence between treatment groups’ grades in both comprehensive and upper secondary school. In treatment group 2011, 40% of students interviewed mentioned that they have participated to the CSCL pilot phase of this study in the course of analytical geometry. In treatment group 2011, 50% of students participated in the CSCL pilot phase, whereas in treatment group 2012, only 2% of students participated in the CSCL pilot phase. This detail can be seen as a difference in background information between treatment groups 2011 and 2012 in Students’ earlier experiences of CSCL.

<table>
<thead>
<tr>
<th>School level</th>
<th>Treatment group 2011 (n=46)</th>
<th>Treatment group 2012 (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  Standard deviation</td>
<td>Mean  Standard deviation</td>
</tr>
<tr>
<td>Comprehensive school</td>
<td>9.000 0.816</td>
<td>8.759 0.709</td>
</tr>
<tr>
<td>Upper secondary school</td>
<td>7.931 1.209</td>
<td>7.987 1.346</td>
</tr>
</tbody>
</table>

4.2.1 *What is the contribution of the CSCL environment in learning statistics in students’ opinions?*

Students’ earlier experiences of CSCL in school are marginal. This teaching experiment is the first experience for most students of working in a CSCL environment. One fifth of students interviewed remember some single lessons in ICT-class in chemistry and religion, but not exactly in the same way as in this teaching experiment.

In the interview, almost all of the students respond that the technology had worked very well during the teaching experiment. In most students’ opinion (56.25%), CSCL is a feasible approach in learning mathematics. Especially the use of MS-Excel is beneficial in learning statistics, and this kind of learning style could be suitable in other topics in mathematics, for example geometry and vectors.
The research-data from the questionnaire and interviews are organized by themes such as: *utility and constraints in collaboration, activity in interactions in conversational acts, success in CL and personal proficiency.*

**Utility and constraints in collaboration**

The utility and constraints of collaboration in the teaching experiment are summarized in Table 21 on a scale of 1 to 4. It seems that the teaching experiment was beneficial for the treatment group 2011 in all the cases listed above. The results of the questionnaires show that the students in the treatment group 2012 are not certain that studying by using CSCL method fostered their learning in statistics.

Yet, the majority of the students in both treatment groups agree that the electronic material clarified and supported their understanding of the learned topics (MTG2012 =2.482, SDTG2012 =0.910; MTG2011=2.616, SDTG2011=0.870). In the Mann-Whitney U test, \( p > 0.1 \) indicates perfect concurrence between the treatment groups in all questions: “In my opinion, the electronic material supported my learning. In my opinion, the electronic material clarified the learned topics.”

Mann-Whitney U test with \( p \leq 0.05 \) was considered statistically significant between treatment groups in the following cases:

- Teacher’s guidance was adequate in the group (\( p = 0.000 \)). (MTG2012 = 2.054, SDTG2012 = 0.961; MTG2011 = 3.349, SDTG2011 = 0.72)
- The rate of study was adequate (\( p = 0.001 \)). (MTG2012 = 2.345, SDTG2012 = 0.849; MTG2011 = 3.000, SDTG2011 = 0.900)
- In my opinion, it was more difficult to work in a group than in a standard mathematics lesson (\( p = 0.007 \)). (MTG2012 = 2.064, SDTG2012 = 0.774; MTG2011 = 2.605, SDTG2011 = 1.055)
- In my opinion, I learned during the teaching experiment lessons as well as in standard mathematics lessons. (\( p = 0.007 \)). (MTG2012 = 1.804, SDTG2012 = 0.616; MTG2011 = 2.326, SDTG2011 = 0.919)
- Studying in a group fosters my learning in Treatment group 2012 (\( p = 0.007 \)). (MTG2012 = 2.375, SDTG2012 = 0.814; MTG2011 = 2.756, SDTG2011 = 0.867)

The previous list shows the differences between the treatment groups. One fundamental and crucial difference between the treatment groups is that 50% of the students participated in the CSCL pilot phase in the year 2011, whereas only 2% of the students participated in the CSCL pilot phase in the year 2012. Also Friedman’s Chi-square test with \( p \leq 0.05 \) was considered statistically significant within
treatment groups in the item: “Studying in a group fosters my learning.” Students in the treatment group 2011 seems to be more familiar with the CSCL method. The results of students’ opinions of the items “In my opinion it was more difficult to work in a group than in a standard mathematics lesson” and “In my opinion, I learned during the teaching experiment lessons as well as in standard mathematics lessons.”, shows significant difference between treatment groups in Mann-Whitney U test (p ≤ 0.05). It seems that students in the treatment group 2011 who have earlier experiences of CSCL are more confident of the rate of studying and teacher’s guidance than students in the treatment group 2012. It seems that students are not sure that studying in a group fosters their learning in treatment group 2012. Finally all students agree that the electronic material supported their learning.

For the items “Studying in group fosters my learning” and “In my opinion the electronic material supported my learning”, the Cronbach’s alpha values of the Treatment group of 2011 are ≥0.7, suggesting acceptable levels of reliability. For the item “Studying in group fosters my learning”, the Cronbach’s alpha value of the Treatment group of 2012 is ≤0.7, suggesting a questionable level of reliability. For the item “In my opinion the electronic material supported my learning”, The Cronbach’s alpha value of the Treatment group of 2012 is ≥0.7, suggesting an acceptable level of reliability.
Table 21. The utility and constraints of collaboration in the teaching experiment on a scale of 1 to 4.

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Treatment group 2011</th>
<th>Treatment group 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N 1 M 2 SD 3 X 2(4) CA 5 p 6</td>
<td>N 1 M 2 SD 3 X 2(4) CA 5 p 6</td>
</tr>
<tr>
<td>In my opinion, I learned during teaching the experiment lessons as well as in standard mathematics lessons.</td>
<td>43 2.326 0.919 0.007</td>
<td>56 1.804 0.616</td>
</tr>
<tr>
<td>In my opinion it was more difficult to work in a group than in a standard mathematics lesson.</td>
<td>43 2.116 1.117 0.007</td>
<td>56 2.679 0.834</td>
</tr>
<tr>
<td>Studying in group fosters my learning. (2 Items)</td>
<td>43 2.756 0.867 0.798 0.030</td>
<td>54 2.375 0.814 17.894 0.003</td>
</tr>
<tr>
<td>In my opinion the electronic material supported my learning. (2 Items)</td>
<td>43 2.616 0.870 3.267 0.878 57 2.482 0.910 2.632 0.742 0.251</td>
<td></td>
</tr>
<tr>
<td>Teacher’s guidance was adequate in the group.</td>
<td>43 3.349 0.72 56 2.054 0.961 0.000</td>
<td></td>
</tr>
<tr>
<td>The rate of studying was adequate.</td>
<td>43 3.000 0.900 58 2.345 0.849 0.001</td>
<td></td>
</tr>
</tbody>
</table>

1 N = sample size,  
2 M = mean,  
3 SD = standard deviation,  
4 $X^2$ = Friedman’s chi-square,  
5 CA = Cronbach’s alpha based on standardized items,  
6 p = significance
“What fosters/retards your learning?” is an explanatory question in the questionnaire to the question: “In my opinion it was more difficult to work in a group than in a standard mathematics lesson.” The answers are classified into two mainstreams: promoting factors and retarding factors. There are 48% promoting responses in this question. In the interview, students are asked about promotion in learning: “Did collaboration in small groups promote your learning? What promoted learning in a group?”

Distribution of promoting factors are classified and presented in Table 22. It seems that, during students’ learning-process, it is possible for students to hear: “What other students think about the current problem?”, and they feel it has been beneficial to participate to the group conversations. A good group spirit is another crucial factor which fosters collaboration.

Table 22. Distribution of promoting factors in collaboration.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Questionnaire</th>
<th>Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 47)</td>
<td>(n=10, f=33)</td>
</tr>
<tr>
<td></td>
<td>all frequency</td>
<td>all frequency</td>
</tr>
<tr>
<td>A good group spirit.</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>It was possible to hear other students thinking and discussing in the group.</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Implementation of the material helped.</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Group-working skills developed.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Nice variation from traditional learning.</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

All the indiscriminately chosen students in the interview agreed that collaboration in small groups promoted their learning. Students explained that peer learning supported their learning. According to students’ answers, it is easier to adapt statistics when the problem-solving process is mutually going on. The most prominent factors facilitating their learning were peer learning support and a fruitful conversation with questioning and explanations, as well as mutual sharing of understanding in knowledge building. The following students’ statements elaborate how collaboration facilitates their learning.
Rafael: “Well, maybe, if everything had to be thought out all by myself, I would not have necessarily understood. But, if one of us understood, he could tell it to the others.”

Brian: “In my opinion, it is better to think in a group with mates.”

Andrew: “Well, of course, all that teaching materials. They helped and you were able to ask your schoolmates and that was good.”

Rose-Marie: “And when you were able to see clips many times sequentially, until you got it. And it was pausable.”

Based on the results in the questionnaire and the interview, the most retarding factor in collaboration is Unfamiliarity with the CSCL-method. The second most retarding factor is that it was not possible to proceed at one’s own rate or level of noise. In the interview, one student reports: “At times it was too noisy, because there were so many listeners at the same time, so we had to go near the loudspeaker.” Noisiness has disturbed their concentration and, therefore, it has obstructed their learning. Table 23 shows the distribution of students’ opinions of retarding factors in learning in a group during the teaching experiment.

**Table 23. Retarding factors in collaboration.**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Questionnaire 1 (n = 51)</th>
<th>Interview (n=10, f=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>Technical problems.</td>
<td>8</td>
<td>15.69%</td>
</tr>
<tr>
<td>Only one student knew how to utilize computer.</td>
<td>7</td>
<td>13.73%</td>
</tr>
<tr>
<td>It was not possible to proceed at your own rate.</td>
<td>14</td>
<td>27.45%</td>
</tr>
<tr>
<td>Noise.</td>
<td>5</td>
<td>9.80%</td>
</tr>
<tr>
<td>Teacher-tutoring was insufficient.</td>
<td>3</td>
<td>5.88%</td>
</tr>
<tr>
<td>Unfamiliarity with the CSCL-method.</td>
<td>14</td>
<td>27.45%</td>
</tr>
</tbody>
</table>

In the Questionnaire there was an open question: “What factor fostered or retarded your learning in a group, and how?” (see Appendix 2, Questions 10, and 14) Based on students’ responses, it seems that there have been many more fostering factors than

---

Question 5: “Did collaboration in small groups promote your learning?”

Question 7: “What promoted learning in a group?”

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retarding factors in collaboration. Retarding factors in collaboration are presented in Figure 15. There seem to be three main retarding factors in collaboration. Lack of teamwork skills is the most retarding factor mentioned in students’ responses.

![Figure 15. Retarding factors in collaboration (f=51, Questionnaire 1).](image)

The most prominent fostering factors in collaboration are the possibility to ask or/and get advice, support from the group and allowing you to hear other group-members’ thoughts. Fostering factors are presented in Figure 16.

![Figure 16. Fostering factors in collaboration (f=108, Questionnaire 1).](image)

Table 24 depicts the distribution of students’ opinions of teaching material. The most facilitating factor in the learning material is that teaching material and examples support learning. In students’ opinions, the material demonstrated well new topics and it was visual and narrative. The interview reveals that the narration in the learning material contributes students’ understanding of the problem-solving process in statistics and how the solution has been found. The second most facilitating feature of the material is the possibility to pause or repeat if needed. In the interview, one student says: “And a video-stream was possible to pause which enabled you to think about the problem.”
Table 24. Students’ opinions of the teaching material.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Questionnaire</th>
<th>Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=92 , f=170)</td>
<td>(n=10, f=42)</td>
</tr>
<tr>
<td></td>
<td>all frequency</td>
<td>all frequency</td>
</tr>
<tr>
<td>Not in any way or I preferred traditional teaching.</td>
<td>24</td>
<td>14.12%</td>
</tr>
<tr>
<td>It clarified the use of Excel or calculator.</td>
<td>20</td>
<td>11.76%</td>
</tr>
<tr>
<td>Material demonstrated well new topics – i.e. visuality and narration.</td>
<td>81</td>
<td>47.65%</td>
</tr>
<tr>
<td>Learned to solve problems.</td>
<td>19</td>
<td>11.18%</td>
</tr>
<tr>
<td>If needed, it was possible to pause or repeat.</td>
<td>26</td>
<td>15.29%</td>
</tr>
</tbody>
</table>

In the interview, students describe the teaching material in the following way:

Ines: “It was good, when we had those recorded materials and it was possible to repeat again, if you didn’t hear or understand exactly the first time. It was possible to pause, if you didn’t follow.”

Brian: “Well, the fact that it was clear and proceeded phase after phase. And it was possible to see all the intermediate steps and it didn’t show only the solution. It helped and the material was self-explanatory.”

Based on the results in the questionnaire, students clearly expressed that they preferred traditional instruction in mathematics. CSCL seems to be unfamiliar to most of the students, and students can be reluctant to exceed the collaboration rules during the first collaboration which can present itself as a lack of team-work skills.

From the students’ point of view, CSCL can be a feasible learning approach. All the students interviewed would like to use computers in the future in learning mathematics. One student comments: “It was a pretty nice variation, when we were learning in a different way than usual. Good alternative. I hope for this kind of treatment in the middle of the course, at some point. At the same time, it would break sitting in the class.” Table 25 shows students’ opinions of the future prospects of CSCL in learning.
Table 25. Students’ opinions of future prospects of CSCL in learning (n=10, f=16).

<table>
<thead>
<tr>
<th>Opinion</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, I would like CSCL in learning.</td>
<td>10</td>
<td>62.50%</td>
</tr>
<tr>
<td>A few lessons.</td>
<td>3</td>
<td>18.75%</td>
</tr>
<tr>
<td>As a change from the traditional method.</td>
<td>3</td>
<td>18.75%</td>
</tr>
</tbody>
</table>

Activity in interactions in conversational acts

Students’ self-evaluation of their participation in collaboration shows that the majority of the students are very active in launching a conversation, participating in conversations, thinking aloud, and getting ideas from other teammates’ thoughts. Students’ self-evaluations of their activity in conversational acts are summarized in Table 26. The Cronbach’s alpha values of both treatment groups (2012 and 2011) are ≥0.7, suggesting acceptable levels of reliability (M_{TG2012} = 3.073, SD_{TG2012} = 0.820; M_{TG2011} = 3.178, SD_{TG2011} = 0.723). In the Mann-Whitney U test, p > 0.1 indicates perfect concurrence between the treatment groups in all questions: “Did you initiate conversations? Did you participate in conversations? Did you think aloud?”

Table 26. Self-evaluation of participation in collaboration on a scale 1 to 4.

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Treatment Group 2011</th>
<th>Treatment Group 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=43)</td>
<td>(n=56)</td>
</tr>
<tr>
<td></td>
<td>M¹</td>
<td>SD²</td>
</tr>
<tr>
<td>Student’s activity in conversational acts. (3 items)</td>
<td>3.178</td>
<td>0.723</td>
</tr>
<tr>
<td>Did you get ideas from other group-members thoughts?</td>
<td>2.837</td>
<td>0.721</td>
</tr>
</tbody>
</table>

1 M = mean,  
2 SD = standard deviation,  
3 χ² = Friedman’s chi-square,  
4 CA = Cronbach’s alpha based on standardized items,  
5 p = significance

Students’ answers in the interview give an expression that conversations in small-groups are beneficial and fruitful for their statistical learning. In general, the
students are active in communicating during the teaching experiment. They have been thinking aloud, especially in the demanding situations. Eight of the students remember that they got some ideas from other teammates’ thoughts – especially in problematic cases, but it is difficult for them in the interview to give a concrete example of situations.

Table 27 illustrates the context in which students discuss with other team members. There are at least 9 students, who have not been thinking aloud at all. According to the questionnaire, most of participated students in the present teaching experiment have been thinking aloud in their own opinion in cases: “When I explained, how to solve the problem?”, “When there were difficulties in problem solving.” and “When, I did not understand at all.”

Table 27. Students’ activity in thinking aloud property.

<table>
<thead>
<tr>
<th>Activity orientation</th>
<th>Questionnaire</th>
<th>Interview (n=10, f=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment group 2011 (n=37)</td>
<td>Treatment group 2012 (n=59)</td>
</tr>
<tr>
<td></td>
<td>all freq.</td>
<td>relative freq.</td>
</tr>
<tr>
<td>I did not think aloud.</td>
<td>4</td>
<td>10.81%</td>
</tr>
<tr>
<td>I thought aloud, but I don’t remember the context.</td>
<td>2</td>
<td>14.29%</td>
</tr>
<tr>
<td>When I explained how to solve the problem.</td>
<td>12</td>
<td>32.43%</td>
</tr>
<tr>
<td>When there were difficulties in problem solving.</td>
<td>13</td>
<td>35.14%</td>
</tr>
<tr>
<td>When I did not understand at all.</td>
<td>8</td>
<td>21.62%</td>
</tr>
</tbody>
</table>

All the students in the interview say, that they have been active in communicating during the teaching experiment and problem-solving. Especially the difficult problems such as using the calculator and working with the assignment activate their discourse: “How can we calculate this problem? How can we solve the current problem?” It seems that thinking aloud of the problem and shared ideas combined with demanding situations support mutual understanding in small-groups.
Success in Collaborative Learning

Students’ self-evaluation of their success in collaborative learning is shown in Table 28 on a scale of 1 to 4. The Mann-Whitney U-test with a p-value of $\leq 0.05$ is considered to be statistically significant between treatment groups in some cases:

“We managed to deal with the statistical problems.” (MTG2012 =2.702, SDTG2012=0.626; MTG2011=3.093, SDTG2011=0.684)\textsuperscript{10}

“In my opinion, it was a good change to have mathematics lesson in small CSCL-group.” (MTG2012 =2.491, SDTG2012 =1.020; MTG2011=3.000, SDTG2011=0.951)\textsuperscript{10}

It seems that treatment group 2011, who participated in the pilot-phase and have earlier experiences of CSCL, evaluated their success in collaboration more positively. Students’ self-evaluation in success on collaboration reveals that students’ are confident of their statistical competence. They have also expressed that CSCL has been a good change in a mathematics lesson. In the Mann-Whitney U test, $p > 0.1$ indicates perfect concurrence between the treatment groups in question: “As a group we learned upper secondary school’s mathematics essential contents of statistics.”

Table 28. Self-evaluation of success in collaboration on a scale of 1 to 4.

<table>
<thead>
<tr>
<th>Opinion</th>
<th>Treatment group 2011 (n=43)</th>
<th>Treatment group 2012 (n=56)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M¹</td>
<td>SD²</td>
</tr>
<tr>
<td>In my opinion I learned better during teaching experiment lessons than in standard mathematics lessons.</td>
<td>1.698</td>
<td>0.773</td>
</tr>
<tr>
<td>As a group we learned upper secondary school's mathematics essential contents of statistics.</td>
<td>2.488</td>
<td>0.703</td>
</tr>
<tr>
<td>We managed to deal with the statistical problems.</td>
<td>3.093</td>
<td>0.684</td>
</tr>
<tr>
<td>In my opinion it was a good change to have mathematics lesson in small CSCL-group.</td>
<td>3.000</td>
<td>0.951</td>
</tr>
<tr>
<td></td>
<td>M¹</td>
<td>SD²</td>
</tr>
<tr>
<td></td>
<td>1.411</td>
<td>0.626</td>
</tr>
<tr>
<td></td>
<td>2.482</td>
<td>0.687</td>
</tr>
<tr>
<td></td>
<td>2.702</td>
<td>0.626</td>
</tr>
<tr>
<td></td>
<td>2.491</td>
<td>1.020</td>
</tr>
</tbody>
</table>

1 M = mean, 2 SD = standard deviation, 3 p = significance

The distribution of students’ experiences about learning in CSCL environment is presented in Table 29. Only a few students do not like to study in CSCL environment. The results suggest that CSCL is a nice variation from traditional mathematics instruction from the students’ point of view. Students’ experiences in learning in the CSCL environment in treatment group 2011 seem to be more positive than students in treatment group 2012. Unfamiliarity with the method seems to be influential in students’ experiences. It seems that students in the treatment group 2011 are more confident of learning in the CSCL environment.

Table 29. Students’ experiences about learning in the CSCL environment.

<table>
<thead>
<tr>
<th>Description of experience</th>
<th>Treatment group 2011 (n=38)</th>
<th>Treatment group 2012 (n=57)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>I do not like it.</td>
<td>1</td>
<td>2.56%</td>
</tr>
<tr>
<td>Difficult or not well-functioning.</td>
<td>6</td>
<td>15.38%</td>
</tr>
<tr>
<td>I prefer traditional mathematics instruction in learning.</td>
<td>10</td>
<td>25.64%</td>
</tr>
<tr>
<td>Nice variation from traditional learning.</td>
<td>14</td>
<td>35.90%</td>
</tr>
<tr>
<td>Good or useful experience.</td>
<td>8</td>
<td>20.51%</td>
</tr>
</tbody>
</table>
In the interview, students are asked their opinions on learning statistics during the teaching experiment. All students respond that there has been enough time to access all problems as well as the rate of learning has been appropriate and adequate. 45% of students agree that they learn as well as in standard mathematics lessons. 22% of students comment that it has been more demanding to learn collaboratively than in standard mathematics lessons. 11% of students respond that they have learned less than usually. In addition, 22% of comments suggest that this kind of learning strategy is beneficial in statistics. Student’s mention some distinct retarding factors such as fast rate of learning, and the internet which can capture their attention.

**Personal proficiency**

Students’ statements of the development of their personal proficiency are given in Table 30. The Mann-Whitney U-test with a p-value of $> 0.1$ indicates perfect concurrence between treatment groups in cases: “I learned to use the calculator in statistics.” and “Tutorial on using the calculator was beneficial.”

The majority of students in both treatment groups have in their own opinion learned to utilise MS-Excel in statistics (Mean > 2.5). Nevertheless, the Mann-Whitney U-test with p-value of $\leq 0.05$ is considered to be statistically significant difference between treatment groups. It seems that students in the treatment group in 2011 who have earlier experiences of CSCL, are more confident of their personal proficiency to utilize MS-Excel in statistics.

**Table 30. Students’ statements of the development of their personal proficiency.**

<table>
<thead>
<tr>
<th>Proficiency</th>
<th>Treatment Group 2011 (n=43)</th>
<th>Treatment Group 2012 (n=56)</th>
<th>p, significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I learned to utilise a calculator in statistics.</td>
<td>2.302 0.914</td>
<td>2.448 1.079</td>
<td>0.4438</td>
</tr>
<tr>
<td>Tutorial on using the calculator was beneficial.</td>
<td>2.595 0.964</td>
<td>2.754 1.074</td>
<td>0.3916</td>
</tr>
<tr>
<td>I learned to utilise MS-Excel in statistics.</td>
<td>3.233 0.812</td>
<td>2.679 0.741</td>
<td>0.002</td>
</tr>
</tbody>
</table>

The use of the programs MS-Excel and MS-Word have benefits in the students’ opinions. Students’ answers reflect that use of MS-Excel and MS-Word is seen as beneficial for them in their later work-carrier.
“It was easier to construct statistics and it cut out many intermediate steps.”

“They helped a lot, but actual use of MS-Excel and MS-Word should be rehearsed more.”

“Ione important gain was to learn to use MS-Excel, later for the work carrier.”

“Both are beneficial in the future, for me personally best in this teaching experiment.”

“At work, you’ll need (information about) them but information of their use was rather good.”

“Statistics clarified enormously. There was no need to calculate anything when the computer did all that.”

“The use of MS-Excel and Word is a good skill to accomplish.”

“The use of MS-Word was beneficial.”

Many students responded that, before the teaching experiment, they had not used MS-Excel. It seems that students are more familiar with MS-Word. The demo of the use of the calculator and MS-Excel has been sufficient for students to become familiar with it. All students respond that instructions in the use of the calculator have been beneficial to them. Table 31 illustrates more features of students’ responses.

Table 31. Students’ opinions of adequacy and utility of calculators’ instructions.

<table>
<thead>
<tr>
<th>Opinion</th>
<th>(n=10, f=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>They were beneficial, but I wouldn’t remember them anymore.</td>
<td>2</td>
</tr>
<tr>
<td>Instructions were repeatable.</td>
<td>3</td>
</tr>
<tr>
<td>Yes, they were beneficial for me.</td>
<td>17</td>
</tr>
<tr>
<td>Instructions were clear, and I have utilised them later in new contexts.</td>
<td>2</td>
</tr>
</tbody>
</table>

Students have experienced that the use of MS-applications are skills needed in the future. Table 32 shows more features of the utility of MS-Excel from the students’ point of view.
Table 32. Students’ opinions of the utility of MS-Excel.

<table>
<thead>
<tr>
<th>Opinion</th>
<th>(n=10, f=26)</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is possible to utilise MS-Excel in other subjects and contexts.</td>
<td>7</td>
<td></td>
<td>26.92%</td>
</tr>
<tr>
<td>The MS-Excel was novel for me.</td>
<td>6</td>
<td></td>
<td>23.08%</td>
</tr>
<tr>
<td>I learned the basics of MS-Excel.</td>
<td>3</td>
<td></td>
<td>11.54%</td>
</tr>
<tr>
<td>I learned to apply MS-Excel in statistics.</td>
<td>8</td>
<td></td>
<td>30.77%</td>
</tr>
<tr>
<td>The use of MS-Excel was clarified.</td>
<td>2</td>
<td></td>
<td>7.69%</td>
</tr>
</tbody>
</table>

Students are asked what they remember best of the teaching experiment. In their own opinion, they remember the teaching experiment best: an assignment to analyse the size of shoes and heights, summation, and the use of MS-Excel.

4.2.2 Summary of results (RQ2)

The results and main findings of the contribution of the CSCL environment in statistics learning are presented in this summary, (RQ2) 2. What is the contribution of the CSCL environment in learning statistics in students’ opinions?

One fundamental and crucial difference between the treatment groups is that 50% of the students participated in the CSCL pilot phase in the year 2011, whereas only 2% of the students participated in the CSCL pilot phase in the year 2012. Students’ previous experiences of CSCL seem to reflect in the results.

Results suggest that the electronic material clarified learned topics and studying in a group fostered their learning. The most prominent factors facilitating their learning were good group spirit, peer learning support, and fruitful conversation with questioning and explanations, as well as mutual sharing of understanding in knowledge-building. Especially, they respected the novel possibilities of hearing, asking, and getting advice from other students in the small-group context. One student crystallized: “This can be seen as a development of the group work skills. Each used their own strengths. And then, when all strengths were combined, it became a good mix.”

It seems that teaching material and examples supported students learning and generated debate. About half of the students respond that visuality and narration demonstrate new topics well, and the material seems to be crucial in facilitating students’ collaboration. Video-stream’s pause property seems to be beneficial for students in small-group collaboration.
Conversations in small groups seem to be beneficial and fruitful for students’ statistical learning. The research data mediates that the thinking aloud property is inherent and helpful in demanding statistical problems in activating interactions and sharing mutual understanding in small-groups collaboration. CSCL-orientation and student-centred learning approach in learning is a nice variation from traditional mathematics instruction and good as well as a useful experience.

Nevertheless, the results suggest that majority of students would prefer standard mathematics lessons. They imply that “they have not learned better” during the teaching experiment. Students’ attitudes towards traditional mathematics instruction seem to be quite permanent.

4.3 Students’ collaborative processes in learning statistics

The major objective of this chapter of the present study is to indicate the nature of statistical learning processes in terms of the form of collaboration in CSCL environment. In this study, the impact of using CSCL environment in learning statistics is evaluated through the following research-question:

3. **What kind of differences can be found in learning processes among different small groups during collaboration in a CSCL environment in statistics?**

In the following chapters the empirical examples of this part of the study are presented. The following selected episodes are first coded by using the CSS-instrument. Students’ comments are translated into English. Episode 3 is videotaped during the first lesson. Episodes 8 and 11 are videotaped during the second lesson. Episode 35 is videotaped in the third session of the course and teaching experiment.

Chronological representations of discourse features and task-related activity are used to gain an integrated understanding of how a student-generated representation mediates collaborative knowledge building.

4.3.1 What kind of differences can be found in learning processes among different small groups during collaboration in a CSCL environment in statistics?

The following subchapters depict results of four episodes during the teaching experiment. Students’ collaborative work in CSCL-module is observed and videotaped. Four different kind of episodes present students various type of collaboration.
It seems that students are not familiar with CSCL-method. The following subchapters present what kind of differences can be found in CSCL processes.

**Results of episode 3**

In episode 3, the students are coded B1, B2, and G1, and their repartees are translated into English, as shown in Appendix 14. In this episode, the students accomplish exercise 2 from the learning tasks (see Fig. 17). Episode 3 is the first time when the students practice the notation of sum. In the Finnish upper secondary school curriculum, summation is taught later in mathematics courses. The comprehension of statistical formulas is essential for students to learn the use of summation.

**Exercise 2.** Calculate \[ \sum_{i=1}^{3} i \]

*Fig. 17. Exercise 2. in the learning tasks.*

After the last row of students’ conversational acts, the frequencies of each column are summarised (see Appendix 14). This episode shows a high-functioning collaboration, where the students conversational acts are focused on task-related activities. The quality of students’ conversational acts depicts the students’ collaborative knowledge building process. It seems that all group members participated in social knowledge building through communication.

**Results of episode 8**

In episode 8, the students are coded B3, B4, B5, and B6, and their conversational acts are translated into English, as shown in Appendix 15. In this episode, the students accomplish exercise 3 from the learning material. This exercise intends to make the students recall the use of mean, standard deviation, mode, and median, especially the use of their own calculator. This episode was recorded during the second lesson of the teaching experiment. None of the students in group 8 participated in the pilot phase. After the last row of students’ conversational acts, the frequencies of each column are summarised (see Appendix 15). All interactions are task-related, but the group cohesion reflects that they are not used to collaboration.
Results of episode 11

In episode 11, the students are coded G2, G3, G4 and G5 and their conversational acts are translated into English in Appendix 16. None of the students in group 7 have participated to the pilot phase. This episode is recorded during the second lesson of the teaching experiment. After last row of students’ conversational acts is summarised frequencies of each column (see Appendix 16). This episode includes both task-related and not task-related interactions and many of students’ conversational acts are dysfunctional. It seems that girls are not yet familiar with the CSCL method.

In episode 11, students are discovering the main concepts and definitions in statistics. They are using internet search engines as well as textbook and write or copy that knowledge to a file and mention references.

Results of episode 35

In episode 35, the students are coded G6, G7, G8, G9 and G10 and their conversational acts are translated into English in Appendix 17. None of the students in group 3 have participated to the pilot phase. This episode is recorded during the third lesson of the teaching experiment. After last row of students’ conversational acts is summarised frequencies of each column. Most of students’ conversational acts in this episode are task-related. It seems that girls are becoming more familiar with the CSCL method.

In this episode, five girls are analysing the relation of the girls’ and boys’ heights and shoe sizes from a sample taken from the class. The results of students’ work are presented in Figure 18 and Figure 19; the English translations appears in blue font in the textboxes. Most students have not used Excel at all. After last row of students’ conversational acts is summarised frequencies of each column (see Appendix 17). There are only few not task-related conversational acts in this episode.
Results of episodes 3, 8, 11 and 35

Table 33 summarises students’ conversational acts in functional roles and orientations in episodes 3, 8, 11, and 35. In episode 3, the level of collaboration in small-group events is high and all group members participated in the collaborative knowledge-building process. Their personal understanding is transformed into
social knowledge-building through communication. In episode 35, non-task-related interactions and individual roles occur are low-level. There are more non-task-related interactions and individual roles in episodes 8 and 11. The level of collaboration seems to be high in episodes 3 and 35, unlike in episodes 8 and 11.

Table 33. Students’ functional roles and orientation in episodes 3, 8, 11 and 35.

<table>
<thead>
<tr>
<th>Role / Orientation</th>
<th>Episode 3 (n = 14)</th>
<th>Episode 8 (n = 21)</th>
<th>Episode 11 (n = 54)</th>
<th>Episode 35 (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role</td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
</tr>
<tr>
<td>Individual role</td>
<td>0 0.00%</td>
<td>5 23.81%</td>
<td>8 14.81%</td>
<td>2 9.52%</td>
</tr>
<tr>
<td>Maintenance role</td>
<td>2 14.29%</td>
<td>4 19.05%</td>
<td>17 31.48%</td>
<td>5 23.81%</td>
</tr>
<tr>
<td>Task role</td>
<td>12 85.71%</td>
<td>12 57.14%</td>
<td>29 53.70%</td>
<td>14 66.67%</td>
</tr>
<tr>
<td>Orientation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task-related</td>
<td>14 100.00%</td>
<td>16 76.19%</td>
<td>34 62.96%</td>
<td>18 85.71%</td>
</tr>
<tr>
<td>Non-task-related</td>
<td>0 0.00%</td>
<td>5 23.81%</td>
<td>20 37.04%</td>
<td>3 14.29%</td>
</tr>
<tr>
<td>interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 AF = all frequency,  
2 RF = relative frequency

There are plenty of task-related interactions in all episodes. The following list portrays the quality of task roles in conversational acts. In the end of conversational acts are presented episode’s number and quality of conversational acts:

“*What if we use copy paste.*” (E11, Planning)

“*Oh yes. Well, no it isn’t. ... 3 power to 3 equals 9*” (E3, Thinking aloud”

“*And how about the height and shoe size, do they correlate?*” (E35, Interrogative question)

“*What it is?*” (E3, Procedural question)

“You have here on settings List 1 and List 2 and normally one variable, over there is standard deviation and sample.” (E8, Formal explanation)

“*Notice, that you know the centers of classes and you can see frequencies from the paper. That's how you can infer option b.*” (E8, Causal explanation)
“For example, if we consider that here (on the computer’s screen) could in principle be observable data: length of the shoe size. Observation data processing, in turn, formed the regression equation. And in the results there can be some deductions about regression line, what does it reveal? In that correlation can be interpreted, for example. How do they correlate with each other?“ (E35, Evaluation)

“Oh yes, now I apprehend that, it comes that way and it is this way, thank you!” (E3, New idea)

Maintenance roles maintain group-centred attitudes and orientation with other group members by strengthening and regulating the group. In the following list are some examples of these activities:

“Yeah, that’s correct.” (E3)

“Calculate this again and infer it, you will find it out!” (E3)

Nods and makes sure that they are proceeding in correct way. (E11)

(Participates by spelling) “Correlate” (E35)

“The results present something from the data. And the sample of data processing is how they are calculated.” (E35)

There are also some individual and non-task-related interactions in episodes 8, 11 and 35. The individual roles include dysfunctional behaviours which are not relevant to the task at hand and the following list elucidates these functional roles:

“Piece of cake. Today to Hese or Kotipitsa.” (E11, Nonsense)

Boys are processing individually …. On paper, on computer on calculator… almost three minutes (E8, Individual)

“What if it will delete everything?” (E11, Technical)

Talk with each other (Two girls), and do not take part in the collaboration in this episode. (E35, No participation)

Based on classroom observations, students’ reactions to CSCL were inspired. Students worked collaboratively, and they shared cognition as well as learning experiments. Table 34 presents the quality of the students’ conversational acts in episodes 3, 8, 11, and 35.
Table 34. Quality of students’ conversational acts in episodes 3, 8, 11 and 35.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Episode 3 (n = 14)</th>
<th>Episode 8 (n = 21)</th>
<th>Episode 11 (n = 54)</th>
<th>Episode 35 (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
<td>AF(^1) RF(^2)</td>
</tr>
<tr>
<td>Non-task-related</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No participation</td>
<td>0.00% 0.00%</td>
<td>0.00% 8.14%</td>
<td>0.00% 11.11%</td>
<td>2 9.52%</td>
</tr>
<tr>
<td>Nonsense</td>
<td>0.00% 0.00%</td>
<td>0.00% 11.11%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Social</td>
<td>0.00% 0.00%</td>
<td>6 11.11%</td>
<td>1 4.76%</td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>0.00% 0.00%</td>
<td>6 11.11%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Task-related</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>0.00% 5 23.81%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Planning/Thinking aloud</td>
<td>5 35.71% 1 4.76%</td>
<td>21 38.89% 3 14.29%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QA</td>
<td>0.00% 2 9.52%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>QI</td>
<td>1 7.14% 2 9.52%</td>
<td>2 3.70% 3 14.29%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QP</td>
<td>1 7.14% 1 4.76%</td>
<td>3 5.56% 0.00%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QC</td>
<td>0.00% 0.00%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>QS</td>
<td>0.00% 0.00%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>QR</td>
<td>0.00% 0.00%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Explanation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EF</td>
<td>3 21.43% 3 14.29%</td>
<td>1 1.85% 1 4.76%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>0.00% 2 9.52%</td>
<td>1 1.85% 2 9.52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ED</td>
<td>1 7.14% 0.00%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>EE</td>
<td>0.00% 0.00%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>4.76%</td>
</tr>
<tr>
<td>Support</td>
<td>2 14.29% 4 19.05%</td>
<td>5 9.26% 4 19.05%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>0.00% 0.00%</td>
<td>1 1.85% 2 9.52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New idea</td>
<td>1 7.14% 1 4.76%</td>
<td>0.00% 0.00%</td>
<td>0.00%</td>
<td>4.76%</td>
</tr>
</tbody>
</table>

1 AF = all frequency,  
2 RF = relative frequency

Table 34 shows that in episodes 3 and 8, conversational acts are mostly task-related. There are no non-task-related conversational acts in the episodes. In episodes 3 and 35, the conversational acts indicate high-functioning collaboration, and the quality of the students’ conversational acts demonstrate the students’ active collaborative knowledge-building process. Most group members participated in social knowledge-building through communication in episodes 3 and 35.

In episode 3, students’ questions are interrogative and procedural. Explanations are mostly formal and descriptive. The descriptive explanations describe statistical phenomena based on experimentation.
In episode 8, the students’ conversational acts are task-related, but they indicate non-functioning collaboration, and the quality of students’ conversational acts signal that they are not used to collaborating. In episode 8, the students’ questions are mostly attunement or interrogative questions. In conversational acts, the questions check attunement between participants’ understanding and seek demonstrated mutual agreement or they are interrogative question for information that is not procedural. In episode 8, the students’ explanations are mostly formal and causal. In conversational acts, the explanations reflect formal language and procedures of statistical issues or include informal reasoning in statistics.

In episode 11, conversational acts are both task-related and non-task-related. Many of the students’ conversational acts are dysfunctional. The quality of students’ conversational acts signals that the CSCL method is novel for them. In episode 11, students’ questions are confirmatory or interrogative. In conversational acts, questions seek confirmation request by participant regarding student’s own conceptual understanding. In episode 11, the explanations are formal, causal, and everyday.

In episode 35, students’ questions are mainly interrogative. In conversational acts, the questions seek information that is not procedural. In episode 35, the explanations are formal, causal, and everyday.

Based on the statistical literature constructs, the idiosyncratic, informal, inconsistent, consistent non-critical, critical, and critical mathematical levels were recoded and collapsed into three categories: critical and critical mathematical, which demand critical thinking skills, as statistical thinking; inconsistent and consistent non-critical as statistical reasoning; and idiosyncratic and informal as statistical literature.

Table 35 depicts students’ statistical literature constructs in episodes 3, 8, 11, and 35. In episode 3, students’ conversational acts are focused on task-related activities, and the level of statistical literature constructs is the highest.
Table 35. Students’ statistical literature construct in episodes 3, 8, 11 and 35.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Episode 3 (n = 14)</th>
<th>Episode 8 (n = 21)</th>
<th>Episode 11 (n = 54)</th>
<th>Episode 35 (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AF¹ RF²</td>
<td>AF¹ RF²</td>
<td>AF¹ RF²</td>
<td>AF¹ RF²</td>
</tr>
<tr>
<td>Statistical literacy</td>
<td>4 28.57%</td>
<td>5 23.81%</td>
<td>2 3.70%</td>
<td>3 14.29%</td>
</tr>
<tr>
<td>Statistical reasoning</td>
<td>2 14.29%</td>
<td>2 9.52%</td>
<td>0.00%</td>
<td>4 19.05%</td>
</tr>
<tr>
<td>Statistical thinking</td>
<td>1 7.14%</td>
<td>1 4.76%</td>
<td>0.00%</td>
<td>1 4.76%</td>
</tr>
<tr>
<td>Statistical literature</td>
<td>7 50.00%</td>
<td>8 38.10%</td>
<td>2 3.70%</td>
<td>8 38.10%</td>
</tr>
</tbody>
</table>

¹ AF = all frequency,
² RF = relative frequency

4.3.2 Summary of results (RQ3)

The results and the main findings of students’ collaborative processes in learning statistics are presented in this summary. 3. What kind of differences can be found in learning processes among the different small groups during collaboration in a CSCL environment in statistics learning?

The quality of the students’ conversational acts varied considerably. Based on class monitoring and notes of the researcher, launching a collaboration seemed to require several rehearsals, and after a few lessons, the students began to engage in more task-related conversational acts. It seems that learning how to collaborate productively needs practice. Heterogeneity in groups seems to support collaboration, and in this teaching experiment, the most high-functioning small groups seemed to have members of both genders. According to the results, the articulation and quality of mathematical discussion increased as students’ acquaintance with their teammates improved.

In the analysed episodes there are four different kinds of small groups. Students in episode 3, one girl and two boys are familiar with CSCL. They had participated in the pilot phase. The quality of collaboration seems to be more productive than in other small-groups. This small-group collaboration includes only maintenance and task roles.

At the beginning of the course, small-group collaboration in Episodes 8, 11 and 35 is unproductive first-time collaboration. There are plenty of non-task-related conversational acts. After a few lessons, there is an increased level of task-related collaboration.
In episode 8, four mathematically orientated boys tend to comprehend learning statistics as an individual matter. The occurrences of individual roles reflect the lack of productive discourse and task-related collaboration. The group members work intensively and in a task-related manner, but during this episode, neither verbal nor social abilities of common understanding have developed.

In episode 11, four girls collaborate unproductively. This episode is a concrete example of first-time collaboration. The group members have implied that CL is “an unproductive nuisance”. The individual roles during the small group episode are not relevant to the task at hand and include dysfunctional products. All questions in Episode 11 are interrogative or confirmatory questions. The relative numbers of questions and explanations are at a low level. Individual roles and non-task-related participation seem to reduce statistical learning.

In episode 35, five girls began to communicate and collaborate more productively in the third lesson. The data also shows their high-level activity in task- and maintenance-related conversational acts.

The research data reveals that student-centred collaboration is a new approach for most upper secondary school students in learning mathematics. Students seem to learn to use more task- and maintenance-related conversational acts during the collaboration. The research data indicates high levels of activity in statistical learning processes in episodes 3, 8 and 35. In general, mathematical articulation and cohesion seem to increase during the teaching experiment.

4.4 Students’ learning outcomes

In this chapter of this study, students’ learning outcomes are evaluated through a course exam and delayed post-test. The purpose of the course exam and delayed post-test is to point out the similarities as well as differences in deeper learning between students in the teaching experiment and comparison class. In addition, students’ learning outcomes in treatment group 2012 are evaluated through immediate electronic-test after teaching experiment. The main aim of the electronic-test is to evaluate how students have adapted to the utilization of the computer in statistics in the topics of the course. Research questions are:

4. What is the difference in student achievement in statistics when compared CSCL and traditional mathematics instruction?

   a) How students have adapted utilization of the computer in statistics?
4.4.1 How students have adapted utilization of the computer in statistics?

First, students’ (in treatment groups) learning outcomes and their opinions of the electronic-test are presented.

Students learning outcomes in the electronic-test

The results of students’ learning outcomes in the electronic-test are presented in the following Table 36. Students’ adaptation of the use of computer in statistics is analysed by the evaluation of the electronic-test in 2012 (see Table 6).

Table 36. The evaluation of the electronic-test (N=60).

<table>
<thead>
<tr>
<th>Proficiency</th>
<th>Correct answer (1 p)</th>
<th>False (0 p)</th>
<th>M¹</th>
<th>SD²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>Construct a table based on Figure 1.</td>
<td>60</td>
<td>100.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Construct a figure from your table.</td>
<td>58</td>
<td>96.67%</td>
<td>2</td>
<td>3.33%</td>
</tr>
<tr>
<td>Calculate median.</td>
<td>55</td>
<td>91.67%</td>
<td>5</td>
<td>8.33%</td>
</tr>
<tr>
<td>Calculate mode.</td>
<td>49</td>
<td>81.67%</td>
<td>11</td>
<td>18.33%</td>
</tr>
<tr>
<td>Calculate mean.</td>
<td>50</td>
<td>83.33%</td>
<td>10</td>
<td>16.67%</td>
</tr>
<tr>
<td>Calculate standard deviation.</td>
<td>47</td>
<td>78.33%</td>
<td>13</td>
<td>21.67%</td>
</tr>
<tr>
<td>Calculate the correlation between two variables.</td>
<td>46</td>
<td>76.67%</td>
<td>14</td>
<td>23.33%</td>
</tr>
<tr>
<td>Predict values in the future by using linear regression.</td>
<td>25</td>
<td>41.67%</td>
<td>35</td>
<td>58.33%</td>
</tr>
</tbody>
</table>

1 M = mean, 2 SD = standard deviation

In the first task, all students have been able to construct a table based on the figure, and only two students (3.33%) have problems in constructing a bar chart. 91.67% of students are able to calculate median. 81.67% of students are able to calculate mode. 83.33% of students are able to calculate mean. 78.33% of students are able to calculate standard deviation.
In the second task, 76.67% of students are able to calculate correlation from the given data. The most difficult task for students is to predict values in the future by using linear regression. Only 41.67% of students are able to calculate them.

*Students' opinions of the electronic-test*

Table 37 presents students’ opinions of the electronic-test and its feasibility in learning statistics.

<table>
<thead>
<tr>
<th>Question</th>
<th>Girls Mean (n = 28)</th>
<th>Girls SD (n = 27)</th>
<th>Boys Mean (n = 30)</th>
<th>Boys SD (n = 30)</th>
<th>p²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the electronic mathematical test work?</td>
<td>M 2.000</td>
<td>SD 0.770</td>
<td>M 1.773</td>
<td>SD 0.785</td>
<td>0.189</td>
</tr>
<tr>
<td>How well the part in which you used a computer measured your statistical proficiency?</td>
<td>M 2.370</td>
<td>SD 0.742</td>
<td>M 2.400</td>
<td>SD 0.814</td>
<td>0.792</td>
</tr>
</tbody>
</table>

1 M = mean,  
2 SD = standard deviation,  
3 p = significance

Table 38 presents students’ opinions concerning the electronic-test. It provides information on how well they are succeed in using their own proficiency with the computer and how they feel about the implementation of the electronic-test in mathematics.

The Mann-Whitney U-test in Tables 37 and 38 with a p-value of > 0.1 indicates perfect concurrence between genders. Two-thirds of students respond that they have managed to answer questions by using a computer based on their own proficiency. 88% of the students do not want to have an electronic-test in mathematics in the future. However, 60% of students agree that the electronic-test has fitted well in testing statistical proficiency. The majority, 83%, of students disagree that the electronic mathematical test has worked. Only 42% of students agree that the part in the electronic-test in which they used a computer has measured their statistical proficiency.
Table 38. Students’ opinions about electronic-test I.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
<th>Girls</th>
<th>Boys</th>
<th>AF¹</th>
<th>RF²</th>
<th>AF¹</th>
<th>RF²</th>
<th>p²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you managed to answer questions by using computer based on your own  proficiency?</td>
<td>No / Disagree</td>
<td>19</td>
<td>18</td>
<td>73.08%</td>
<td>62.07%</td>
<td>7</td>
<td>11</td>
<td>26.92%</td>
</tr>
<tr>
<td></td>
<td>Yes / Agree</td>
<td>7</td>
<td>11</td>
<td>26.92%</td>
<td>37.93%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you wish that part of the mathematical test is electronic in the future?</td>
<td>No / Disagree</td>
<td>22</td>
<td>28</td>
<td>81.48%</td>
<td>93.33%</td>
<td>5</td>
<td>2</td>
<td>18.52%</td>
</tr>
<tr>
<td></td>
<td>Yes / Agree</td>
<td>5</td>
<td>2</td>
<td>18.52%</td>
<td>6.67%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the electronic test fit well in testing statistical proficiency?</td>
<td>No / Disagree</td>
<td>11</td>
<td>9</td>
<td>45.83%</td>
<td>34.62%</td>
<td>13</td>
<td>17</td>
<td>54.17%</td>
</tr>
<tr>
<td></td>
<td>Yes / Agree</td>
<td>13</td>
<td>17</td>
<td>54.17%</td>
<td>65.38%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 AF = all frequency,  
2 RF = relative frequency,  
3 p = significance

The course exam and the delayed post-test have been used as an instrument to measure students’ learning outcomes in statistics. Students’ achievements in statistics are presented in this chapter between students in the treatment group and control group in 2011 (see Table 5).

4.4.2 What is the difference in student achievement in statistics when compared CSCL and traditional mathematics instruction?

The following subchapters depict student achievement in statistics when compared CSCL and traditional mathematics instruction. In this chapter students learning outcomes in treatment and control groups in the course exam are presented.

Students learning outcomes in the course exam

Table 39 shows students’ evaluation in the course exam in treatment and control groups. The Mann-Whitney U-test indicates a perfect consensus in samples (p>0.1). Eight points is the maximum score in the course exam.
Table 39. Results in the statistical tasks (see Appendix 6, 7 and 8) in the course exam between students in the teaching experiment and control groups.

<table>
<thead>
<tr>
<th>Result</th>
<th>Treatment group (n=48)</th>
<th>Comparison group (n=25)</th>
<th>p, significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.07</td>
<td>4.08</td>
<td>0.277</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.76</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>

**Students’ learning outcomes in delayed post-test**

Tables 40–45 present the results from the delayed post-test, which was held about two months after the course in statistics and probability. Results in Table 40 illustrate students’ competence in basic statistical levels in their own opinion.

Table 40. Evaluation of students’ own opinions of their level in statistics.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Treatment group (n=42)</th>
<th>Control group (n=26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Informal level</td>
<td>Inconsistent level</td>
</tr>
<tr>
<td></td>
<td>AF¹ RF²</td>
<td>AF¹ RF²</td>
</tr>
<tr>
<td>Binomial distribution</td>
<td>24 57.14% 8 19.05%</td>
<td>12 46.15% 3 11.54%</td>
</tr>
<tr>
<td>Pie chart</td>
<td>32 78.05% 27 65.85%</td>
<td>24 92.31% 22 84.62%</td>
</tr>
<tr>
<td>Multiplication rule</td>
<td>30 71.43% 19 45.24%</td>
<td>20 80.00% 12 48.00%</td>
</tr>
<tr>
<td>Permutation</td>
<td>30 73.17% 8 19.51%</td>
<td>13 50.00% 8 30.77%</td>
</tr>
<tr>
<td>K-combination</td>
<td>28 68.29% 8 19.51%</td>
<td>13 50.00% 9 34.62%</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>36 87.80% 19 46.34%</td>
<td>24 92.31% 11 42.31%</td>
</tr>
<tr>
<td>Correlation</td>
<td>34 80.95% 13 30.95%</td>
<td>18 69.23% 7 26.92%</td>
</tr>
<tr>
<td>Frequency</td>
<td>39 95.12% 25 60.96%</td>
<td>24 92.31% 18 69.23%</td>
</tr>
<tr>
<td>Density function</td>
<td>39 95.12% 25 60.96%</td>
<td>24 92.31% 18 69.23%</td>
</tr>
<tr>
<td>Median</td>
<td>40 97.56% 28 68.29%</td>
<td>25 100.00% 20 80.00%</td>
</tr>
<tr>
<td>Histogram</td>
<td>31 75.61% 21 51.22%</td>
<td>20 76.92% 16 61.54%</td>
</tr>
<tr>
<td>Linear regression</td>
<td>16 39.02% 4 9.76%</td>
<td>7 26.92% 2 7.69%</td>
</tr>
<tr>
<td>Mode</td>
<td>37 90.24% 24 58.54%</td>
<td>24 92.31% 20 76.92%</td>
</tr>
<tr>
<td>Conditional probability</td>
<td>30 73.17% 13 31.71%</td>
<td>17 65.38% 8 30.77%</td>
</tr>
<tr>
<td>Variance</td>
<td>23 56.10% 6 14.63%</td>
<td>17 68.00% 8 32.00%</td>
</tr>
<tr>
<td>Type value</td>
<td>32 75.05% 21 51.22%</td>
<td>24 92.31% 20 76.92%</td>
</tr>
</tbody>
</table>

1 = all frequency,

2 = relative frequency

Results show that students are familiar with most statistical concepts. It seems that there is no significant difference between the treatment and control group. In Table
40, students in the treatment group have self-evaluated themselves in concept histogram as follows:

“I don’t know this concept” 24.39%.

“I know this concept” 24.39%.

“I know this concept and I’m able to use it” 51.22%.

The students in the control group have self-evaluated themselves in concept histogram as follows:

“I don’t know this concept” 23.08%.

“I know this concept” 15.38%.

“I know this concept and I am able to use it” 61.54%.

There is a difference in values of self-evaluated and measured proficiency in constructing a histogram and a bar chart. It seems that students in the control group self-evaluated themselves more positively than students in the treatment group. Table 41 demonstrate students’ proficiency in constructing a histogram or a bar chart in the delayed post-test. It indicates that 52.00% from the comparison class have succeed in constructing a histogram, and 68.00% are capable of constructing the bar chart. Table 41 shows that 88.89% of students in the teaching experiment are able to construct a histogram and 83.33% are able to construct the bar chart.

Table 41. Students’ proficiency in constructing a desirable diagram in the delayed post-test.

<table>
<thead>
<tr>
<th>Proficiency</th>
<th>Treatment group (n=36)</th>
<th>Control group (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>Student didn’t know how to construct a histogram</td>
<td>4</td>
<td>11.11%</td>
</tr>
<tr>
<td>Student did know how to construct a histogram</td>
<td>32</td>
<td>88.89%</td>
</tr>
<tr>
<td>Student didn’t know how to construct a bar chart.</td>
<td>6</td>
<td>16.67%</td>
</tr>
<tr>
<td>Student did know how to construct a bar chart.</td>
<td>30</td>
<td>83.33%</td>
</tr>
</tbody>
</table>
The statistical problem regarding diagrams measured how students interpret graphs. The majority of students report that a diagram is a concept that they knew and are able to use. The diagram was a pie chart regarding the most common causes of death of Finnish women in 2005. The website in the statistical diagram problem is manipulated and fictional (see Appendix 8, Question 5).

As in the pre-test, all students were able to interpret the pie chart and found the required information in order to choose the two most common causes of women’s deaths based on the diagram. The majority of students responded that they were critical concerning the pie chart (see Appendix 8, Question 5c). This criticality is not the same as the Critical level in statistical literacy. Only 2.99% of participants comprehended and are critical justifying mathematically that the pie chart does not present 100% of the quantity (see Appendix 8, Question 5d). In this data-manipulated statistical graphic, the total percentage is 90.00%. The pie chart is a basic statistical graphic and belongs to basic statistical literacy. The majority of students are at Inconsistent level in statistical literacy as in the pre-test. Students’ levels in statistical literacy in the delayed post-test are presented in Table 42.

### Table 42. Students’ levels in statistical literacy in the delayed post-test in Item 5 (N=67).

<table>
<thead>
<tr>
<th>Level of statistical literacy</th>
<th>all frequency</th>
<th>relative frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>No answer</td>
<td>2</td>
<td>2.99%</td>
</tr>
<tr>
<td>Idiosyncratic level</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Informal level</td>
<td>10</td>
<td>14.93%</td>
</tr>
<tr>
<td>Inconsistent level</td>
<td>31</td>
<td>46.27%</td>
</tr>
<tr>
<td>Consistent non-critical level</td>
<td>20</td>
<td>29.85%</td>
</tr>
<tr>
<td>Critical level</td>
<td>2</td>
<td>2.99%</td>
</tr>
<tr>
<td>Critical mathematical level</td>
<td>2</td>
<td>2.99%</td>
</tr>
</tbody>
</table>

In Figure 20 is shown the analysis of students’ scores in the delayed post-test by using the Mann-Whitney U-test. Learning outcomes in the treatment group tend to be bigger than in the control group because the distance between medians is greater than one third (p<0.05) which is statistically significant.
Table 43 explicates results between treatment and control groups in the delayed post-test. Seven of the students’ responses are rejected, because some of the students did not have calculators. The arithmetic mean in the treatment group is 9.6
The results and main findings of students’ learning outcomes are presented in this summary. **4. What is the difference in student achievement in statistics when compared CSCL and traditional mathematics instruction? a. How students have adapted utilization of the computer in statistics?**

Students’ learning outcomes between the treatment and control groups in the course exam are quite equal. It seems that students in the CSCL experiment have better learning outcomes in the delayed post-test, and there is a statistically significant difference in comparing with the students with traditional mathematics instruction. The effect size indicates a medium effect between samples which suggests that there have been differences in deeper learning.

Based on results, it seems that implementing CSCL has been beneficial for students’ learning outcomes in learning statistics. Students in the treatment group seem to be more capable in constructing a histogram and bar chart. In the CSCL environment, students had an opportunity to utilise MS-Excel whereas electronic material was not used in traditional mathematics instruction.

Student achievement in statistics especially in using MS-Excel is examined in the treatment groups. In general, the results in the electronic-test suggest students’ good ability to utilise MS-Excel. The majority of students respond that they have
managed to answer questions by using a computer based on their own proficiency. The majority of the students express their reluctance to have an electronic-test in mathematics in the future. A contradictory result of the present study is that the majority of students agree that the electronic-test has fitted well in testing their statistical proficiency.

4.5 Comparing students’ statistical literacy in the pre-test and delayed post-test

Students’ levels in statistical literacy in the delayed post-test and pre-test are presented in Table 44. There is conspicuous complexity in interpreting a manipulated pie chart. It seems to be very demanding to realize the principle that a pie chart presents exactly 100% of the quantity, no less – no more. As in the pre-test in Table 44, a few students (2.99%) comprehend and have been critical in justifying mathematically that the pie chart does not present 100% of the quantity. The majority of students are at the Inconsistent level in statistical literacy as in the pre-test.

Table 44. Students’ levels in statistical literacy in the pre-test and delayed post-test.

<table>
<thead>
<tr>
<th>Level of statistical literacy</th>
<th>Pre-test (N=74)</th>
<th>Post-test (N=67)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all frequency</td>
<td>relative frequency</td>
</tr>
<tr>
<td>No answer</td>
<td>6</td>
<td>8.11%</td>
</tr>
<tr>
<td>Idiosyncratic level</td>
<td>9</td>
<td>12.16%</td>
</tr>
<tr>
<td>Informal level</td>
<td>5</td>
<td>6.76%</td>
</tr>
<tr>
<td>Inconsistent level</td>
<td>44</td>
<td>59.46%</td>
</tr>
<tr>
<td>Consistent non-critical level</td>
<td>6</td>
<td>8.11%</td>
</tr>
<tr>
<td>Critical level</td>
<td>1</td>
<td>1.35%</td>
</tr>
<tr>
<td>Critical mathematical level</td>
<td>3</td>
<td>4.05%</td>
</tr>
</tbody>
</table>

In general, the students’ level in statistical literacy seems to transfer into the better level from the pre-test to the delayed post-test. The Mann-Whitney U-test suggests this with a statistically significant difference between tests (p<0.05) in Table 45.
### Table 45. Comparison between pre-test and delayed post-test in students’ levels in statistical literacy on a scale of 1 to 6.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Pre-test (n = 68)</th>
<th>Post-test (n = 65)</th>
<th>p, significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Level of statistical literacy</td>
<td>2.912</td>
<td>1.075</td>
<td>3.308</td>
</tr>
</tbody>
</table>
5 Conclusions

The present empirical study can be seen as an example of how mathematics education can be developed in our schools. In this teaching experiment, students have been able to exploit online material based on the curriculum of upper secondary school statistics. In order to adjust learning material and teaching design in a pedagogically useful manner, there has been a broad approach in the research design. It involves several instruments, e.g. pre-test, course exam, delayed post-test, CSS -instrument in authenticating students’ collaboration, learning processes and learning outcomes as well as students’ adaptation of the use of statistical software. However, the premise in this study has been to promote students’ statistical learning in a CSCL context.

In this chapter, conclusions of the main findings and results of the present study and their relation to the previous studies are presented. Hopefully, this comprehensive study contributes new aspects and findings to promote statistics as well as mathematics education. Dissemination of findings of this design-based research may lead to a deeper discussion of statistics education and possible implementation of a similar kind of studies.

5.1 Central findings

Participating students have been well orientated in learning mathematics both in comprehensive and upper secondary school, and their attitudes towards statistics are quite positive. Still, even mathematically talented students have severe difficulties in mastering the final assessment of mathematics in comprehensive school (Finnish National Board of Education 2015: 167, Opetushallitus 2004):

“The pupils will know how to read various tables and diagrams, and to determine frequencies, average, median and mode of the given material.”

It seems that for many students, it is demanding to read, identify, describe, calculate or interpret statistical data.

The most well-known statistical concepts after comprehensive school are mean, diagram, and median. The level of statistical literature is informal or inconsistent in the concepts mean, diagram, and median and at the idiosyncratic level in other statistical concepts. Measured proficiency in statistical literacy does not advocate students’ self-evaluation, and it seems that students’ ability to solve statistical problems is weaker than they have expected.
The histogram, frequency, and mode seem to be unfamiliar concepts to the majority of students after comprehensive school. Previous studies have also shown that students have difficulties in correctly reading information from histograms (delMas et al. 2005, Kaplan et al. 2014, Meletiou & Lee 2002). Difficulties in being critical of graphics have been documented in other studies too (see Watson 1997). Only a few students seem to understand the principle that a pie chart represents 100% of a given quantity. Basic statistical skills, such as understanding the use of statistical symbols, are forgotten. Statistical ideas are often misunderstood by students (delMas et al. 1999). The problem involving the diagram showed that even 17 year-old students have difficulties in being critical of computer-edited, reliable-looking data.

The teaching of probability and statistics in our school mathematics have a poor status (Shaughnessy 2006). Students’ and teachers’ interviews in this study also reflect the present state of statistical literacy in the comprehensive school. It seems that there is not enough time to teach statistics thoroughly.

The electronic learning material and examples can be seen as a fostering factor in learning statistics. CSCL seems to support group interactions when technology is used to control interactions, regulate tasks, rules, and roles and inform new knowledge. The majority of students have learned to exploit a calculator and MS-Excel in statistics. In the students’ opinion, the profitable use of the programs MS-Excel and MS-Word are beneficial for carrier future career. Goos et al. study (2003) suggest that calculators as well as computers can re-shape interactions between teachers, students, and the technology itself. These tools should not be seen as passive or neutral objects. Technology is treated as a partner or extension of the self. Technological implementation in education should not lead to passive learning where students become passive observers (Lane & Peres 2006).

Students’ high-level activity in questioning, statement and regulatory statement during the teaching experiment mediates learning and collaborative knowledge-building learning (Hmelo-Silver & Barrows 2008). Group activity in successful collaborative knowledge-building in the present study seems to confirm high activity in students’ conversational acts. The articulation of mathematical discussion seems to need several rehearsals. Lazakidou and Retalis (2010) have found that students can be reluctant to exceed the collaboration rules during the first collaboration, and their participation is constrained to absolutely submissive observance of the collaboration rules. Lazakidou and Retalis advocate that most students can exceed the collaboration rules and that students can increase their problem-solving skills in a relatively short period of time. Collaboration in the
Garfield et al. (2008) stated that students should learn and experience collaboration, as well as teamwork, and develop their communication skills as a part of their learning process. Accordingly, the use of CSCL in statistics learning facilitates CL skills. The artefact in this teaching experiment is developed based on the multimedia principle of CTML (Mayer 2005). It enabled the students to learn statistics asynchronously in small groups. The shift towards student-centred learning seems to facilitate students’ mathematical articulation, cohesion, proficiency of collaboration, use of computers, in addition to promoting greater enjoyment of learning (Oikarinen et al. 2014, Sengupta-Irving & Enyedy 2015).

Students mentioned that the contributions of the CSCL environment in learning statistics are: good group spirit, peer learning support and a fruitful conversation with questioning and explanations as well as a mutual sharing of understanding in knowledge-building. Fostering aspects of collaboration from the students’ point of view are mutual discussion, acquiring ideas from the others, the possibility to hear the others’ thoughts and ability to ask or/and get advice in problem-solving. Collaboration has the potential to improve problem-solving and learning (Slavin 1996). Mutual explanations and joint discussions can be seen to be beneficial in terms of successful knowledge acquisition in mathematics learning processes (Mullins et al. 2011).

Several students in the treatment group 2011 have participated to the CSCL pilot phase in the course of analytical geometry. The treatment group 2012 has a novel experience of CSCL. The treatment group 2011 students’ opinions of CSCL are more positive than those of treatment group 2012. The first-time collaboration seems to constrain students’ participation.

One obstacle in the CSCL approach in learning is students’ permanent attitudes towards traditional didactic instruction. In a traditional, didactic instruction learning setting, the teacher often conveys the textbook’s curriculum-saturated knowledge in a strict and rather learner-passive manner (Röj-Lindberg 2001). Unfamiliarity with the CSCL-method seems to be influential in students’ opinions. It seems that students in the treatment group 2011 are more confident of learning with CSCL-method. A clear difference in students in the treatment group 2012 is that they do not like CSCL or found CSCL-method difficult or not well-functioning. They seem to prefer traditional teaching. It seems that the shift to novel CSCL-approach requires more implementation and repetition in mathematics education.
The core of collaboration in learning statistics in a CSCL environment can be described by using one student’s expression: “This can be seen as a development of the group work skills. Each used their own strengths. And then when they are all combined strengths, then it became a good mix.” Working in small groups can contribute common understanding (Nussbaum et al. 2009) and develop verbal and social abilities. Stahl (2006: 93) has stated: “In particular, collaborative information environments must provide functionality that facilitates the construction of new knowledge and the shared understanding necessary to use this knowledge effectively within communities of practice.”

To develop students’ statistical outcomes, it is crucial to depict the hierarchical nature of the statistical literature construct. CSCL is one possible method for fostering statistical proficiency from basic literacy to thinking, and it seems to increase effectiveness and activity, as well as students’ motivation to learn (Lehtinen et al. 1999, Soller 2001).

A lack of statistical literacy causes difficulties in correctly interpreting statistical information, and it may even lead to making wrong decisions. Hence, statistical skills should be thought of as being as important as civics.

The quality of the students’ conversational acts varied from unproductive first-time collaboration to task- and maintenance-related conversational acts. Students’ collaborative learning processes in statistics vary from individual roles to task roles, from not participating to mutually sharing understanding. As the students become more acquainted with collaboration and with their teammates, their articulation and the quality of mathematical discussion seem to improve. The number of the students’ productive conversational acts increased as their ability to comprehend statistical data and convert it into figures and statistical numbers improved.

Productive peer collaboration has proved to be a successful and powerful learning method in active and high-functioning learning teams (Soller 2001). According to Soller (2001: 41): “Traditional lecture-oriented classrooms do not teach students the social skills they need to interact effectively in a team…”

The teacher’s role is essential in developing collaboration and statistical thinking processes into a productive discourse (Hmelo-Silver & Barrows 2008). The shift from traditional teacher-led learning requires practice and greater implementation in education (Hmelo-Silver & Barrows 2008). Effective collaboration with peers involves discussing strategies, questioning, and aligning outcomes with prior experiences (Sengupta-Irving & Enyedy 2015).

The electronic-test suggests that students have learned to utilise the MS-Excel program. Students’ responses involving the MS-Excel spreadsheet reveal that it has
promoted students’ statistical learning processes. Engerman et al. (2014) have found the utility of MS-Excel in high school mathematics. Nevertheless, students’ opinions about the electronic-test suggest that they have felt unsure about working in electronic-test environment. The majority of students would not like to use the electronic-test in mathematics to measure their statistical proficiency.

Based on the information gathered from classroom monitoring, students realise that among other things, they have learned to use computers, MS-Excel, MS-Word, web browsers, and CL. The findings of this teaching experiment show that students’ learning outcomes in the teaching experiment classes are encouraging. Students in the treatment groups are more capable of constructing figures from given statistical data because they have constructed figures in statistics by using real data, in addition to using MS Excel in small groups. Katz and Yablon (2002) has also found that students in the ICT-based course became increasingly more confident with the technology used in the course as the course progressed (2002).

The treatment and control group have succeeded equally in the course exam. Students in the CSCL-experiment have better learning outcomes in the delayed post-test than students with traditional mathematics instruction. When students’ learning outcomes in deeper learning in the delayed post-test are compared, it seems that students in the treatment group have benefitted. The effect size indicates a medium effect. Some studies have also indicated the effectiveness of CSCL-learning methods in improving students’ achievement in statistics (Giraud 1997, Kalaian & Kasim 2014, Ragasa 2008).

To improve quality in learning outcomes in deeper learning, the policy of education design should be taken under consideration. The CSCL-approach and more concrete examples are feasible methods to implement in statistics education. The findings also suggest that carefully designed learning trajectories in CL processes can stimulate students to gain access to inferential concepts and reasoning processes (Arnold et al. 2011) in deeper learning. The learning-material in the present teaching experiment seems to foster students’ adaptation of statistical learning trajectories.

One additional observation from the classroom and from the students’ interviews is that varied instructional designs are related positively to students’ affects (Sengupta-Irving & Enyedy 2015). One student crystallised: “Now, I know other students better, and it is nicer to come to the mathematics lessons”. Moreover, after the teaching experiment, the atmosphere in the classroom has been altogether more relaxed. The findings of the present study suggest that CL can facilitate
cohesion and responsibility, and reduce students’ feelings of detachment in the classless, periodic system in upper secondary schools (Oikarinen et al. 2014).

5.2 Discussion

Finnish comprehensive school students have been successful in PISA, but the emergent PISA results show that proficiency in mathematics has decreased notably from the level of the year 2003 (Kupari et al. 2013, Sahlberg 2009, Thomson & De Bortoli 2008). It is obvious that a shift in mathematics education is needed, not only for the protection of the reputation of the Finnish school system, but essentially to promote the competitiveness and civilization of our society. The results of this study show that CSCL is one possible method to foster statistical proficiency.

Most students felt that it is useful to learn to use different types of technological equipment and software. The appearance of students’ high-level activity in questioning, statement, and regulatory statement during the teaching experiment reflects learning via collaborative knowledge-building.

Based on the results of this study, students can be reluctant to exceed collaboration rules and prefer traditional, didactic instruction in learning (see Lazakidou & Retalis 2010). The technology-enhanced learning environment is a novel and, therefore, confusing experience for students. Furthermore, difficulties in collaboration occur when using computers, lack of concentration or teamwork skills, and noisiness. Teamwork is seen as a novel and beneficial way to work in classroom settings, but unfamiliarity with the new learning method disturbed most of the students. According to the results of learning outcomes, the CSCL environment is beneficial for statistics learning despite the fact that students were reluctant to collaborate at first. In the delayed post-test, the effect size indicates a medium effect between treatment and comparison groups which suggests that there has been differences in deeper learning. Rehearsals in CSCL led to an increase in learning activity, effectiveness, and students’ motivation (Lehtinen et al. 1999, Soller 2001).

There is obviously a fear of not learning well enough when the classroom situation changes. Students can be less satisfied with how the classroom structure orientation is altered (Strayer 2012). In classrooms settings, the implementation of classroom architecture does not necessarily support successful CSCL. An appropriate environment for small-group collaboration is needed.

Students’ conceptions of the importance of statistics in their lives are quite positive. The majority of students agree that the interpretation and understanding
of statistics, statistical thinking in general, private, professional, and personal life is an important skill in life (Rumsey 2002, Wallman 1993). Nevertheless, there seem to be limitations in students’ ability to identify and describe essential statistical concepts and interpret and calculate statistical problems, based on the criteria of the final assessment of comprehensive school. Presumably it is challenging for students to remember statistical tasks learned in comprehensive school in the pre-test.

In comparing the results of the present study with those of previous analyses, task roles facilitate and coordinate group problem-solving activities, whereas maintenance roles perpetuate group-centred attitudes and orientations with other group members by strengthening and regulating the group (Mudrack & Farrell 1995). In small-group episodes, task and maintenance roles reflect students’ collaboration in statistics learning. The amount of productive discourse and mutually shared understanding of solutions increased as the teaching experiment proceeded. It seems that students in the treatment group 2011 who have earlier experiences of CSCL are more confident of learning statistics than students in the treatment group 2012. According to the results, students in the group 4 (see Appendix 17, Episode 35), began to communicate and collaborate more productively in the third lesson.

Effective orchestration of pedagogical intervention needs rehearsals, time and practice. Empirical research on statistics education contributes an emergent value of the empirical implementation of statistical learning (Nolan & Lang 2007). In helping students to learn statistics (Chance & Garfield 2002), there is and has been a strong emphasis to develop collaborative learning, the use of real data in the classrooms and the innovative use of technology. In statistics teaching in comprehensive school, ICT and statistical programs should be utilised during lessons in order to motivate students. The use of innovative instructional approaches and software can have positive effects on students’ understanding of statistics (Chance et al. 2004, Garfield & Ben-Zvi 2007), but difficulties with concepts can still occur after the use of innovative instructional approaches and software. The shift from optional statistics to statistics as an important part of the mathematics curriculum of Finnish comprehensive schools will have a major role in improving the position of statistics.

The CSS -instrument is used to explicitly analyse selected video clips so as to distinguish the levels of student collaboration in small groups. It has been used to make students’ thinking visible, and it helps to depict collaborative statistical learning processes (Miles & Huberman 1994). The CSS -instrument depicts
statistical learning as a social conceptualisation of distributed or mutually shared cognition (Van den Bossche et al. 2006).

Conversations in small-groups seem to be beneficial and fruitful for statistical learning. Mullins et al. (2011: 437) have reported how: “The analysis of student collaboration confirmed that conceptual instructional material was able to stimulate mutual elaboration and explanation giving.” Most students feel that it has been a good change to have mathematics lessons in small CSCL-groups.

Education policy makers such as The National Council of Teachers of Mathematics (2000: 24) stress the importance of CL in students’ knowledge acquisition in learning mathematics: “The computational capacities of technological tools extends the ranges of problems accessible to students and also enables them to execute routine procedures quickly and accurately, thus allowing more time for conceptualization and modelling”. This mandate of NCTM should be taken in consideration in learning and teaching mathematics, and the results of this study are in the line with this. According to Garfield & Ben-Zvi (2007: 388): “Technological tools should be used to help students visualize and explore data, not just to follow algorithms to pre-determined ends. Instructional software may be used to help students to understand abstract ideas.” Technology in collaborative groups should be easy to use from the beginning in order to make technology communicative and repeatable (Stahl 2005).

The statistical education should be developed in schools and GAISE recommendations (Franklin & Garfield 2006) are good premises to do that. Collaboration in the classroom allows students to learn from each other, discover, construct, understand and share important statistical ideas and to model statistical thinking (see Chance et al. 2007, Garfield 1993, Hmelo-Silver & Barrows 2008, Stahl 2005). Recently there have been more studies of statistical education based on GAISE and NCTM recommendations.

Statistical teaching should be given more attention in the curriculum. One obvious reason for students’ weak statistical literacy competence after comprehensive school can be the weak status of statistics in the curriculum. In the school books, it is often the last subject taught in late spring of the 9th grade. It might be the case that there is not enough time to work through statistics thoroughly; and therefore teaching statistics has been reduced to the status of colouring other subjects in mathematics. In other words, students’ statistical literacy has not had an opportunity to develop. The teachers interviewed report that textbooks have a very important role in teaching statistics, and they have missed having a real-life connections in praxis. Better teaching materials in statistics are needed. Motivating
statistical topics and activities helps to convey basic statistical concepts (Nolan & Lang 2007), even if textbooks have not gone far enough in this matter. The reform of textbooks must extend beyond our introductory courses to the entire curriculum (Nolan & Lang 2007).

There should be more e-learning material included with the textbook and course materials. The results of the present study show that the electronic learning material seems to facilitate students’ learning. The possibility to pause or repeat the stream of the material and narration in the video seems to promote learning processes. Students’ justifications are very similar to the most effective multimedia principle assumptions of the CTML (see Clark & Paivio 1991, Mayer & Moreno 2002a).

Technology has an important role in statistics education in changing views of statistical knowledge, pedagogy and learning (Schuyten & Thas 2007). It seems that CSCL as a learning environment leads to an increased learning effectiveness. Technology seems to facilitate sharing and distributing of knowledge and improves students’ interactions in CSCL. According to Lipponen (2002: 1): “... CSCL is focused on how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members.”

The use of CSCL in mathematics education is a great potential to help students to comprehend the power of team and communication in team setting. Students should learn and experience collaboration and teamwork as a part of their learning process.

In the 21st century, technological tools and their implementations in education have emerged. Nevertheless, novel studies in this domain are needed marking hallmarks and showing effective learning trajectories with educational technology innovations. Based on the results of this study, students’ reactions to CSCL have been encouraging. Students felt it to be easier and more pleasant to study mathematics after the first experience of CSCL when they had built social relationships in a group. Socially shared meta-cognition seems to reduce students’ feelings of difficulty in learning statistics (cf. Hurme et al. 2009).

As far as we know, studies from the electronic-tests have not yet emerged, and this area of mathematics education has just taken the first steps. It would be important first to utilise a sufficient amount of ICT in the education in praxis before electronic-testing. The Matriculation Examination Board in Finland is in the process of delineating the environments and possible instruments in national electronic-test systems in the matriculation examination (i.e. exit examinations) and more studies and experiments are needed.
Based on the results, it also seems that students need more experience of electronic-tests as a part of mathematics education. The majority of the students worked with MS-Excel for the first time. This implementation of the electronic-test is one possible opportunity to assess students’ proficiency in mathematics. To enrich mathematics education, collaboration and technology-based teaching experiments are needed in order to educate active, creative, vigilant, social and technology-based citizens.

Discussion of validity and reliability in the present study

The issues of validity and reliability were considered both in the design and analyses of the current research project. First, data was collected through multiple methods including interviews, surveys, classroom observations, videotaped episodes, questionnaires, course exams, and delayed post-tests. The data was collected from the same participants over an extended period of time. This detailed and rich information enables us to triangulate the data and corroborate our findings.

In the chapter 3.6, the reliability and validity of the present study have been demonstrated. Two independent coders were employed in the qualitative data analyses to gain and build upon the reliability and validity of the collected data. In the quantitative data analyses, consistency coefficient, or Cronbach’s alpha, was used to indicate the internal consistency of items, which indicates the reliability of an instrument (Gilem & Gilem 2003).

Inter-rater agreement values, Cohen’s kappa in students’ interviews, students’ videotaped small-group collaborations, the course exams, and the delayed post-test indicate an almost excellent concurrence (Gwet 2012). Cohen’s kappa values in the questionnaires and in the electronic tests indicate excellent concurrence (Gwet 2012). It can be concluded that the reliability of the agreement between the two independent coders proves the developed instrument to be a valid and reliable methodological tool.

The reliability coefficient, Cronbach’s alpha, normally ranges between 0 and 1, and the Cronbach’s alpha coefficient of a scale should ideally be more than 0.7. Cronbach’s alpha values are quite sensitive to the number of items in the scale. For scales with fewer than ten items, Cronbach’s alpha values are usually quite low, for example, 0.5 (Pallant 2005). In general, the measurement practice in the present study has been to collapse two categories into one if students were responding in different ways. Open questions in the questionnaire were formulated to confirm and correspond with the quantitative data from the Likert-scale questions. After an open
question (e.g. “What fostered/retarded your learning?”), more detailed specific questions related to the same context follow, for example, “Studying in a group fosters my learning. How did the teaching material facilitate learning?” (see Appendix 2, Questionnaire 1.). If qualitative interpretation suggested that students were responding in different ways, common characteristics were recoded and analysed by content. Many items in the questionnaire could be improved and formulated in different way based on the present research experience.

5.3 Contributions and implications

The contributions of this study have been to enrich statistics and mathematics teaching as well as to demonstrate the benefits of technological implementations in education. Contemporary ICT provides excellent potential to implement pedagogical innovations to education. CSCL and CL are one feasible methods to enrich and develop education. The practical and theoretical contributions and implications are discussed in this chapter.

5.3.1 Practical contributions and implications

In order to achieve the aims of the Finnish curriculum, statistical teaching should be developed in our schools. The shift towards student-centred learning is a great possibility to enrich our education – it also enables a development of cohesion in classroom settings. Collaboration in learning is emphasized in the new curriculum. Contributions of CL have resulted in increased group-cohesion and activity in shared knowledge-building. It seems that team-work reduces students’ feelings of detachment in the classless, periodic system in Finnish upper secondary schools.

The mathematics curriculum in Finnish comprehensive schools should focus on improving the status of statistics. It is a matter of concern for all educators. Based on the results of this study, the development of statistical literacy may happen too late if students think that statistics have not been taught to them during comprehensive school at all. Changes in the curriculum and implementing technology in the learning environment could promote the position of statistics in our schools.

Statistics teaching can have a significant role in promoting future citizens and policy makers’ ability to comprehend surrounding statistical information in demanding real-life situations. Furthermore, it is urgent to educate students to be
sensitive and vigilant in reading and understanding new data and to give them enough challenging and secure learning situations to face such data.

In order to achieve statistical reasoning and thinking in the upper secondary school, statistical literacy should be developed in comprehensive school. Basic literacy is the framework of statistical education, but basic statistical literacy cannot develop without good statistical teaching in our schools. In order to develop statistical teaching, statistics should be implemented also in pre-service teachers’ education.

5.3.2 Theoretical contributions and implications

The present study explores Finnish upper secondary school students’ statistical learning in the CSCL context. The aim has been to examine, depict and develop statistics education in upper secondary level. Students’ level in statistical literacy, students’ collaboration, statistical learning processes and learning outcomes in electronic test can be seen to be contemporary topics in mathematics education research.

According to Krzywacki et al. (2012), the trend in mathematics education research in Finland is quite narrow and it is focused more on themes such as affects in mathematics learning and studying rather than classroom study in particular. The present study is filling a gaping void in classroom study and disseminates new knowledge with a novel approach in combining CSCL, mathematics education at secondary level and statistical literacy. At the international level there has been a large number of studies focusing on the teaching and learning statistics over the past few decades (Garfield 1993, Garfield & Ben-Zvi 2007), but studies at secondary level are still needed.

The present study contributes a perspective in shift from traditional classroom settings into student-centred approaches in learning mathematics. It seems that the majority of students are unfamiliar with the CSCL approach in education at secondary level. Students tend to comprehend learning in mathematics as an individual matter. Students’ verbal productive discourse and social abilities may not develop if learning in mathematics is seen only as an individual matter.

In this study, upper secondary school students’ learning outcomes are measured by using the electronic-test, which disseminates its feasibility in learning statistics. Based on the results of this study, the amount of electronic testing should increase. The electronic-test seems to be a profitable instrument for testing statistical proficiency. Students as well as mathematics teachers need experience to use
electronic tests, because the matriculation examination is in the process of taking electronic a computerised form.

Collaboration during mathematics lessons seems to strengthen social cohesion and improve group spirit. Novel pedagogical approaches support students’ mathematical conversational acts. Learning in mathematics should challenge students to articulate by using mathematical utterances, which has not been inherent in mathematics education tradition in Finland.

CSS -instrument in analyses of conversational acts can be seen as a contribution of this study. It made visible mutual knowledge-building and the quality of conversational acts. The CSS instrument enables researchers to distinguish and indicate the nature of statistical learning processes in terms of the form of collaboration in a CSCL environment. The basic idea of the CSS instrument is easily transformed to the specific area of education in content analysis.

5.4 Limitations and suggestions for future research

This study explores a technology-enhanced statistics learning experiment. As with all empirical studies, this study also has limitations in the generalization of the results. The participants in this study are not randomly selected, and the sample-size of data-collection is rather small. The present study only involves five classes of students and two participating teachers. There are limitations in the research-design concerning data-collection, data-analyses and the nature of the collected data. The endeavor has been to use diverse research methods to attain objective research-data and triangulation. The curriculum of upper secondary school can be seen as directive to learning objectives during the teaching experiment. Also the timetable of the course gives its own limitations to the DBR-cycles. High-functioning collaboration and productive discourse requires time and rehearsal.

The orchestration of collaborative learning in the mathematics classroom requires careful planning. This study indicates that there are technical obstacles to using computers. To obtain more videotaped episodes for analysis, a greater number of video-cameras must be used simultaneously. In order to attain wider and more reliable perspective of small-group interactions there should be greater number of video-taped observations. Four analysed episodes give an overview of quality and versatility of conversational acts as well as the effectiveness of the CSS instrument in content analysis. In noisy school classroom video and audio recording is challenging to carry out. In comprehensive methodological framework these specific settings should have been taken into consideration. Presumably various
valuable observations from the early iterations were lost. Moreover, social obstacles such as noise in the classroom or inhibition in participating in conversational acts in the group and deficiency of video-taped examples can be seen as limitations of this study.

In students’ interview one purpose is to investigate students’ opinions of secondary school statistics teaching. Statistics is taught only in the 9th grade for a period of a few weeks in secondary school mathematics. Time-interval between interview and secondary school statistics teaching is about 16 months which can be seen also as a one limitation in the present study. Presumably students cannot remember secondary school statistics teaching.

As a participating teacher in the design-based research, it is demanding to realise the extent of the data selected. It raises questions about subjectivity versus objectivity. Also, significant data may be down-played or even ignored, which may generate problems as regards interpretation (Bell & Opie 2002). The danger of distortion occurs when a single researcher gathers and selects data (Bell 2005). To increase the reliability and validity, in the present study, there are two independent coders in data-analyses.

Generalization in a case study is not always possible and “The extent to which findings from the case study can be generalized to other examples in the class depends on how far the case study example is similar to others of its type” (Denscombe 1998: 36). The case study example should fit in relation to the overall picture, but very few published studies have empirically explored technology-enhanced statistics learning experiment at upper secondary level.

Suggestions for future research would be to implement similar case studies to obtain significance features of technology-enhanced statistics learning experiments in upper secondary level. The CSS -instrument in content analyses used in this study can be generalize to other examples. Further implementation of the CSS instrument in other studies will obtain more information about the usage of the instrument. The role of an asynchronous small-group in using student-centred and CSCL in mathematics are important aspects for further research. More studies and experiments from electronic-tests are needed in order to accustom teachers and students to electronic-testing.

As mathematics teacher, it has been a great opportunity to have an experience as a part-time researcher. I have enlarged my proficiency as a teacher as well as a researcher. The present study has convinced me that the use of diverse methods in mathematics education is beneficial. Not only for the better grades, but for the life. After the research project my teaching has developed – I often contemplate: “What
could be the best approach and implementation to develop student's mathematical thinking?” I hope, it could be also a premise for other teachers and researchers in planning future research. In the age of information and smart technology, there are many paths available in utilising collaboration, technology and electronic evaluation. I hope that the present study will encourage others to travel similar paths.
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**APPENDIX 1 Pre-test**

Gender

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
</table>

Please indicate (with an X) your final grade in mathematics in the comprehensive school.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Please indicate your grades frequency in mathematics at upper secondary school.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

1. Please indicate (with an X) to describe at which level you know the following statistical terms or concepts.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>I DON’T KNOW THIS CONCEPT</th>
<th>I KNOW THIS CONCEPT</th>
<th>I KNOW THIS CONCEPT AND I’M ABLE TO USE IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the relative frequency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>type value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>median</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sample standard deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>diagram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>histogram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>linear regression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>correlation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Which of the following definitions describe the concept of mode? Choose the correct statements or definitions. (X)

- … in value of the data, which frequency is the biggest.
- … in the middle number in numerical order? If the frequency of the all numbers is an even number, the median is the mean of the middle two values.
- … in the arithmetic mean of the data.
- … in the most typical value of the data.

3. Which of the following definitions describe the concept of histogram? Choose the correct statements or definitions. (X)

- The histogram is used to illustrate data which varies in trends or incrementally. The data is pictured as a line which combines values of sets.
- The histogram is similar to an area diagram, but the presentation of the data emphasizes trends.
- The histogram is called a “pie chart” in the everyday language. The whole circle presents all 100% of quantity and each sector of the circle are presented in percentages.
- The histogram is a graphical presentation, which depicts the distribution of values in specific classifications by using areas of rectangles.
- The histogram is an area diagram in which the rectangles are joined to each other.

4. Describe in your own words the meaning of the following concepts?

   a) statistics?

   b) statistics in mathematics?

   c) statistical literacy?
Evaluate in Likert-scale (1–4) which statement describes you best in your own opinion.

1. totally disagree  (does not describes me at all)
2. disagree  (describes be a little bit)
3. agree  (describes me well)
4. totally agree  (describes me very well)

Choose the correct statements or definitions. (X)

5. In my opinion, I have solid abilities in terms of reading and interpreting statistical information.

6. When I read newspapers or watch television programmes or other media, statistical numbers and graphs are easy to understand.

7. I am critical with regard to statistical data.

8. I think that statistics is an important part of upper secondary school mathematics.

9. I need statistics in my post-graduate studies.

10. I think that the understanding and interpretation of statistics are important skills from a postgraduate studies point of view.

11. I think that the interpretation and understanding of statistics is an important skill in life.
12. The next diagram (pie chart) represents the most common causes of death among Finnish men in 2005.

The most common causes of death of Finnish men in 2005

- Ischaemic heart disease; 25.00%
- Cancers; 23.00%
- Respiratory diseases; 20.00%
- Other cardiovascular diseases; 13.00%
- Accidents; 10.00%
- Dementia and Alzheimer's disease; 6.00%
- Other reasons; 19.00%

Source: http://suomi.lukuina.fi/Kuolema(03.07.2009)

a) Which are the two most common causes of men’s deaths based on the diagram?

b) I think that the diagram is easy to read and interpret.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

c) I would be critical regarding this diagram.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

d) Explain your answer to question c
13. The following diagram presents the number of plum-tomatoes in packages prepared for sale.

Define the number of the plum-tomatoes in the selling packages

a) type value

b) median

c) mean

d) the length of the range

14. In what kind of practical situations did students assume statistical skills to be beneficial?
APPENDIX 2 Questionnaire 1

Gender

Please indicate (with an X) your final grade in mathematics in comprehensive school.

Please indicate your grades frequency in mathematics in upper secondary school.

Evaluate in the Likert-scale (14) the statement that describes you best in your own opinion.

1. totally disagree (does not describes me at all)
2. disagree (describes be a little bit)
3. agree (describes me well)
4. totally agree (describes me very well)

Choose the correct statements or definitions. (X)

1. In my opinion, I learned during teaching the experiment lessons as well as in standard mathematics lessons.

2. In my opinion, I learned better during the teaching experiment lessons than in standard mathematics lessons.
3. Why?

4. As a group, we learned the essential contents of statistics in upper secondary school mathematics.

5. We managed to deal with the statistical problems.

6. In my opinion, it was more difficult to work in a group than in a standard mathematic lesson.

7. What fostered / retarded your learning?

8. In my opinion, it was a good change to have mathematics lessons in small CSCL-group.


10. What was the factor in working in the group which fostered or retarded your learning?

11. In my opinion, the electronic material supported my learning.

12. How did the teaching material facilitate learning?


14. How did collaboration foster your comprehension?
15. Teacher’s guidance was adequate in the group. 

16. In my opinion, the electronic material clarified the learned topics. 

17. How did the learning material facilitate understanding the studied topic? 

18. Rate of study was adequate. 

19. Justify the rate of study 

20. I learned to use the calculator in statistics. 

21. The tutorial on using the calculator was beneficial. 

22. Why? 

23. I learned the basics of using MS-Excel for statistics. 

24. I would have needed more practice in MS-Excel. 

25. What is the value of the use of MS-Excel and Word or other ICT equipment in learning statistics? 

26. Mention some ICT skills you learned or in which you were able to deepen your knowledge during the teaching experiment.
27. Did you initiate conversations?  

28. Did you participate in conversations?  

29. Did you think aloud?  

30. Can you describe how and in which kind of situations you thought aloud?  

31. Did you get ideas from other group-members’ thoughts?  

32. Depict in an example, how and what kind of ideas you got?  

33. Have you any earlier experiences of CSCL in school in mathematics or in other subjects? If you have, please mention when and in which subject.  

34. What was your own experience about learning in the CSCL environment?  

35. Please comment on the technical appearance of the teaching materials.
APPENDIX 3 Interview 1

Students were asked the following open questions:

**Question 1:** Describe a traditional and ordinary mathematic lesson.

**Question 2:** Did you learn during the teaching experiment as well as during traditional mathematic lessons, in your own opinion?

**Question 3:** How did the technology work during the teaching experiment? Were there any problems?

**Question 4:** In what way did you handle statistical exercises as a group?

**Question 5:** Did collaboration in small groups promote your learning?

**Question 6:** Give a concrete example of the situation where collaboration promoted your learning?

**Question 7:** What promoted learning in a group?

**Question 8:** What aggravated learning in a group? Describe more specifically or give a concrete example, please.

**Question 9:** How did the teaching material support learning?

**Question 10:** Was the demo of the use of the calculator sufficient for you to become familiar with it?

**Question 11:** Did you become familiar with the use of excel in supporting learning statistics?

**Question 12:** Did the examples support your learning? How? Did it raise discussion?

**Question 13:** How did the teaching material help you to comprehend the problem you were solving?

**Question 14:** Was there enough time for working in groups? Did you manage to do the given tasks?

**Question 15:** What did you think about the speed of progress in studying?

**Question 16:** Was it beneficial for you to be instructed in using the calculator?

**Question 17:** What was the point of using Excel and Word, in your opinion?
Question 18: Describe in which situations you discussed with other team members?

Question 19: Describe how and in what kind of situations you thought aloud?

Question 20: Did you get ideas from other teammates’ thoughts? Describe and give a concrete example, please.

Question 21: Have you previously been in a computer-supported collaborative teaching experiment in mathematics and done teamwork by using the computer? What about in some other school subject? If you have, please mention when and in which subject?

Question 23: Give some feedback about the technical materialization of the teaching material? How would you develop the teaching material?

Question 24: Would this kind of learning style be feasible for some other topics in mathematics?

Question 25: Would this kind of learning style be feasible for some other subjects studied in upper secondary school?

Question 26: Would you like to have some teaching sessions in groups using computers in the future?

Question 27: What can you remember best of the teaching experiment? Why?

Question 29: How and to what extent were statistics taught in comprehensive school?
APPENDIX 4 Interview 2

Teachers were asked the following open questions:

**Question 1:** In what position is statistics in comprehensive school mathematics in your opinion?

**Question 2:** How extensively is statistics taught in comprehensive school?

**Question 3:** Please estimate how many classes are devoted to statistics on average?

**Question 4:** Have you had enough time to work through the statistics that should be taught, according to the curriculum? Please describe the curriculum, if you can.

**Question 5:** What textbook are you using at the moment?

**Question 6:** How do the students react to studying statistics?

**Question 7:** How would you develop statistics teaching in comprehensive school?
1. In the following, statistics related to patents applications filed in Finland in 2000–2009 are presented.

### Patent applications filed in Finland, 2000–2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Private assignee</th>
<th>Enterprise/association</th>
<th>Domestic applications total</th>
<th>Foreign applications</th>
<th>Total applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>695</td>
<td>1883</td>
<td>2575</td>
<td>338</td>
<td>2913</td>
</tr>
<tr>
<td>2001</td>
<td>627</td>
<td>1764</td>
<td>2391</td>
<td>277</td>
<td>2668</td>
</tr>
<tr>
<td>2002</td>
<td>550</td>
<td>1606</td>
<td>2156</td>
<td>216</td>
<td>2372</td>
</tr>
<tr>
<td>2001</td>
<td>467</td>
<td>1506</td>
<td>1973</td>
<td>214</td>
<td>2187</td>
</tr>
<tr>
<td>2004</td>
<td>443</td>
<td>1567</td>
<td>2010</td>
<td>215</td>
<td>2225</td>
</tr>
<tr>
<td>2005</td>
<td>464</td>
<td>1371</td>
<td>1835</td>
<td>226</td>
<td>2061</td>
</tr>
<tr>
<td>2006</td>
<td>419</td>
<td>1394</td>
<td>1813</td>
<td>205</td>
<td>2018</td>
</tr>
<tr>
<td>2007</td>
<td>452</td>
<td>1349</td>
<td>1801</td>
<td>211</td>
<td>2012</td>
</tr>
<tr>
<td>2008</td>
<td>401</td>
<td>1397</td>
<td>1798</td>
<td>148</td>
<td>1946</td>
</tr>
<tr>
<td>2009</td>
<td>401</td>
<td>1403</td>
<td>1804</td>
<td>127</td>
<td>1931</td>
</tr>
</tbody>
</table>


a) Calculate statistical variables for private persons and foreign appliers of patents. You can interpret the numbers if needed. Does any parameter differ particularly from the data in general?

b) Estimate how many patents were applied for by foreigners in 2012?

c) Is it possible that in a certain year, foreigners have applied for as many patents as private assignees did?

c) Plot a line graph of the data in the column ‘Total applications’.

Calculate and plot these tasks for separate papers. When counting standard deviation, mark the task step.
APPENDIX 6 Course exam 2

Kuopion Lyseon lukio 18.09.2011

MAA06, Statistics and probability Name: ____________________

1. In the following table, statistics related to household-dwelling units by number of persons are presented for the years 1960–2010.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>1 person</th>
<th>2 persons</th>
<th>3 persons</th>
<th>4+ persons</th>
<th>Average size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>1 204 385</td>
<td>188 995</td>
<td>245 921</td>
<td>229 824</td>
<td>539 645</td>
<td>3.34</td>
</tr>
<tr>
<td>1970</td>
<td>1 420 723</td>
<td>288 970</td>
<td>323 640</td>
<td>284 336</td>
<td>523 777</td>
<td>2.99</td>
</tr>
<tr>
<td>1975</td>
<td>1 567 941</td>
<td>376 904</td>
<td>392 367</td>
<td>322 321</td>
<td>476 349</td>
<td>2.73</td>
</tr>
<tr>
<td>1980</td>
<td>1 781 771</td>
<td>482 476</td>
<td>457 667</td>
<td>345 769</td>
<td>495 859</td>
<td>2.64</td>
</tr>
<tr>
<td>1985</td>
<td>1 887 710</td>
<td>532 094</td>
<td>514 825</td>
<td>347 127</td>
<td>493 664</td>
<td>2.56</td>
</tr>
<tr>
<td>1990</td>
<td>2 036 732</td>
<td>646 229</td>
<td>597 928</td>
<td>332 295</td>
<td>460 280</td>
<td>2.42</td>
</tr>
<tr>
<td>1995</td>
<td>2 180 934</td>
<td>766 636</td>
<td>652 608</td>
<td>323 921</td>
<td>437 769</td>
<td>2.31</td>
</tr>
<tr>
<td>2000</td>
<td>2 295 386</td>
<td>856 746</td>
<td>722 437</td>
<td>312 646</td>
<td>403 557</td>
<td>2.21</td>
</tr>
<tr>
<td>2005</td>
<td>2 429 500</td>
<td>964 739</td>
<td>789 950</td>
<td>297 276</td>
<td>377 535</td>
<td>2.12</td>
</tr>
<tr>
<td>2010</td>
<td>2 537 197</td>
<td>1 040 378</td>
<td>837 234</td>
<td>290 767</td>
<td>368 818</td>
<td>2.07</td>
</tr>
</tbody>
</table>


a) Calculate the statistical variables for household-dwelling units with 2 persons and 4+ persons. You can interpret the numbers if needed. Does any parameter differ particularly from the data in general?

b) Estimate the numbers of 2- and 4+-person household-dwelling units. In which years were the numbers of the above two types of household-dwelling units equal?

c) In which years is the number of 2-person household-dwelling units four times larger than the number of 4+-person household-dwelling units?

d) Plot a bar chart of the household-dwelling units’ average column data. Calculate and plot these tasks for separate papers. When counting standard deviation, mark the task step.
APPENDIX 7 Course exam 3

Kuopion Lyseon lukio 18.09.2011

MAA06, Statistics and probability Name: ____________________

1. In the following statistics is presented Government expenditure / Research & Development funding 2000 – 2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>Government expenditure  (€ mill.)</th>
<th>State expenditure excluding debt (€ mill.)</th>
<th>R &amp; D funding (€ mill.)</th>
<th>R &amp; D expenditure as a share of government expenditure,% 1)</th>
<th>R &amp; D funding, in real terms,%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>38 472,0</td>
<td>28 141,0</td>
<td>1 295,9</td>
<td>4,6</td>
<td>-2,1</td>
</tr>
<tr>
<td>2001</td>
<td>36 072,0</td>
<td>29 672,0</td>
<td>1 352,4</td>
<td>4,6</td>
<td>0,7</td>
</tr>
<tr>
<td>2002</td>
<td>35 511,0</td>
<td>30 877,0</td>
<td>1 388,7</td>
<td>4,5</td>
<td>-0,3</td>
</tr>
<tr>
<td>2003</td>
<td>36 897,0</td>
<td>32 244,0</td>
<td>1 452,8</td>
<td>4,5</td>
<td>1,6</td>
</tr>
<tr>
<td>2004</td>
<td>36 320,0</td>
<td>33 939,0</td>
<td>1 535,1</td>
<td>4,5</td>
<td>3,1</td>
</tr>
<tr>
<td>2005</td>
<td>41 247,0</td>
<td>35 204,0</td>
<td>1 614,1</td>
<td>4,6</td>
<td>2,3</td>
</tr>
<tr>
<td>2006</td>
<td>40 871,0</td>
<td>37 124,0</td>
<td>1 694,3</td>
<td>4,6</td>
<td>2,5</td>
</tr>
<tr>
<td>2007</td>
<td>43 251,9</td>
<td>37 986,6</td>
<td>1 739,6</td>
<td>4,6</td>
<td>0,1</td>
</tr>
<tr>
<td>2008</td>
<td>44 923,0</td>
<td>41 277,0</td>
<td>1 813,8</td>
<td>4,4</td>
<td>-1,1</td>
</tr>
<tr>
<td>2009</td>
<td>46 897,0</td>
<td>45 025,0</td>
<td>1 928,4</td>
<td>4,3</td>
<td>2,2</td>
</tr>
<tr>
<td>2010</td>
<td>50 185,2</td>
<td>48 109,2</td>
<td>1 989,4</td>
<td>4,1</td>
<td>0,8</td>
</tr>
<tr>
<td>2011</td>
<td>50 269,3</td>
<td>48 336,3</td>
<td>2 065,0</td>
<td>4,3</td>
<td>2,1</td>
</tr>
</tbody>
</table>

1) The share of government expenditure, excluding the cost of government debt

a) Calculate statistical variables for R & D funding of Government expenditure. You can interpret numbers if needed. Does any parameter differ particularly from the data in general?

b) Estimate when R & D funding is 3% of Government expenditure?

c) How many € millions is 3% of R & D funding of Government expenditure?

d) Plot a histogram of R & D funding, R & D funding in real terms of column’s data.

Calculate and plot these tasks for separate papers. When counting standard deviation, mark the task-step.
APPENDIX 8 Delayed post-test

Gender

Please indicate (with an X) your final grade in mathematics in comprehensive school.

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please indicate (with an X) your grade in the course MAA06 (Probability and statistics).

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you participate in the CSCL teaching experiment?  

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. In secondary school statistics was taught in more than two lessons.  

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What topics were taught in statistics during secondary school?

3. Evaluate your own capacity by using following concepts.

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>I DON’T REMEMBER THE CONCEPT PRECICELY</th>
<th>I COMPREHEND THIS CONCEPT</th>
<th>I COMPREHEND THIS CONCEPT AND I AM ABLE TO USE IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>binomial distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pie chart</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the multiplication rule</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>permutation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k-combination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>correlation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. In which situations and how can you utilise skills learned on course MAA06?

5. The next diagram (pie chart) represents the most common causes of death among Finnish women in 2005

**The most common causes of death of Finnish women in 2005**

- Ischaemic heart disease; 22.30%
- Cancer; 17.60%
- Cerebrovascular diseases; 11.20%
- Respiratory diseases; 4.20%
- Dementia and Alzheimer’s disease; 12.10%
- Other cardiovascular diseases; 2.00%
- Accidents; 5.00%
- Other reasons; 15.60%

Source: http://suomi.lukuina.fi/Kuolema(03.07.2009)
a) Which are the two most common causes of men’s deaths based on the diagram?

b) I think that the diagram is easy to read and interpret.

YES NO

c) I would be critical regarding this diagram.

YES NO

d) Explain your answer to question c.

6. The following table shows magazine revenues in 1999–2009.

<table>
<thead>
<tr>
<th></th>
<th>Tilaukset</th>
<th>Irtonumeromyynti</th>
<th>Mainonta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subscriptions</td>
<td>Single copy sales</td>
<td>Advertising</td>
</tr>
<tr>
<td>%</td>
<td>1999</td>
<td>62</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2001</td>
<td>59</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2002</td>
<td>60</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>61</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>62</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>62</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>62</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>63</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>64</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>69</td>
<td>7</td>
</tr>
</tbody>
</table>

Luvut ovat karkeita arvioita. - The figures are crude estimates.

Lähde: Tilastokeskus/Joukkovestintätilastot
Source: Statistics Finland/Media statistics

a) Draw a histogram of magazine revenues in years 1999 and 2009.

Histogram 1999

Histogram 2009

b) Is this set of statistics well drawn up?

c) Is there anything you should be critical about in these statistics?

7. The following statistics present different religious affiliations in Finland in 2000-2010.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lutheran</td>
<td>98.1</td>
<td>95.1</td>
<td>87.9</td>
<td>85.1</td>
<td>84.9</td>
<td>84.7</td>
<td>84.3</td>
</tr>
<tr>
<td>Orthodox</td>
<td>1.7</td>
<td>1.7</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Other</td>
<td>0.2</td>
<td>0.4</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>No religious affiliation</td>
<td>-</td>
<td>2.8</td>
<td>10.2</td>
<td>12.7</td>
<td>12.9</td>
<td>13.1</td>
<td>13.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Religion</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lutheran</td>
<td>83.8</td>
<td>83.2</td>
<td>82.6</td>
<td>81.8</td>
<td>80.7</td>
<td>79.9</td>
<td>78.3</td>
</tr>
<tr>
<td>Orthodox</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Other</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.3</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>No religious affiliation</td>
<td>14.0</td>
<td>14.5</td>
<td>15.1</td>
<td>15.9</td>
<td>16.9</td>
<td>17.7</td>
<td>19.2</td>
</tr>
</tbody>
</table>

b) Count statistical parameters for Lutherans. You may interpret data. Does any parameter differ particularly from the data in general?

c) Estimate the number of perceptual number of Lutherans in 2020.

d) Is it possible that number with no religious affiliation will equal Lutherans one day? Justify this.

e) Construct a bar chart of Orthodox.
8. A fishing vessel caught various fish of different weights based on the following statistical classification.

<table>
<thead>
<tr>
<th>Weight of fish [kg]</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5</td>
<td>4</td>
</tr>
<tr>
<td>5 - 10</td>
<td>20</td>
</tr>
<tr>
<td>10 - 12</td>
<td>38</td>
</tr>
<tr>
<td>13 - 15</td>
<td>45</td>
</tr>
<tr>
<td>16 - 18</td>
<td>5</td>
</tr>
<tr>
<td>19 - 20</td>
<td>90</td>
</tr>
<tr>
<td>20 - 25</td>
<td>5</td>
</tr>
<tr>
<td>25 - 30</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>0</td>
</tr>
</tbody>
</table>

a) Define mean, standard deviation, mode and median of the weight of fish.

b) Is any data significantly different from the statistical classification?
Justify this.
APPENDIX 9 Electronic-test 1, MAA06 statistics

Electronic-test 1, MAA06, statistics:

1. The following figure presents Linnea’s distribution of the grades in her school report.

Solve the sub-items by using the program MS-Excel. Save your file to the path e:\Auxiliary\Surname.xls This exercise can be done to the first tab.

a) Construct a table based on the figure.
b) Construct a figure from your table.
c) Calculate median
d) Calculate mode
e) Calculate mean
f) Calculate standard deviation
2. The following figure presents the number of 65 year-old people in Finland.


Solve by using the program MS-Excel when there will be more than two million inhabitants over 65 years of age in Finland?

What is the correlation between the number of 65 year-old inhabitants and the number of years?

This exercise can be done to the second tab.
**APPENDIX 10 Questionnaire II**

Gender

<table>
<thead>
<tr>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
</table>

Please indicate (with an X) your final grade in mathematics in comprehensive school.

<table>
<thead>
<tr>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Please indicate your grades frequency in mathematics in upper secondary school.

<table>
<thead>
<tr>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Evaluate in the Likert-scale (14) which statement describes you best in your own opinion.

1. totally disagree (does not describes me at all)
2. disagree (describes be a little bit)
3. agree (describes me well)
4. totally agree (describes me very well)

Choose the correct statements or definitions. (X)

37. Did the electronic exam work properly?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

38. How well did this electronic exam measure your proficiency in statistics?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>

39. Were you able to answer by using your own ICT-proficiency?

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

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40. Estimate on a scale of 4–10 your own ICT and MS-Excel proficiency.

41. What was the most difficult thing in the electronic-test?

42. Do you hope that in the future part of the mathematics test is done electronically? 

43. What was the benefit of the electronic-test in your own opinion?

44. Was the electronic-test suitable in measuring statistical proficiency? 

45. Justify your answer to question 44.

46. What kind of practice would be needed in preparing electronic-test?

47. How would you improve electronic evaluation?
APPENDIX 11 Learning tasks

Kuopion Lyseon lukio

Mathematics, Statistics and probability
Juho Oikarinen

Name: ________________________________

Statistics Homework-link

LT1: Your first task is to search from the Internet or a textbook the definitions of the most essential statistical variables and equations and document your findings in an MS-Word file. The most essential variables can be found on the following page. There are also some useful links. You can add some example equations to different statistical variables. When you find a proper source, Take a Screenshot or copy it into your own file; add a corresponding reference. The next example is about mean.

Example presentation of mean:
Mean (see arithmetic mean) is the most common of averages. It is the average you are used to, where you add up all the numbers and then divide by the number of numbers.

The equation of mean is as follows:

\[ \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + \ldots + x_n}{n} \]

The most essential concepts and definitions:

1. discrete variable
2. frequency
3. continuous variable
4. mean
5. standard deviation
6. correlation and its interpretation
7. class centre
8. median
9. mode
10. expected value
11. linear regression
12. statistical literacy
13. typical value
14. range
15. variance

Links:
Concepts and definitions:
http://www.stat.fi/tup/oppilaitokset/vsk_johdanto.html
http://www.stat.fi/tup/oppilaitokset/oppimateriaalit.html
http://www.whfreeman.com/eesee/eesee.html
Use the Internet search robots:www.google.fi www.yahoo.com etc.
Summation

**LT2**: The understanding and application of summation is a fundamental skill when dealing with statistical and mathematical formulas. To be able to correctly interpret formulas in the future, we will look at the notation.

**Get to know summation**

**Summation exercise 1**

Calculate $\sum_{i=1}^{5} i$

**Solution**

**Summation exercise 2**

Calculate $\sum_{i=1}^{3} i^i$

**Solution**

**Summation exercise 3**

From what summation is $\alpha_i + \alpha_j + \alpha_k$?

**Solution**
Mean, Median, and Mode

**LT3:** Get to know the material you found on mean and standard deviation.

**Exercise 1**
Pirkko got grades 7, 8, 9, 8, 10, and 6 in the 3\(^{\text{rd}}\) period. Calculate the standard deviation of the grades in the 3\(^{\text{rd}}\) period.

**Solution**  
Calculator  
Classpad

**Exercise 2.**
Paavo got grades 7, 8, 9, 8, 10, and 6 in 3\(^{\text{rd}}\) period. Calculate the standard deviation of the grades on the school report.

**Solution**  
Calculator  
Classpad

Ponder why in exercise 2 is the denominator of the formula for standard deviation \(n - 1\) instead of \(n\)?

**Exercise 3.**
Elmeri got the following grades in upper secondary school.

<table>
<thead>
<tr>
<th>Grade</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>11</td>
<td>32</td>
<td>20</td>
<td>76</td>
</tr>
</tbody>
</table>

Calculate the standard deviation of the grades in the school report. Define mode and median.

**Solution**  
Calculator  
Classpad
Defining mean of classified sample

**LT4**: In many cases, the interpretation of statistical data becomes easier by classifying variables into groups. In the following table, men’s heights classified into three categories are presented.

<table>
<thead>
<tr>
<th>Height [cm]</th>
<th>Class frequency (fi)</th>
<th>Relative frequency (f %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>170–179</td>
<td>8</td>
<td>40.00 %</td>
</tr>
<tr>
<td>180–189</td>
<td>9</td>
<td>45.00 %</td>
</tr>
<tr>
<td>190–199</td>
<td>3</td>
<td>15.00 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>100.00 %</strong></td>
</tr>
</tbody>
</table>

a) Define the centre of the class.

**Solution**  
**Classpad**

b) Calculate mean

**Solution**  
**Classpad**
Seagull Exercise

**LT5**: After migration in the spring, the population of one of the bird islands was about 400 one-year-old seagulls, 300 two-year-old seagulls, and 280 three-year-old seagulls.

<table>
<thead>
<tr>
<th>Age</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>280</td>
</tr>
</tbody>
</table>

a) What is the average of the age of the seagulls in terms of mode and median?

Solution

b) What is the standard deviation of the age of the seagulls?

Solution

c) How many seagulls should be birthed after nesting in order to decrease the mean of the average age by one year?

Try to solve problem by using MS-Excel

d) What are the new standard deviation, mode, and median of the age of the seagulls?

Solution

Standard deviation by using frequency:

\[ \sigma_n = s_n = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} = \sqrt{\frac{\sum f_i (x_i - \bar{x})^2}{n}} \]
Linear Regression, correlation

**LT6:** Get to know the linear regression and correlation material you found.

**Exercise 1.**
Distribution of the heights and weights of a group of students.

<table>
<thead>
<tr>
<th>Student</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height [cm]</td>
<td>170</td>
<td>180</td>
<td>165</td>
<td>185</td>
<td>180</td>
<td>172</td>
<td>173</td>
<td>160</td>
<td>158</td>
<td>163</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>65</td>
<td>80</td>
<td>70</td>
<td>85</td>
<td>83</td>
<td>73</td>
<td>65</td>
<td>58</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

a) Define possible statistical variables and linear regression.

b) What does correlation mean?
See: Maol s.54

Try to solve problem by using MS-Excel

MS-Excel sheet

Solution variables

Solution linear regression

d) Predict the height of a person whose weight is 70 kg?
The growth of pike

**LT7:** According to a reference, a pike grows in a propitious environment in the following way.


**Input data into the calculator and solve the linear regression.**

a) Why there is a vertical bar at the points?

b) How old is a 145-cm-long pike?

c) If a pike is estimated to be 20 years in age, what is its length?

[Solution](#)  [Classpad](#)

d) Try to solve problem by performing linear regression using MS-Excel.

[MS-Excel sheet](#)

[Solution](#)
Statistics assignment

An assignment in groups of 3 or 4.

**LT8:**

**A:**
The heights and shoe sizes of students in the current course are compared. What data can be found from the statistics?

Analyse the heights and shoe sizes of the students in your own group. Plot the frequency distribution of the shoe sizes, and present it in a chart. Calculate possible statistical variables. Follow similar statistical procedures for the heights students in your group. Explore whether the variables (height, shoe size) have a statistical dependence between them. Present other illustrative charts and statistical variables.

**B:**

Consider the development of men’s and women’s 100-metre race world records by using an electronic stopwatch. What statistical data do those statistics highlight? Is it possible for women’s 100-metre race time to be less than men’s 100-meter race time? If yes, when? Analyse the data.


Assignment sheets:

- MS-Excel sheet
- MS-Word sheet
APPENDIX 12 Learning tasks II homework

Kuopion Lyseon lukio
MAA06, Statistics and probability
Juho Oikarinen

Name: ____________________

Homework MAA06, statistics

1. The following diagram presents the number of cherry-tomatoes in packages prepared for sale.

![Number of packages for sale vs. the number of cherry-tomatoes](image)

Define the number of cherry-tomatoes in the packages for sale

**Tip**

a) type value  
b) median  
c) mean  
d) standard deviation  
e) length of the range  
f) How many 24-pcs cherry-tomatoes packages should be taken off so that the value of standard deviation will decrease by 0.1?

**Solution**

2. The following table presents the results of the first and second course grades of mathematics students. The results of the first course are presented along the
horizontal axis, and the results of the second course are given along the vertical axis.

**Tip**

<table>
<thead>
<tr>
<th>1st course</th>
<th>2nd course</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2nd course</th>
<th>1st course</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

a) Calculate statistical variables for the first and second courses of mathematics.

**Tip***

**Solution**

b) If the grade of the first course is 8, what is the prospect of the grade of the second course?

**Solution**

c) What is the type of relationship among the variables?

**Solution**

f) Does any parameter differ particularly from the data in general?

**Solution**
3. The following figure presents the distribution of Linnea’s grades in her school report. Calculate statistical variables. Does any parameter differ particularly from the data in general? Justify (If the length of the range is two times the standard deviation.)

<table>
<thead>
<tr>
<th>Grade</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>45</td>
<td>32</td>
<td>5</td>
</tr>
</tbody>
</table>

**Solution**

4. In one sample, the observation data values are marked in the following way: a, a + 1, a + 2, a + 3, and a + 4, and the standard deviation of the sample is 2. What are the real values of the sample?

**Solution**

5. The result of Moose accounting before hunting season in a game management circuit is presented in the following table.

<table>
<thead>
<tr>
<th>Age, under</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50</td>
<td>45</td>
<td>30</td>
<td>28</td>
<td>25</td>
<td>18</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Female</td>
<td>60</td>
<td>43</td>
<td>33</td>
<td>25</td>
<td>26</td>
<td>26</td>
<td>17</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

a) Calculate mean of the age of moose and other possible statistical variables

**Solution**

b) Prepare a line chart.

**Solution**

c) Calculate correlation according to age and frequency. Interpret the results.

**Solution**
APPENDIX 13 Transcription of the teachers’ interview

Question 1: What position does statistics occupy in comprehensive school mathematics, in your opinion?

Teacher 1: “Statistics was only taught in the 9th grade, and even then, only if there is enough time. I, myself, have always had it for a few weeks and have even sat an exam.”

Teacher 2: “Usually, statistics is taught in the 9th grade. All in all, there are too many aims in the 9th grade curriculum that we have to cut it. In most cases, statistics and probability are cut, so the position is very weak.”

Question 2: How well and how extensively are statistics taught in comprehensive school?

Teacher 1: “The interpretation of statistics, especially diagrams, comes through in subjects, and ICT Excel-courses are pretty much statistical mathematics, but that instruction is only for optional course students. My own students create tables from, for example, shoe-sizes and heights, do Gallup polls, and classify the results. We get to know concepts such as mean, mode, median, maximum, minimum, frequency, relative frequency, and length of range by using their own tables. We plot bar, line, and pie chart diagrams. Also, the sample comes up as a concept. In addition, we ponder the facts that affect the reliability of statistics. For example, we discuss the misleading versions of diagrams that might appear in the newspaper.”

Teacher 2: “Very concisely, all in all.”

Question 3: Please estimate, on average, how many lectures were used to work through statistics?

Teacher 1: “16 ± 4”

Teacher 2: “Perhaps 4 – 6 lessons”
**Question 4:** Have you had enough time to work through the statistics that should be taught, according to the curriculum? Please describe the curriculum, if you can.

Teacher 1: “Almost always, I have time to go through the concepts that the curriculum includes, but I know that many of my colleagues do not deal with these issues. The textbook has a major significance in this. Teaching the subject is easier with the help of a good textbook. One that will get students excited in the end of April–May, in the final phase of comprehensive school, is difficult to find. The publishers have not found motivating exercises. I have taken to using an excellent book, Plus 3, from past years. The teaching of statistics is troubled by a lack of time and by timing. It is taught when students are tired and thinking about beginning the summer holidays. The sun is shining, and it is 20 degrees outside the window. Furthermore, there is a lack of good books and ideas, though there are interesting statistical research tips in the teacher’s guides.”

Teacher 2: “In principle, we go through the concepts and representation of statistical graphs, but there is very little practice. Where have all those lessons gone!”

**Question 5:** What textbook are you using at the moment?

Both teachers interviewed had different textbooks.

**Question 6:** How do the students react to studying statistics?

Teacher 1: “Variably over different years. Sometimes the analysis of the measured data and designing a questionnaire and marking results by using tally and classification of the table interests them. We have to invent ways of interesting them: motivation does not come naturally. I use newspapers and the internet, and the research subjects are often the students themselves. I told the students to measure one another’s heights, mark them for everyone to see, and build a table. Those tables are arranged in terms of girls and boys. The means are defined, and other observations are made from the constructed sample. This always seems to interest them. The small risk is for the short boys. How do they feel about it? I have not had any negative feedback either from students or their parents.”
Teacher 2: “Usually, they like statistics because the subject is so different and easy to combine with real life situations. You bump into statistics everywhere.”

**Question 7:** How would you develop statistics teaching in comprehensive school?

Teacher 1: “I would need better teaching materials so that I wouldn’t have to bother my own head so much in the middle of a busy spring when I am tired in order to make teaching interesting. For the course in statistics, there should, for example, be proper laptops with statistical programs if there is not enough money for a permanent classroom with computers. Most adults are not amused by drawing bars into booklets or arranging orders of magnitudes by pencilling in the tabled values. Teaching aids should be based on the needs of the surrounding society and era.”

Teacher 2: “Much more time would be needed as well as the possibility of utilizing ICT. I would also like to effect the critical observation of statistics by using statistical means. Its integration with other subjects, such as social studies, biology, and geographic, could be broader.”
APPENDIX 14 Episode 3, CSS – instrument.

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<td>Timestamp: 15.8.2011 15:26</td>
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What were the main issues or themes that struck you in this contact?

This group is working with the Notation of Sum.

<table>
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<tr>
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<th>Task-related</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>What it is?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27 + 4 + 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 power to 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is 27.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yeah, that’s correct.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oh yes. Well, no it isn’t ... 3 power to 3 equals 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calculate this again and infer it, you will find it out!</td>
</tr>
<tr>
<td>Assignment</td>
<td>Exercise</td>
<td>Cassy, Youtube, Computer or software</td>
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<td></td>
</tr>
</tbody>
</table>

**Comment / Information / Description**

- "It might not be so."
- "It is the power of three."
- "So 3 times 3 is 9 times 3? … no!"
- "Oh yes, now I apprehend that, it comes that way and it is this way, thank you!"
- "Can we now solve the exercise 3?"

**All teammates accepted by gestures the planning.**

### Task-related

- New Idea
- Evaluation
- Support
- Explanation
- Question
- Planning / thinking aloud
- Individual

### Not task-related

- Technical
- Social
- Nonsense
- No participation

210
## Contact Summary Sheet

**Contact n:o 8**

**Group 5**

**Today's date:**

**Duration:** 14:45-19:32

**Written by:** VTS _63_2a.vo

**Timestamp:**

### What were the main issues or themes that struck you in this contact?

- No participation
- Nonsense
- Social
- Technical
- Individual
- Planning / thinking aloud
- Question
- Explanation
- Support
- Evaluation
- New Idea

### Assignment

<table>
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</thead>
<tbody>
<tr>
<td>8</td>
<td>E</td>
<td>E</td>
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<td>E</td>
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</tr>
</tbody>
</table>

### Comment / Information / Description

- Can we see standard deviation from the calculator? And how exactly?
- Here is frequency then. (The second list in the calculator.)
- You have here on setting List 1 and List 2 and normally one variable over there is standard deviation and sample standard deviation.
- Standard deviation is marked by either little sigma or letter s. One or another is used. It means this is a practical exam and it is marked on paper-up and value comes directly from the calculator.

### Task-related

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>8</td>
<td>E</td>
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<tr>
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<td>Participation</td>
<td>Social</td>
<td>Technical</td>
<td>Individual</td>
<td>Planning / thinking aloud</td>
<td>Questioning</td>
<td>Support</td>
<td>Evaluation</td>
<td>Episode no.</td>
<td>Time</td>
<td>Person or Group</td>
<td>Gender</td>
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<td></td>
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<td>8</td>
<td>T M</td>
<td>x</td>
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<td></td>
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<td>B3 M</td>
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</tr>
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<td></td>
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<td></td>
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<td>8</td>
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### APPENDIX 16 Episode 11, CSS – instrument.

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<td>15.8.2011 15:26</td>
<td></td>
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</tbody>
</table>

**What were the main issues or themes that struck you in this contact?**

Girls have just started to work in a group and their first task is to learn how to use screenshot. They are searching for definitions to statistical concepts which they copy for themselves into electronic form. ICT as well as collected material they will need in their project later. This is their second first session during the course. Girls did not take part in pilot phase in spring.

<table>
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<th>Task type</th>
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</tr>
<tr>
<td>0355</td>
<td>G4 F x</td>
</tr>
<tr>
<td>0420</td>
<td>G3 F x</td>
</tr>
<tr>
<td>0422</td>
<td>G2 F x</td>
</tr>
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<td>G5 F +</td>
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<td>0450</td>
<td>G4 +</td>
</tr>
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<td>G2 F x</td>
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<td>G2 F x</td>
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<td>G3, F</td>
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<td>N or Natural</td>
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<tr>
<td>x 11 1307 G4 F x Now it is in the standard deviation. Hmm. Elsa!</td>
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<tr>
<td>x 11 1317 G2 F + I see. (laughing)</td>
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<tr>
<td>x 11 1322 G5 F x x Just take it off and copy.</td>
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<td>x 11 1410 T M x You can put it in electric form.</td>
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<td>x 11 1640 G3 F x x You can continue with the notation of Sum.</td>
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<td>x 11 1710 G2 F My fingers are frozen.</td>
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<td>x 11 1723 G3 F x It is not there, it has to be first.</td>
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<tr>
<td>x 11 1735 G4 F x Then linear regression.</td>
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<tr>
<td>x 11 1750 G5 F x OK, that's it.</td>
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<tr>
<td>x 11 1755 G2 F x Statistical literacy.</td>
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<tr>
<td>x 11 1810 G6, G5 F x Median, Typical value, Mode...</td>
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<tr>
<td>x 11 1910 G2 F Piece of cake. Today to Hese or KotiPitsa.</td>
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<tr>
<td>x 11 1935 G2 F x Now we should go on this assignment.</td>
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<tr>
<td>x 11 1943 G5, G6 F + Soon we can join the Champions of plagiarism.</td>
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<td>x 11 2010 G3 F x What if it will delete everything?</td>
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<tr>
<td>x 11 2037 G3 F x No wonder?</td>
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</table>
APPENDIX 17 Episode, 35 CSS –instrument.

<table>
<thead>
<tr>
<th>Contact type</th>
<th>Videoanalysis</th>
<th>Contact date:</th>
<th>15.8.2011</th>
<th>Contact Summary Sheet</th>
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<td>Contact n:o</td>
<td>35 Group 3</td>
<td>Today's date:</td>
<td>10.3.2012</td>
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<tr>
<td>Duration</td>
<td>0110-0312</td>
<td>Written by:</td>
<td>Juho</td>
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What were the main issues or themes that struck you in this contact?

Group members are working with an assignment.

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<th>Not task-related</th>
<th>Task-related</th>
<th>Episode n:o</th>
<th>Time</th>
<th>Person or Group</th>
<th>Knowledge</th>
<th>Calculator</th>
<th>Exercise</th>
<th>Assignment</th>
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<td>G7 F</td>
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<td>G7 F</td>
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</tbody>
</table>

Comment / Information / Description

- And how about the height and shoe size, do they correlate?
- (Participates by spelling) "Correlate"
- Correlate!
- So after that, it is defined.
- Especially with boys.
- So, we just calculated them here (and points out the Excel chart)
- And especially in the way that …
- Ok, was it a year that came over here? (And points out the screen.)
<table>
<thead>
<tr>
<th>Time mm:ss</th>
<th>Comment / Information / Description</th>
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<tbody>
<tr>
<td>0101</td>
<td>&quot;0101&quot;</td>
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<tr>
<td>0130</td>
<td>Yes, as a result of bigger sample.</td>
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<tr>
<td>0142</td>
<td>What is the difference between observation data and results? (She asks when teacher walks by.)</td>
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<tr>
<td>0145</td>
<td>The results present something from the data. And the sample of data processing is how they are calculated.</td>
</tr>
<tr>
<td>0153</td>
<td>Ok, yes.</td>
</tr>
<tr>
<td>0158</td>
<td>I cannot write here anymore ...</td>
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<tr>
<td>0205</td>
<td>Does anyone have the MAOL: table book?</td>
</tr>
<tr>
<td>0206</td>
<td>For example, if we consider that here (on the computer's screen) could in principle be observable data: length of the shoe size. Observation data processing, in turn, formed the regression</td>
</tr>
<tr>
<td>0238</td>
<td>Weaker, but it may be in that correlation ...</td>
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<tr>
<td>0239</td>
<td>Talk with each other, and do not take part in the collaboration in this episode.</td>
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<tr>
<td>0240</td>
<td>The correlation is likely to be weaker because ... there is dispersion in the regression line.</td>
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<tr>
<td>0305</td>
<td>From both that is put in there (points out the PC screen.)</td>
</tr>
<tr>
<td>0310</td>
<td>8 and then 9!</td>
</tr>
</tbody>
</table>
154. Pudas, Anna-Kaisa (2015) A moral responsibility or an extra burden?: a study on global education as part of Finnish basic education
157. Sitomaniemi-San, Johanna (2015) Fabricating the teacher as researcher: a genealogy of academic teacher education in Finland
159. Kinnunen, Susanna (2015) How are you?: the narrative in-between spaces in young children’s daily lives
162. Watanabe, Ryoko (2016) Listening to the voices of dementia: the therapist’s teaching-learning process through co-construction of narrative and the triadic relationship with Alzheimer’s disease sufferers
166. Sulkakoski, Marjut (2016) ”Ihan vaan perussiat pitää osata hyvin”: ammatikorkeakoulujen insinööriopiskelijoille lukion kokemusten pohjalta rakentunut matematiikkakoulu

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TECHNOLOGY-ENHANCED STATISTICS LEARNING EXPERIMENT

A CASE STUDY AT UPPER SECONDARY LEVEL