Tampere University

MERJA KUISMA

Bliss and Curse of Autonomy

Implementing Inquiry Learning in a Domain-Specific and Cross-Curricular Context

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ACADEMIC DISSERTATION
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To my amazing daughters Jenni and Katariina.

Real learning requires stepping into the unknown, which initiates a rupture in knowing.
Schwartzman, 2010, p. 38

CONTENTS

ACKNOWLEDGEMENTS

I sit here typing this last chapter to my dissertation with a sense of relief, bittersweet yearning, and deep gratitude. My path into the world of scientific research and different views of education has opened a new world with new friends for me and, I am sure, I have much more to offer to my students and teacher trainees from now on. Like every other researcher, I have also gained from the knowledge, skills, and understanding that talented researchers have shared with us. I could not have done this journey alone, and there are many amazing people I want to express my warmest gratitude to.

Firstly, I want to thank my supervisor Petri Nokelainen for not only listening to my ideas but for actually hearing what was in my heart and giving my ideas space to become real and boundaries for not getting entirely lost. I owe you for being my trustworthy guide when choosing a path in the puzzling crossroads and finding new horizons in how people learn. Without your support in the quantitative sections of the study, this dissertation would look quite different. It was a pleasure to cowrite with you in our joint article. You have been the bedrock underlying the whole dissertation process.

One of the obstacles I met was the absence of the faculty of geography or biology in the Tampere University, which results in not having a university lecturer of didactics of these subjects. Fortunately, I found an incredibly talented researcher and university lecturer of didactics of geography in the University of Jyväskylä, moving later to the University of Lapland: Ilkka Ratinen. In times of confusion, our discussions helped me to get back on track and get inspired again. Thank you for sharing the love for geography and teaching its wonders and reasoning for children and adolescents. Our long talks during the joint writing process were not only educational but also empowering. I have been extremely lucky to have found you.

When I was struggling with the analysing phase of the first narrative interview data, there was one person who took the time to listen. I thank Jari Eskola for valuable questions and encouragement. I also want to thank Jonna Kangas with all my heart for being an inspiring example of a talented, self-reliant, and determined educational researcher and for reassuring me of the possibility to implement quantitative research elements in my educational research.

Pirjo Nikander, Johanna Ruusuvuori, and Matti Hyvärinen introduced me with their invigorating lectures to the qualitative research orientation and analysis of interview data. For a novice researcher who has only applied quantitative research methods when investigating the habitat selection of the hazel grouse (*Bonasa bonasia*), this was ground-breaking. Together with studies of ontological and epistemological issues, I realized how different realities can exist and how you can study them. Without Petteri Eerola's humane wisdom and guidance in the intriguing field of narrative inquiry, this dissertation would not be the same. He opened up the world of narratives and their stories with events, existents, and discourses in a lively and compelling way. Our discussions changed my worldview in a profound way.

It is my privilege to work with adolescents who are discovering the surrounding world and seeking to find their place in the society in middle school and as young adults during their time in upper secondary school. Their openness to discover new terrain from points of view of a variety of disciplines never ceases to amaze me. Thank you all who volunteered to participate in these studies; I am forever thankful to each one of you for believing in me as a teacher *and* as a researcher.

Only a few know the hardships that subject teachers in middle school and upper secondary school face every day. My life would not be the same without the support and friendship of my closest colleagues and friends Tiina Wiklund, Maarit Virnes, and Raija Lehtonen. These amazing ladies rock my world. Special thanks to Irma Kakko, Terhi and Tapani Koskinen, Kaisa Makkonen and Timo Kiira, who have stood by me and supported this scientific project every step of the way. I was very fortunate to meet with many incredibly talented young scholars along the way, and I am deeply grateful for all our lively discussions. Special thanks to the amazing Vappu Susi and Samuli Nordberg for sharing the dilemmas of the scientific writing process, suggesting diverse viewpoints to philosophical questions, and, of course, for being there for me in our countless morning sessions.

As is often the case in this kind of writing, the most important ones are mentioned last. Without the joy and inspiration given by my magnificent daughters, this, or anything else for that matter, would not have been accomplished. Our youngest daughter, Katariina, helped tremendously at the age of 12 with organizing hundreds of paper questionnaires, and our eldest daughter Jenni by helping with the organizing and digitalization phases, and patiently discussing English grammar with her mother. Jenni's artistic talent and aesthetic eye are evident in the drawings of this dissertation summary. You two truly are the light of my life, and I have no words to describe the love and wonder I feel for you. And Mika, thank you for taking care of the household when I was hopelessly immersed in the world of science. You are the love of my life.

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ABSTRACT

This dissertation consists of three case studies presented in three scholarly articles: (1) Effects of progressive inquiry on cognitive and affective learning outcomes in adolescents' geography education, (2) Narratives of inquiry learning in middle school geography when studying with geographic inquiry, and (3) Students' narratives and conceptual changes in a cross-curricular inquiry-based study unit in a Finnish upper secondary school. The first article is written together with Petri Nokelainen and the third together with Ilkka Ratinen. There is also a nonpublished section encompassing results from the second and third case study concerning digitalization in a learning context.

All three case studies deal with inquiry-based learning. Inquiry learning has for a long time been regarded as one of the beneficial approaches when designing pedagogical models for understanding science, its concepts, phenomena, and methods. Inquiry learning has been implemented, not only for science teaching, but for other disciplines' education as well and for non-domain specific, cross-curricular studies. For this dissertation, three different pedagogical models for inquiry learning were designed. They are based on the progressive inquiry model developed by Kai Hakkarainen and Sami Paavola and two of them were designed for geography education in middle school and upper secondary school, and the third one applies a two-level inquiry model specifically designed for a cross-curricular study unit in upper secondary school.

The first case study investigated the progressive inquiry model's effects on cognitive learning outcomes and motivation level in two different developmental stages: adolescents in middle school and upper secondary school. Geography offers a great context for studying inquiry learning, because it is a school subject that enhances skills to acquire information, analyse, transform, construct, and compare knowledge. A quasi-experimental design was applied to compare inquiry learning classes' cognitive learning outcomes and motivation level with classes that were taught in a more teacher-centred model. The results show that cognitive learning outcomes were improved at both education levels, and the older students profited even more than the middle school students. Moreover, previous self-regulated learning (SRL) skills had no effect on cognitive outcomes, hence the necessary

regulation skills were adopted during the course. Inquiry learning affected motivation levels positively in the middle school context.

The second and third case studies indicate that narrative interview is well-suited for collecting data in the form of narratives from adolescents 14 to 15 and 17 to 18 years of age. The results of these two case studies' narrative analysis and analysis of narratives were in line with previous studies indicating that, in middle school and upper secondary school, learners with positive and realistic self-efficacy beliefs and good SRL skills benefitted from the high level of autonomy provided by inquiry learning. This was suggested by the dominant narrative identified in the datasets. The first counter-narrative in two educational levels resembled each other, as both depicted a learner struggling with SRL skills at all three levels, namely cognition, motivation, and behaviour. These students fell behind schedule and found forming research questions relevant to oneself difficult, and their teacher failed to support these students' self-regulatory process. Therefore, secondary school students also need more practice to engage in scientific thinking. The second counter-narrative varied a lot between the two datasets; in middle school it portrayed a learner who had excellent SRL skills but insisted on studying alone, whereas in upper secondary school it depicted a learner with excellent negotiating skills but poor effort regulation skills.

The third case study differed from the first and second one by the context, as the studied course is not geography or any other single school subject, but a cross-curricular study unit. Moreover, it adds a point of view of personal achievement goal orientation to investigate how a learner's goal orientation relates to the SRL skills and academic learning outcomes, such as conceptual changes. The results of the narrative analysis and analysis of narratives are in line with the second case study's results, as the dominant narrative described a learner whose goal orientation is either mastery or a performance approach, and they benefit from the autonomy of inquiry learning. A learner with a performance approach benefits from inquiry learning mostly by achieving high-level performance in the course tasks (portfolio and concept map), whereas the mostly mastery-oriented learners do not excel in the written performances but showcase conceptual change and threshold concepts in the interview, as they prioritize deeper thinking and competence in understanding the concepts and phenomena over recording their ideas in a portfolio. Additionally, the third case study suggests that multimodal assessment is needed to assess the concept perception and conceptual changes that take place in a cross-curricular context. In the third case study, the joint artwork served as an excellent assessment

tool, as it highlighted how learners had learned perspectives from different school subjects and how they combined them.

Keywords: action research, cross-curricular approach, geography education, inquiry learning, self-regulated learning skills

TIIVISTELMÄ

Tämä väitöskirja koostuu kolmesta artikkelista, joista kukin esittelee yhden tapaustutkimuksen: (1) Effects of progressive inquiry on cognitive and affective learning outcomes in adolescents' geography education, (2) Narratives of inquiry learning in middle school geography when studying with geographic inquiry, sekä (3) Students' narratives and conceptual changes in a cross-curricular inquiry-based study unit in a Finnish upper secondary school. Ensimmäinen artikkeli on kirjoitettu yhdessä Petri Nokelaisen kanssa ja kolmas yhdessä Ilkka Ratisen kanssa. Lisäksi esitellään toisen ja kolmannen tapaustutkimuksen julkaisemattomat tulokset koskien opetuksen digitalisoitumista.

Kaikki kolme tapaustutkimusta käsittelevät tutkivaa oppimista. Tutkivaa oppimista on pitkään pidetty yhtenä hyödyllisistä lähestymistavoista suunniteltaessa pedagogisia malleja luonnontieteen opetukseen käsitteiden, ilmiöiden ja menetelmien oppimista varten. Tutkivaa oppimista on jo ennestään toteutettu paitsi luonnontieteiden opetuksessa myös muiden tieteenalojen opetuksessa sekä monialaisissa opinnoissa. Tätä väitöskirjaa varten suunniteltiin kolme pedagogista mallia, jotka pohjautuvat Kai Hakkaraisen ja Sami Paavolan kehittämään tutkivan oppimisen malliin. Tämä väitöskirja esittelee toteutusmallin käytettäväksi yläkoulun ja lukion maantieteen opetuksessa sekä lukion monialaisessa opetuksessa.

Ensimmäisessä tapaustutkimuksessa selvitettiin tutkivan oppimisen vaikutuksia kognitiivisiin oppimistuloksiin ja motivaatiotasoon kahdessa nuoren eri kehitysvaiheessa: yläkoulussa ja lukiossa. Maantiede tarjoaa loistavat puitteet tutkivaan oppimiseen, koska se on kouluaine, joka parantaa taitoja hankkia, analysoida, muokata, rakentaa ja vertailla tietoa. Kokeellisella tutkimuksella verrattiin tutkivan oppimisen interventioryhmien kognitiivisia oppimistuloksia ja motivaatiotasoa kontrolliryhmiin, joita opetettiin perinteisemmällä, opettajakeskeisemmällä opetusmenetelmällä. Tulokset osoittavat, että kognitiiviset oppimistulokset olivat parempia interventioryhmissä sekä yläkoulun että lukion puolella, ja että vanhemmat oppilaat hyötyivät vielä enemmän kuin yläkoulun oppilaat. Lisäksi havaittiin, että aikaisemmat oppimisen itsesäätelytaidot eivät vaikuttaneet kognitiivisiin tuloksiin, joten tarvittavat säätelytaidot opittiin kurssin

aikana. Tutkiva oppiminen vaikutti myönteisesti yläkoulun oppilaiden motivaatiotasoon.

Toinen ja kolmas tapaustutkimus osoittavat, että narratiivinen haastattelu ja narratiivinen analyysi sopivat hyvin 14–15-vuotiaita ja 17–18-vuotiaita nuoria koskevaan tutkimukseen. Näiden kahden tapaustutkimuksen narratiivien ja narratiivisen analyysin tulosten mukaan yläkoulussa ja lukiossa oppijat, joiden minäpystyvyyden uskomukset ovat myönteisiä ja realistisia ja joilla on hyvät oppimisen itsesäätelytaidot, hyötyvät tutkivan oppimisen mahdollistamasta korkeasta autonomiasta. Tämä ilmeni molempien tapaustutkimusten vallitsevana narratiivina. Yläkoulun ja lukion aineistosta löytynyt ensimmäinen vastakertomus muistutti toisiaan, koska molemmat kuvaavat oppijaa, joka kamppailee oppimisen itsesäätelytaitojen kanssa kaikilla kolmella eli kognition, motivaation ja käyttäytymisen säätelyn tasolla. Nämä opiskelijat eivät pysyneet aikataulussa ja pitivät itselleen tärkeiden tutkimuskysymysten muodostamista vaikeana, eikä heidän opettajansa tukenut riittävästi näiden oppilaiden oppimisen itsesäätelyprosessia. Näin ollen myös lukion opiskelijat tarvitsevat enemmän harjoittelua oppiakseen tieteellistä ajattelua. Toinen vastakertomus vaihteli suuresti yläkoulun ja lukion välillä; Yläkoulussa se kuvaa oppijaa, jolla on erinomaiset oppimisen itsesäätelytaidot, mutta vaatii saada opiskella yksin, kun taas lukiossa se kuvaa oppijaa, jolla on erinomaiset neuvottelutaidot, mutta heikko oppimisen eteen ponnistelun säätelytaito.

Kolmas tapaustutkimus poikkesi ensimmäisestä ja toisesta kontekstinsa puolesta, koska tutkimuksen kohteena ei ollut maantiede tai muu yksittäinen oppiaine, vaan monialainen opintojakso. Lisäksi se antoi uuden näkökulman henkilökohtaiseen tavoiteorientaatioon tutkiessaan, miten oppijan tavoiteorientaatio liittyy oppimisen itsesäätelytaitoihin ja akateemisiin oppimistuloksiin, kuten käsitteellisiin muutoksiin. Narratiivien analyysin ja narratiivisen analyysin tulokset ovat yhdenmukaisia edellisen tapaustutkimuksen tulosten kanssa, koska vallitseva kertomus kuvaa oppijaa, jonka tavoiteorientaatio on joko oppimishakuinen tai suoritusorientaatio ja joka hyötyy tutkivan oppimisen tarjoamasta autonomiasta. Suoritusorientaation omaava oppija hyötyi tutkivasta oppimisesta lähinnä suoriutumalla erinomaisesti kurssitehtävissä (portfolio ja käsitekartta), kun taas oppimishakuiset oppijat eivät menestyneet kirjallisissa suorituksissa vaan haastattelun paljastamissa korkeamman ajattelun taidoissa, joka ilmeni käsitteellisinä muutoksina ja kynnyskäsitteiden oivalluksina. Oppimishakuiset oppijat asettivat etusijalle ajattelun syventymisen ja laajemman ymmärryksen käsitteiden ja ilmiöiden ymmärtämisessä kuin ideoidensa dokumentoinnin kurssisuoritteisiin. Kolmas tapaustutkimus viittaa näin ollen siihen, että tarvitaan multimodaalista arviointia, jos halutaan huomioida ajattelun taitoja

kurssiarvioinnissa. Yhteistaideteos toimi kolmannessa tapaustutkimuksessa erinomaisesti arvioinnin välineenä, sillä se toi esiin, miten oppijat olivat oppineet eri oppiaineiden näkökulmia ja miten he yhdistivät niitä.

Avainsanat: maantieteen opetus ja oppiminen, monialainen opetus ja oppiminen, oppimisen itsesäätely, toimintatutkimus, tutkiva oppiminen

ABBREVIATIONS AND DEFINITIONS

AR, action research: rigorous practice-based research, which integrates theory and practice in a seamless way but with a critical view on both and their relationship. Additionally, progressing action is a key element of the research process, where strategic planning is followed by implementing the plan by action, observation, assessment, and self-critical reflection resulting in planning the next phase. I–III

belief revision: entails changes in learners' beliefs or in the perception of a theory. In belief revision, beliefs are tied to and constrained by certain ontological and epistemological presuppositions. Therefore, beliefs instead of smaller fragmented conceptual structures create a uniform structure. III

concept: perceived regularity or pattern in events or objects, or records of events or objects, that have been named. New information is linked with concepts in cognitive structure. III

conceptual change: shifting a concept from one ontological tree to another. III

conceptual enrichment: entails adding new information to existing conceptual structures. III

CR, critical realism: a branch in the philosophy of science that is mostly applied in social sciences to understand, critique, and suggest solutions for social conditions, but, as in this dissertation, it has been used in educational research as well. I–III

cross-curricular approach: approach to teaching that is characterized by understanding and synthesis of knowledge and skills from various school subjects. These compose an enriched pedagogy with various methods that promotes an approach to learning which embraces and explores all involved subjects. Similar to a multidisciplinary approach, a cross-curricular approach maintains the identity of each subject as a separate field of study while serving student learning across disciplines around a joint theme or idea. III

digitalization: this concept is not precise; in this dissertation it refers to the rapid technological developments of the past decades. Social networking software has changed the ways people communicate, receive information, learn, and work with

others. Digitalization involves the high-speed wireless networks, interactive whiteboard, smartphone, laptop, tablet computer, and other devices as well as "digital learning". Digital learning is regarded as the pedagogical implementation of digital devices, software, applications, and learning environments. I–III

discipline: academic discipline is a field or branch of learning affiliated with an academic department within a university, formulated for the advancement of research and scholarship and the professional training of researchers, academics, and specialists. III

geographic inquiry: specific features of inquiry learning in the context of geography that entail (1) human and physical phenomena and their associated relations, (2) geospatial reference systems such as events, places, and regions, (3) the spatial perspective, and (4) geographic vocabulary. I–II

inquiry learning: inquiry learning consists of (1) orientation and question making, (2) hypothesis generation in a quantitative approach, (3) planning, (4) investigation, (5) analysis and interpretation, (6) model exploration and creation, (7) conclusion and evaluation, (8) communication, and (9) prediction. In this dissertation, four levels of freedom (confirmation, structured inquiry, guided inquiry, and open inquiry) are considered to intertwine with a holistic perspective. I–III

interdisciplinary studies: approach to learning where the subjects are relatively clear in their differences and unique contributions but the emphasis is on the interdisciplinary key concepts (e.g. sustainability), skills (e.g. communication, problem solving), and actions. Interdisciplinarity contrasts to multidisciplinarity in that it constructs a common model for the disciplines involved, based on a process of dialogue between disciplines. III

MSLQ, Motivated Strategies for Learning Questionnaire: a self-reporting instrument that measures regulatory activities of academic learning. I

multidisciplinary studies: approach to learning that is based on a comprehension of many disciplines yet stays within discipline boundaries. In this approach, a central theme is used to organize and correlate the subjects being integrated. III

PALS, the Patterns of Adaptive Learning Scales: questionnaires which derive from a goal orientation theory that tackles the relationship between the learning environment and students' motivation, affect, and behaviour. The questionnaire for students' personal achievement goal orientations was chosen for this study. III

PMLQ, Pedagogically Meaningful Learning Questionnaire: self-reporting instrument that was used for measuring motivation level. I

progressive inquiry: inquiry learning model based on active learning activities with learner-centred teaching strategies. It is a question-driven process of understanding; learning is an expansive process were activities produce new activities and collaborative communities induce innovations. In addition to individual knowledge acquisition processes and learning induced by social interaction, collaboratively created, shared knowledge-laden artifacts can induce learning. I–III

SRL, self-regulated learning: active, constructive process whereby learners set goals for their learning and attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and contextual features in the environment. I–III

subject: to clarify the differences between school subjects and academic disciplines: school subject is an area of learning within the school curriculum that constitutes an institutionally defined field of knowledge and practice for teaching and learning. III

threshold concept: changes one's understanding or interpretation of something. They are gateways for understanding the critical content of a discipline. It transforms the learner to view matters as a biologist, a philosopher, an artist, and so on, whereby perceiving a threshold concept involves both an ontological as well as a conceptual shift. III

worldview: a fundamental set of beliefs that guide action. Some apply concept paradigm, epistemologies and ontologies, or research methodologies as a synonym. I–III

Note. Numbers I–III refer to the case studies, which are explained in the following introductory section.

LIST OF ORIGINAL PUBLICATIONS AND DIVISION OF TASKS AMONG AUTHORS

Publication 1 Kuisma, M., & Nokelainen, P. (2018). Effects of progressive inquiry on cognitive and affective learning outcomes in adolescents' geography education. *Frontline Learning Research*, *6*(2), 1–19. https://doi.org/10.14786/flr.v6i2.309

The independent empirical case study was designed and carried out by the first author Merja Kuisma. Co-author Professor Petri Nokelainen contributed by providing comments to the implementation and analyses of research instruments MSLQ and PMLQ questionnaires and by providing comments and modifications to the introduction section about competence-oriented research. The manuscript was written and submitted by the first author.

Publication 2 Kuisma, M. (2018). Narratives of inquiry learning in middle school geographic inquiry class. *International Research in Geographical and Environmental Education*, *27*(1), 85–98. https://doi.org/10.1080/10382046.2017.1285137

The independent empirical case study was designed and carried out by the author. Manuscript was written and submitted by the author.

Publication 3 Kuisma, M., & Ratinen, I. (2021). Students' narratives and conceptual changes in a cross-curricular inquiry-based study unit in a Finnish upper secondary school. *International Journal of Educational Research*, *110*, 1–14. https://doi.org/10.1016/j.ijer.2021.101889

The independent empirical case study was designed and carried out by the first author, Merja Kuisma. Data collection, analyses of the PALS questionnaire, learning diaries, portfolios, and concept maps were done by Kuisma. Additionally, individual narratives and composite narratives were formulated and analysed by the first author. The co-author, Assistant Professor Ilkka Ratinen, contributed to the analysing phase as both authors read through the transcribed student interviews, thus enabling the comparison of thematic analyses of data. Moreover, Ratinen contributed to the

writing process of the manuscript by providing comments and modifications, particularly in the concept mapping section. The manuscript was written and submitted by the first author.

1 INTRODUCTION

1.1 Motivation for the research

Teaching is driven by a strong intrinsic motivation to help learners to find new paths to think, reason, and feel and to get inspired by what they learn and feel empowered to act upon according to their knowledge. Learning is defined as constructing knowledge that is new to the learner and creating new meanings for objects and events surrounding them near and far (Novak, 2010). During the last 28 years as a subject teacher of biology and geography, I have applied a plethora of different learning and teaching models with various pedagogical practices and tools. Lesson plans are affected by many things, such as nature of the topic, the connection of the topic to current events, the features of the student group and its individual learners, what they already know, and even whether it is an early morning or late afternoon. There are many learning and teaching models that are well-suited for different occasions, but inquiry learning stood out. It seemed to raise the motivation level of learners with both poorer and more advanced academic skills and also the learning outcomes seemed to get fortified more than with other teaching and learning models. After becoming more acquainted with the scientific literature dealing with inquiry learning, and especially progressive inquiry, a study plan was made and specific teaching and learning models started to take form for geography education in middle school and upper secondary school context.

For decades there has been an ongoing public discussion about digitalization of society and what implications it has in the field of education. It was decided to participate in this discussion with this dissertation in the international research forums in order to learn more about it and find out if inquiry learning could contribute to learning the subject matter, digital learning skills, and other skills needed in the digitalized information- and knowledge-based society (e.g. Binkley et al., 2012; Costes-Onishi et al., 2020; Lin et al., 2017; Pauw, 2015) and if digital learning environments could support inquiry learning (e.g. Cerratto-Pargman et al., 2012; Pedaste et al., 2015; Tan et al., 2021). Later on, the cross-curricular approach to learning became topical when the national upper secondary school curriculum

reform was implemented in Finland in the autumn of 2021 (Finnish National Agency for Education, n.d.). That led to broaden the dissertation to design and investigate further an inquiry learning teaching and learning model in a cross-curricular context (Beane, 1997; Savage, 2010). One of the aims of the curriculum reform was to establish a balance between subject knowledge delivery and cross-curricular learning with transversal competence areas such as civic skills and multidisciplinary and creative competence. Thus, contributing to that dialogue as a part of an international research community became one of the objects of this study. This dissertation sets out the theoretical background, methodology, results, and conclusions of this scientific endeavour. Hopefully, both young and more matured learners will get inspiration and understanding of themselves and others as learners and the thrilling world of teaching and learning from this dissertation.

1.2 Case studies of action research

As the researcher is also a subject teacher and the target of investigation involves classroom teaching and learning, and the goal is to develop and improve practices in teaching and learning models, this dissertation depicts an action research where each study constitutes its own step of a cyclical process (Carr & Kemmis, 1986; McAteer, 2013; Zuber-Skerritt, 1996). In this dissertation, action research (**AR**) is defined as rigorous practice-based research which integrates theory and practice in a seamless way but with a critical view on both and their relationship (McAteer, 2013). Additionally, as the concept of AR implies, progressing action is a key element of the research process, where strategic planning is followed by implementing the plan by action, observation, assessment, and self-critical reflection, resulting in planning the next phase (Zuber-Skerritt, 1996). This study represents all three types of AR (Carr & Kemmis, 1986), which are built on the ideas of knowledge-constitutive interests by Habermas (1974) while depicting critical educational science. **Technical** AR aims at increased effectiveness of educational practice and professional development of the teacher-researcher and their teacher colleagues. Because the researcher is co-operating with other participants and encourages others to improve their practices by self-reflection, this study is also **practical** AR. Additionally, the study entails **emancipatory** AR, as the aim is also to liberate the participants from previous traditions of education and transform the educational system, as well as to empower the participants about their ability to solve complex educational problems collaboratively (Carr & Kemmis, 1986). The emancipatory angle is most eminent in

the third case study, as the study unit is being planned, executed, and assessed together with six subject teachers amongst whom the responsibility is being shared equally.

As the researcher is also the familiar teacher to all students who participated in the qualitative studies and to some who took part in the quantitative quasi-experimental study, it is reasonable to consider the pros and cons of this dual role. Usually, AR is carried out by outside researchers (McAteer, 2013), and their academic authority can result as reassuring and calming the participants. On the other hand, the same reassuring and calming effect can be induced by the familiar subject teacher. According to this research, case studies II and III, with the intimate dialogue that a narrative interview is, benefitted from mutual trust and respect as the interviewer was a familiar teacher of biology and geography. The researcher should know well the target of investigation, and the subject teacher is an expert not only in their subject matter and teaching practice or didactics but also in perceiving what the objective of their study is. Additionally, an AR researcher must be aware not to consider familiar everyday things as self-evident but instead consciously see the nature of his or her research target (see Section 3.2; Varto, 1992). One of the aims of this dissertation is to make these everyday phenomena visible, especially for teachers, teacher trainees, and students. As the whole learning community with headmasters, teachers, and students is actively involved in the AR process, democracy at the school level also gets fortified (Huttunen, 2009; Stringer, 2004).

Additionally, teachers often feel that their professional knowledge and judgement are undervalued, as their practices are being investigated by an outside academic (McAteer, 2013). From the point of view of teachers, academic researchers seem to prioritize theory over practice, which may feel like conflicting with teachers' values about practical knowledge that has been constructed by experience of the practice (van Driel et al., 2001; McAteer, 2013). Therefore, teacher colleagues' research may be received more positively. AR regards the underlying theories as an essential, grounding part, of practice (McAteer, 2013). As it seeks to combine theory and practice, epistemologically it should result in revising and clarifying teachers' own beliefs, values, and intellectual reasoning (McAteer, 2013).

As a researcher, after familiarizing myself with the literature of inquiry learning and possible research methods, I reflected on what kind of forethoughts and expectations I had at every stage of the research process: about the events in the classroom when giving instructions to the students, individual learning processes, student collaboration, interviewing situations, and other stages of data collection and analyses. By engaging myself in a dialogue with other researchers, both in the field

of educational research and of different disciplines, I pondered consciously and carefully the ways my life history, and especially my experiences in teaching, had shaped my worldview. As I have adopted both views of natural science and educational research, for example research questions, research design, research methods, and analysing techniques, both quantitative and qualitative orientation were adopted into the research plan (see Section 3.1). Discussions with students and teachers, together with the pilot study, helped to finalize the study plan for the first two case studies. Based on these two case studies, the third one was designed, and the plan for the cross-curricular study unit was complemented by the five other subject teachers. Nevertheless, the researcher can never know exactly what will happen in the phases of collecting or analysing data, as the reality and humans are always more complex as targets of an investigation than expected (Varto, 1992).

All three studies are case studies, one quantitative testing hypothesis by statistical inference, one qualitative and, thus, more in line with the tradition of educational research tradition (Merriam, 1998), and one with a mixed methods research approach. What makes them all case studies is their bounded system (Smith, 1978), as they all study inquiry learning teaching and the learning model in a middle school or upper secondary school context as different stages of AR.

1.3 Objectives, the scope, and research questions

Two different educational stages were chosen: firstly, because self-regulated learning processes are developmental by nature (Loyens, Magda, & Rikers, 2008), and, therefore, comparing two age groups was considered meaningful; and secondly, because there was a research gap in the scientific literature about the inquiry learning implementations among middle school and upper secondary school students (e.g. Costes-Onishi et al., 2020; Furtak et al., 2012). Most of the research investigating learning outcomes when using educational technology have taken place in college (38.4%) and in elementary school (33.9%) where the ages of the children are usually 6-11 years (Sung et al., 2016, p. 257), thus this study aims to clarify the effects among an understudied age group of middle school and upper secondary school students. Secondly, the most often studied subject domains are language arts (34.7%) and science (22.9%) (Sung et al., 2016, p. 257). Science is most often considered to comprise of the subjects physics, chemistry and biology, yet geography or cross-curricular study units are more rarely studied. As we studied a cross-curricular study unit of six school subjects, conceptual changes within each subject and in their

interface were topical. Threshold concepts are in this dissertation seen as the most significant form of changes in conceptual constructs, and it has not been studied in a cross-curricular upper secondary school context before (Flanagan, 2020).

As there is a research gap of teaching and learning models with appropriate scaffolding to support students' development of conceptual understanding, procedural skills and metacognitive capacities (e.g. Costes-Onishi et al., 2020), the main research question **(MRQ)** of this AR dissertation is as follows: **How did the designed models support students' learning?** Inquiry based teaching and learning models were designed and investigated in both domain-specific and cross-curricular study units. The objective was to design research-based teaching and learning models which could fortify the skills that middle school and upper secondary school students need to succeed both in their formal education as well as later in their lives as active citizens of a 21st century knowledge- and information-based society (Costes-Onishi et al., 2020; Hargreaves et al., 2009; Lin et al., 2017; Pauw, 2015; Tan et al., 2021). The Digital Didactical Design (DDD) framework (Jahnke et al., 2017) was applied when designing the didactic processes of the teaching and learning models described in this dissertation. There are three components which interact with each other in the classroom thus contributing to the didactic processes: the teacher, students, and subject matter (Klafki, 1991). Understanding the differences between students' and teacher's activities, and their interaction when aiming to reach the learning objectives included in the curricula is the heart of the concept didactic. According to the didactic principles, without the social relationships and interaction between the students the didactical design would be teacher led instead of student centred (Bell et al., 2005; Lund & Hauge, 2011). This frames the collaborative learner centered teaching and learning models presented in this dissertation (see Section 2.3).

Moreover, digital design refers to different ways of utilizing technology in a didactical design in an almost ubiquitous world of Internet. Integration of technology into teaching and learning shapes the didactical design, while at the same time the didactical design dictates the way technology is being utilized (Jahnke et al., 2017). In this study, Moodle and Microsoft Office Teams were chosen as learning platforms because of their easy access and use for the students. The five design elements for deep and meaningful learning (Jahnke et al., 2017, pp. 2-3) together with their implementation in this study are as follows:

1. Teaching goals and intended learning outcomes (ILO) are clear and visible for students.

2. There are a variety of meaningful learning activities that help students achieve ILOs.
3. Assessment is a process-based form of feedback and evaluation for students to receive guided reflections within the learning process for performance or skill development.
4. Social relations and multiple social roles are supported.
5. Students document, share and reflect on their learning and create student products mainly in digital learning platform Moodle or Microsoft Office Teams.

The 21st century skills entail abilities to inquire and find information, analyse, transform, construct, compare, and experiment with knowledge (e.g. Cerratto-Pargman et al., 2012) and skills related to collaboration, communication, critical thinking, problem solving, creativity, technicality, information management, and self-direction (van Laar et al., 2017; Voogt & Roblin, 2012). These skills entail self-regulated learning (**SRL**) skills of setting goals for their learning and attempting to monitor, regulate, and control their cognition, motivation, and behaviour, constrained by the features in their environment (Pintrich, 2000). From the different constructs of SRL (e.g. Efklides et al., 2018; Pintrich, 2003), this study focuses on motivational and cognitive constructs. Inquiry learning can support both in-depth thinking and SRL skills (Hakkarainen et al., 2004), and self-regulation efficiency has been found to positively affect school achievement from the first years of primary school until adolescence (Bakracevic Vukman & Licardo, 2010; Liew et al., 2008). Thus, this dissertation further addresses the **MRQ** by the sub-research questions **(SRQ) (1): What kind of narratives did middle school and upper secondary school students formulate from the point of view of self-regulated learning?** and **(2) How did these models affect cognitive and affective learning outcomes?**

Geography was chosen to provide a domain-specific context, as it differs from other school subjects due to its analytic and synthetic nature (Leat, 1997; Nagel, 2008; Pauw, 2015); students are challenged with relationships within and between phenomena of human and physical geography, as well as pondering by whom, why, where, when, and how things happen (Leat, 1997, 1998). Hence, geography is well-suited to improving students' higher-order thinking skills. The national curriculum reform for upper secondary school entailed reinforcement of a balance between subject knowledge (Deng, 2013) and cross-curricular learning opportunities (Finnish National Agency for Education, n.d.), and it was decided to design a study unit of six school subjects labelled as "Human being—What am I?" as the third phase of

this AR. The use of visual arts as the means to make a synthesis of other school subjects' viewpoints has rarely studied in upper secondary context (Costes-Onishi et al., 2020). Hence, this research gap was also added to the scope of this dissertation study.

Furthermore, the relationship between **digital learning** (e.g. Zierer, 2019), **goal-setting**, and **proceeding with the tasks** was studied in the second and third case studies, and this is presented as the last SRQ **(SRQ3)** addressing the **MRQ**. The concept of digitalization is not precise. In this dissertation, it refers to the rapid technological developments of the past decades. Social networking software has changed the way people communicate, receive information, learn, and work with others (Tan & Lee, 2018). Digitalization includes the high-speed wireless network, interactive whiteboard, smartphone, laptop, tablet computer, and other devices as well as "digital learning" (Zierer, 2019, p. 2). Digital learning is regarded as the pedagogical implementation of digital devices, software, applications, and learning environments. The aim was to investigate if the digital learning environment, with its specific tools, affected learning processes. The digital learning environments were the same (Moodle or Microsoft Office Teams) that were widely applied in the school in question; thus, they were not specifically chosen or constructed for this study.

To summarize, the research questions (RQs) are as follows:

MRQ How did the designed models support students' learning? (Case study I, II, III)

SRQ1 What kind of narratives did middle school and upper secondary school students formulate from the point of view of self-regulated learning? (Case study II, III)

SRQ2 How did inquiry learning affect cognitive and affective learning outcomes? (Case study I, III)

SRQ3 What was the role of the digital learning environment and digital tools in goal-setting and proceeding with course tasks in an inquiry learning context? (Case study II, unpublished results from case study III)

Table 1. Overview of dissertation aims and research questions.

Dissertation aims and research questions				
Empirical aim for case study I	To investigate statistical relationships between inquiry learning and cognitive and affective learning outcomes in a domain-specific context of geography. MRQ How did the designed models in a domain-specific context of geography support students' learning? SRQ2 How did inquiry learning affect cognitive and affective learning outcomes?			
Empirical aim for case study II	To build understanding on the students' perceptions of inquiry learning and on the relationship between digital learning and inquiry learning in a domain-specific context of geography. MRQ How did the designed model in a domain-specific context of geography support students' learning? SRQ1 What kind of narratives did middle school students formulate from the viewpoint of self-regulated learning? SRQ3 What was the role of the digital learning environment and digital tools in goal-setting and proceeding with course tasks in an inquiry learning context?			
Empirical aim for case study III	To build understanding on the students' perceptions of inquiry learning and on the relationship between digital learning and inquiry learning in a cross-curricular context. MRQ How did the designed model for a cross-curricular study unit support students' learning? SRQ1 What kind of narratives did upper secondary school students formulate from the viewpoint of self-regulated learning? SRQ2 How did inquiry learning affect cognitive and affective learning outcomes? SRQ3 What was the role of the digital learning environment and digital tools in goal-setting and proceeding with course tasks in an inquiry learning context?			
Original publications	MRQ	SRQ1	SRQ2	SRQ3
Publication 1 Case study I	x		x	
Publication 2 Case study II	x	x		x
Publication 3 Case study III	x	x	x	x
Unpublished results Case study III	x			x

Note. The course design for middle school in case study II is the same as in case study I. Case study I also includes the teaching and learning model designed for upper secondary school geography. Nevertheless, the course designs are described in publications 1 and 2, respectively.

2 THEORETICAL FOUNDATION

This study investigates pedagogical models and practices in the field of formal education; hence, the focus is on the processes of human learning, which lay the foundation for theories of teaching. The following theories and aspects of learning and teaching are central for this study and are discussed in more detail: social constructivism, Novak's theory of learning, creating and using knowledge, self-determination theory by Deci and Ryan, Pintrich's motivational expectancy model, inquiry learning, SRL skills, and conceptual change.

2.1 Social constructivism as a theoretical framework for inquiry learning

Constructivism is a theory of knowledge created by Jean Piaget (1968) that argues that knowledge is created subjectively as an interplay between one's prior experiences and conceptions and new ideas. Theory has been developed by many researchers, such as Lev S. Vygotsky (1991) and Albert Bandura (1986), who developed a sociocultural approach to cognitive development and, together with Barry J. Zimmerman (1989), brought self-efficacy to the fore in behavioural and applied sciences, such as educational psychology. Socio-constructivist theories have evolved into various branches of educational philosophies and theories, and it is an umbrella term for many classroom practices such as problem-based learning, phenomenon-based learning, and inquiry learning (Loyens, Rikers, & Schmidt, 2008), of which the last is the focus of this dissertation.

Misleadingly, knowledge is often considered to be static and only comprised of facts that need to be memorized (Bereiter, 2002; Hakkarainen et al., 2004). According to social constructivism, knowledge is not only something that learners assimilate but also knowledge that they accommodate and consciously build, assess the meaning of, and apply in different situations (Bereiter, 2002). Moreover, as individuals require more skills to direct and regulate their cognitive processes, they equally need to share their knowledge and understanding with others in collaborative

ways and learn and create new knowledge together (Hadwin et al., 2018; Hakkarainen et al., 2004).

Constructivism has been embodied in numerous ways, but four core features can always be defined: knowledge construction, cooperative learning, SRL, and the use of authentic problems in education (Loyens, Rikers, & Schmidt, 2008). Knowledge construction comprises of combining prior information with new information and its interpretation. Furthermore, in cooperative and collaborative learning, learners' social interaction and especially negotiation enhance their knowledge acquisition processes (Hakkarainen et al., 2004; Loyens, Rikers, & Schmidt, 2008). The third structure, SRL, is seen as the key to successful learning, and it is composed of goal-setting, metacognition, and self-assessment. Furthermore, authentic problems are meaningful, complex problems that make learning situations more similar to real-life, which promotes the transfer of knowledge. Constructivist learning environments have been described as quite challenging to students, as they are required social skills and self-regulated knowledge constructors (Loyens, Rikers, & Schmidt, 2008). Hence, some students may experience this as a positive challenge, but others may feel uncertainty and confusion (Duke et al., 1998).

2.2 Learning, creating, and using knowledge

This dissertation is in line with Novak's (2010) theory of learning, creating, and using knowledge, which is based on the following proposition:

> The central purpose of education is to empower learners to take charge of their own meaning making. Meaning making involves thinking, feeling, and acting, and all three of these aspects must be integrated for significant new learning, and especially in new knowledge creation. (p. 13)

In another words, this can be regarded as addressing the importance of learners' engagement and skills of effort regulation, other aspects of behaviour regulation, and SRL skills, which will be discussed later in this section. Additionally, educational content must be conceptually rich and challenging (Hakkarainen et al., 2004; Novak, 2010). This enables engaged learners to cognitively reorganize their prior knowledge to accommodate the new knowledge. The concept map is one tool that can be used to make meaning making and knowledge reorganization visible, thus enabling both the enhancement of metacognitive knowledge and skills (Pintrich & McKeachie, 2000; Vermunt & Verloop, 1999) of the learner, and the valid assessment of learning

(Novak, 2010; Åhlberg, 2018). A concept map consists of concept terms, which can be regarded as nodes in a hierarchical network of knowledge. These nodes are connected by lines that are labelled with explanations of the relationship, and only with a claimed connection (proposition) can the linked concepts be regarded as meaningful structures and parts of the surrounding world (Åhlberg, 2018). Concepts are defined as perceived regularities or patterns in events or objects, or records of events or objects, designated by a label (Novak, 2010, p. 25). Concepts belong to the learner's cognitive framework and are shaped by a person's actions and emotions (Novak, 2010); in other words, experiences in a person's life modify the meanings of his or her concepts.

Novak's (2010) theory is based on Ausubel's (1968) idea of meaningful learning, which occurs only when the learner chooses to actively seek for a way to integrate new information with existing information in one's cognitive structure. Meaningful learning is considered as the opposite of rote learning. Novak criticizes the inquiry learning approach by stating that it is unlikely that students discover the concepts that some genius individuals have discovered long before them, no matter how well instructed. He suggests focusing on meaningful learning instead of inquiry learning. However, he names concept mapping and scientific research as examples of meaningful learning (Novak, 2010, p. 64), and inquiry learning strives to mimic the scientific research procedure with specific stages such as formulating research questions (Paavola & Hakkarainen, 2005). Hence, inquiry learning—the way it is defined in this dissertation—can be regarded as meaningful learning (see also Costes-Onishi et al., 2020).

One of the objectives of the designed course tasks was to make learning processes and learning outcomes visible for learners and their teacher. Hattie (2009, p. 238) defines visible teaching/visible learning as a two-way model: when teachers see learning through the eyes of the student, and when students see themselves as their own teachers. The students were guided in each case study to compare their original study plans to their finalized portfolios or course leaflet, which were considered as outcomes to make their learning visible. In the third case study, concept maps were also used as tools for making learning processes visible; hence, they helped the students, teachers, and researchers to monitor learning processes that concern certain sets of objects or events. Furthermore, individual learning processes can be perceived as separate from the processes and outcomes that create and improve public knowledge, thus helping learners to also see their study task as part of a society-wide and worldwide effort to create and advance knowledge (Tan et al., 2021).

2.3 Inquiry learning as a teaching and learning model to achieve the learning objectives and to strengthen self-regulated learning skills

Collaborative inquiry learning is a pedagogical model of teaching and learning where students engage themselves in SRL activities in groups, supported by their teacher (Bell et al., 2010, p. 349). Defining inquiry learning explicitly is impossible, as researchers apply different attributes to define it (Cuevas et al., 2005). From the point of view of science (Quintana et al., 2004, p. 341), inquiry has been defined as "the process of posing questions and investigating them with empirical data, either through direct manipulation of variables via experiments or by constructing comparisons using existing data sets". This dissertation agrees with Bell's and his colleagues' (2010) suggestion that data mentioned in this definition should entail both quantitative as well as qualitative data. This study is also in line with the definition suggested by the US National Science Education Standards (NRC, 1996):

> Learning science is an active process. Learning science is something students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others. … Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers. Students establish connections between their current knowledge of science and the scientific knowledge found in many sources; they apply science content to new questions; they engage in problem solving, planning, decision making, and group discussions; and they experience assessments that are consistent with an active approach to learning. (p. 20)

Pedaste and his colleagues (2015) have studied different pedagogical models of inquiry-based learning and summarized five core phases: orientation, conceptualization, investigation, conclusion, and discussion. Their categorization also helps to better comprehend the two cyclical models underlying this study: the nine inquiry processes depicted by Bell and colleagues (2010) are (1) orientation and question making, (2) hypothesis generation, (3) planning, (4) investigation, (5) analysis and interpretation, (6) model exploration and creation, (7) conclusion and evaluation, (8) communication, and (9) prediction. These processes are quite similar to the progressive inquiry model (Figure 1; Muukkonen et al., 1999), which consists of nine steps: (1) creating a context for learning/cognitive commitment, (2) goal-setting, (3) determining the research questions, (4) constructing working theories, (5) searching and (6) deepening knowledge, (7) conducting a critical assessment of knowledge advancement, (8) sharing expertise, and (9) formulating clarifying

questions and constructing new working theories as a result of conceptual restructuring. Constructing working theories of progressive inquiry entails forethought or hypothesis formation and constructing their own theories based on the background information (Muukkonen et al., 1999; Scardamalia & Bereiter, 1993). By characterizing logical processes in their working theories, learners explain new phenomena and extend understanding; thus, this phase resembles Bell's and colleagues' (2010) phases of model creation and prediction. The progressive inquiry's search for information and knowledge is considered as a time-limited event or task, whereas deepening knowledge is a long-term process.

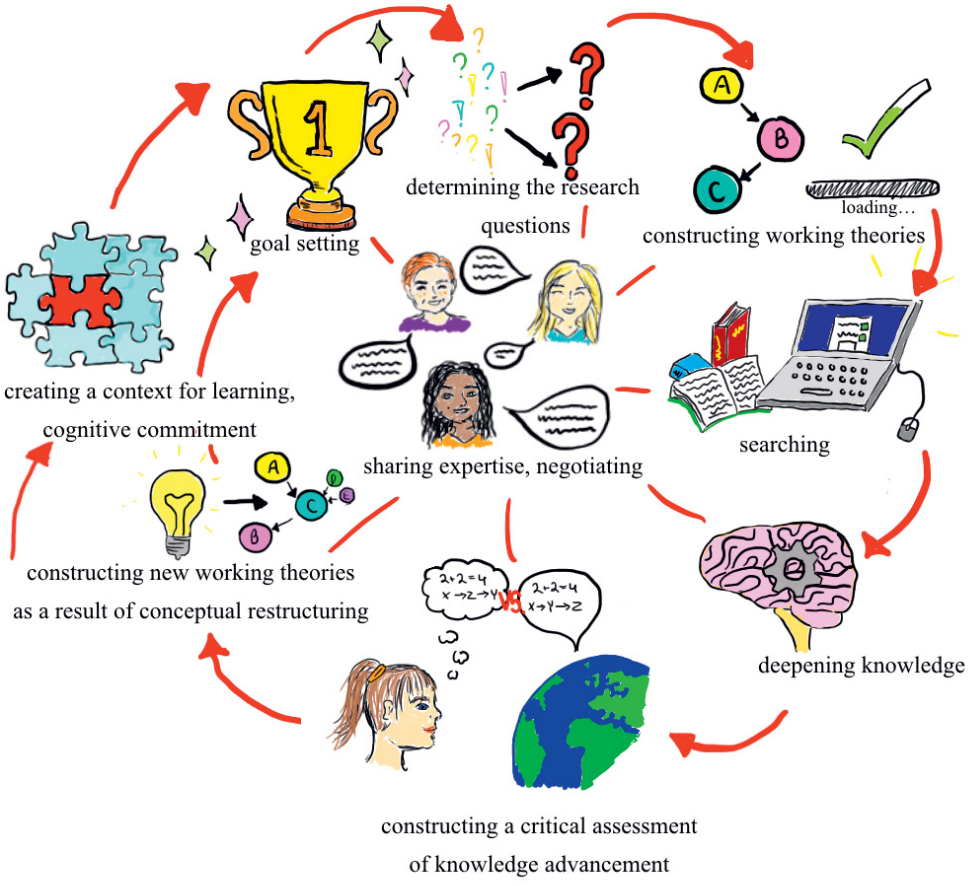

Figure 1. Cyclic model of progressive inquiry (modified from Muukkonen et al., 1999).

As illustrated in Figure 1, communication is at the centre of progressive inquiry. Communication and reflection are potentially present at every phase of the inquiry cycle (Pedaste et al., 2015).

The level of freedom left for the learner varies a lot between the inquiry learning models, and there is often a description of the steps or cycles that students are guided to proceed with (Bell et al., 2010). On the other hand, there are also models that give a lot of freedom to the learner, such as the "knowledge building" approach by Scardamalia and Bereiter (1991), which considers inquiry learning as an unpredictable and holistic (not domain specific) process undertaken by a community of learners. In this dissertation, the holistic approach is considered to intertwine with the four-level model introduced by Bell and his colleagues (2005), as it can be seen as "open inquiry". Also, when a group of learners gets engaged with inquiry learning, no matter what the openness level is, there is always an opportunity that results surprise both learners and their teacher.

The four-level model (Bell et al., 2005, pp. 31–32) illustrates how inquiry-based activities' openness can range from highly teacher-directed to highly student-centred, based on the amount of information given to the student. In addition to the openness of the inquiry learning activities, there is also variation in the complexity. In openness level 1, labelled as "confirmation", students confirm a scientific principle through an activity in which the results are already known to them. In openness level 2, labelled as "structured inquiry", students investigate a question provided by their teacher through a prescribed procedure. In openness level 3, labelled as "guided inquiry", students investigate a question provided by their teacher using procedures designed or selected by students. In openness level 4, labelled as "open inquiry", students form their own questions to investigate the given topic using procedures designed or selected by students. These four openness levels are quite similar to Novak's (2010, p. 64) instruction levels according to the level of autonomy given to the learner. Instead of four levels, Novak suggests three levels: reception instruction, guided discovery instruction, and autonomous discovery instruction. In both sets of scales, the need to use SRL skills increases towards the end of the scale. These similarities support the suggestion that Novak's meaningful learning can be regarded as a form of inquiry learning.

Additionally, all three case studies' pedagogical models were designed to implement the four cornerstones that construct the theoretical foundations of progressive inquiry (Paavola & Hakkarainen, 2005): (1) the knowledge-building theory of intentional learning and expertise (e.g. Bereiter, 2002; Scardamalia, 2002), (2) the interrogative model of inquiry (Hintikka, 1982, 1985), (3) the theory of

expansive learning (Engeström, 1999), and (4) the model of knowledge-creating companies (Nonaka & Takeuchi, 1995). This entails that inquiry learning includes active learning activities with learner-centred teaching strategies. It is a question-driven process of understanding; learning is an expansive process were activities produce new activities and collaborative communities induce innovations. In addition to individual knowledge acquisition processes and learning induced by social interaction, progressive inquiry suggests that collaboratively created, shared knowledge-laden artifacts such as an exhibition in a tourism fair (case study I), a course leaflet (case study II), or a joint artwork (case study III) can also induce learning (Paavola & Hakkarainen, 2005).

Collaborative assignments in education are demanding, as groups need to cope with various tasks while coordinating between diverse learners as they attempt to achieve a shared understanding in a joint task (e.g. Bakhtiar et al., 2018; Hadwin et al., 2018; Malmberg et al., 2015). Collaborative learning can be examined from, for example, the cognitive perspective (e.g. Hmelo-Silver & Barrows, 2008) or motivation and emotions (e.g. Efklides, 2018; Järvenoja et al., 2020), which both fall into the scope of this study. Socially shared regulation of learning emerges when individuals negotiate shared task perceptions, goals, plans, and strategies (e.g. Malmberg et al., 2015), and it entails shifting regulatory ownership from individual (SRL) to group (Hadwin et al., 2018).

Figure 2. The key concepts, models and theories attached to collaborative inquiry learning central to this dissertation.

The main aspects of inquiry learning that are the focus of this dissertation are illustrated as roots, tree trunk, and canopy in Figure 2. Like learning processes, parts of a tree together with nutritious soil constitute a highly interactive and dynamic system. There is a plethora of theories, models, and ideas with different aspects for SRL skills to be derived from, and they are illustrated as roots. Some aspects might be placed as both roots and canopy, and the choice was made according to the logic of the dissertation design. The knowledge-building theory of intentional learning and expertise (e.g. Bereiter, 2002; Scardamalia, 2002), the interrogative model of inquiry (Hintikka, 1982, 1985), the theory of expansive learning (Engeström, 1999), and

collaboration together with socially shared regulation (Hadwin et al., 2018) can be seen as part of the rootstock from where SRL skills and inquiry learning rises. Individual and society's values and norms (e.g. Wigfield & Eccles, 2000) are considered to affect learners' SRL skills together with their self-efficacy beliefs (Bandura, 1989; Elliott & Dweck, 1988; Pintrich et al., 1993; Pintrich & McKeachie, 2000) and self-schemata (Wigfield & Eccles, 2000). Just as roots can intertwine, values and norms are intertwined with self-schemata. The main body, the tree trunk, with its main branches, will be discussed further in the next chapter.

2.4 Self-regulated learning skills to be strengthened by inquiry learning

Self-regulated learning has been considered as the key to successful learning, and it has been seen to compose of goal-setting, metacognition, and self-assessment (Loyens, Magda, & Rikers, 2008; Panadero, 2017). This dissertation concentrates on the cognitive, motivational, and behavioural aspects of SRL and applies a precise model introduced by Pintrich (e.g. 1988; 2000) and further developed by Wolters and his colleagues (2003), where four aspects are identified concerning SRL. Firstly, learners are considered as active constructive participants in the learning process. As in constructivist learning theories in general, learners are not seen as passive recipients of information from teachers but as active knowledge-creative meaning-makers who construct their own meanings, goals, and strategies from both the information that surrounds them and the information of their own minds.

Secondly, learners are able to monitor, control, and regulate their own cognition, motivation, behaviour, and environmental factors, but it is not a constant characteristic in a person (Wolters et al., 2003). There are developmental, contextual, and individual difference constraints that can influence individual efforts at regulation. Thirdly, SRL involves an assumption that learners set goals or standards for their learning and monitor their progress (Wolters et al., 2003). Furthermore, they will then adapt and regulate their cognition, motivation, and behaviour when striving to reach these goals. Lastly, self-regulation of one's cognition, motivation, and behaviour are considered as mediators between individual characteristics, context, and learning outcome (Wolters et al., 2003). Constructivist learning environments are quite challenging to students as they are required social skills and self-regulated knowledge constructors (Loyens, Magda, & Rikers, 2008). Hence, as

argued by Duke and her colleagues (1998), some students may experience this as a positive challenge, but others may feel uncertainty and confusion.

SRL has four areas, each of which can have four phases (Wolters et al., 2003). The four areas are cognition, motivation, behaviour, and context. The four phases than can take place in each of the four areas of regulation are (1) forethought, planning, and activation; (2) monitoring; (3) control; and (4) reaction and reflection. Not all the phases are present in all academic learning processes, but there is strong scientific evidence for their existence (Wolters et al., 2003). Additionally, the phases are not always linear or hierarchical, and they can occur simultaneously and dynamically.

As Wolters and his colleagues (2003) focused on investigating the regulatory activities of one's learning, they introduced relevant measurement scales for the third phase, control, and these scales were applied in the Motivated Strategies for Learning Questionnaire (**MSLQ**) instrument of this study. These scales are:

> Cognition: rehearsal, elaboration, organization, and metacognitive regulation
>
> Motivation/Affect: mastery self-talk, extrinsic self-talk, relative ability self-talk, relevance enhancement, situational interest enhancement, and self-consequating
>
> Behaviour: effort regulation, time/study environment, and help-seeking

For the first case study, five scales were selected from the motivation/affect area (see Section 3.6.3; mastery self-talk, extrinsic self-talk, relevance enhancement, situational interest enhancement, and self-consequating) and one scale from the behaviour scale (environmental structuring).

Pintrich (1988) classifies cognitive learning strategies as rehearsal, elaboration, and organizational strategies, based on categorization by Weinstein and Mayer (1986). Rehearsal strategies include reciting and repeating word lists and are best used for simple tasks when bringing information into working memory or activating information in working memory (Pintrich & McKeachie, 2000). Elaboration strategies help students to store information in long-term memory by building internal connections between new and prior knowledge. For example, taking notes by writing things down in one's own words, asking questions and answering them, and summarizing subject matter in one's own words are elaboration. An organizational strategy helps the learner to select the key information and construct connections among the pieces of information (Pintrich & McKeachie, 2000). Learners can analyse a text by selecting the most important concepts and their connections, which helps them to understand the subject matter and to integrate it with prior knowledge.

The concept of metacognition means, in this context, the conscious selection and assessment of strategies, and it comprises of both knowledge and skills (Nokelainen & Ruohotie, 2004). Metacognitive knowledge involves a learner's knowledge about his or her own schemas, cognitive strategies, and processes, and the conception of one's own learning abilities. Self-schemata are defined as beliefs of task demands, ability beliefs, personal goals, and affective memories that affect expectancies and values (Wigfield & Eccles, 2000). Furthermore, expectations and values influence individuals' functions such as performance, choosing tasks, effort, and persistence. Awareness of one's own learning abilities is connected to motivational components, such as self-efficacy, control beliefs, and expectancy of success (Pintrich & McKeachie, 2000). Pintrich and McKeachie (2000) consider metacognitive skills to be more important for the learner than metacognitive knowledge. These skills comprise of strategies for planning, regulating, monitoring, and modifying cognitive processes for learning. Self-regulating activities improve students' performance by helping them in checking and correcting their behaviour as they proceed on a task (Pintrich & McKeachie, 2000).

Critical thinking skills can be regarded as one of the cognitive strategies that direct the learning process (Hakkarainen et al., 2004; Olson, 2003; Pintrich & McKeachie, 2000). Critical thinking refers to many things, such as the learner's ability to apply previous knowledge to new situations in order to solve problems. It also entails that learners possess the metacognitive skills to identify and comprehend, for example, assumptions as assumptions and conclusions as conclusions, along with understanding the cultural effects of how and what we think (Olson, 2003). These kinds of strategies are at least to some extent domain specific (Pintrich & McKeachie, 2000); thus, critical thinking in a biology course is quite different than critical thinking in a foreign language course.

Resource management strategies help students to manage their environment and the available resources. Resources involve time, physical environment, teachers, peers, and the learners themselves. Even though these management strategies can be regarded as cognitive and metacognitive by their nature, they can be considered to be different enough to form a category of their own (Pintrich & McKeachie, 2000). These SRL strategies help students to adapt to the studying environment as well as to change their environment to better fit their needs. Students' time management strategies matter both in short-term and long-term learning processes. They benefit by managing an effective studying session for, for example, two hours' time or managing a week's studying schedule with the required flexibility. These management skills require metacognitive skills for planning, regulating, and

monitoring the learning process (Pintrich & McKeachie, 2000). Time use is also linked to value components of motivation, such as intrinsic orientation and task value, which affect choice of behaviour and, thus, the choice of an activity.

Another resource management strategy involves the physical studying environment (Pintrich & McKeachie, 2000). It can be almost any space from the kitchen to the library, as long as the learner considers it especially as an area for studying. The setting should be free of visual and auditory distractions, and the learner can organize it in a way that strengthens attention. The third resource management strategy is effort regulation, and it is considered to be one of the most important learning strategies (Pintrich & McKeachie, 2000) as it involves the learner's general self-management of effort and persistence. Students who are able to choose an adequate effort level and when to persist on a task also know when maximal effort for success is not needed; thus, they can choose an adequate learning strategy depending on the task. Moreover, Corno and Rohrkemper (1985) have claimed that coordinating cognitive strategies with appropriate levels of effort is the key element of SRL.

Learning how to seek and obtain help from the peers or teachers is also an important resource management strategy (Pintrich & McKeachie, 2000). It is beneficial for the learners to recognize when they need help and to identify someone else as a provider of assistance.

2.5 Intrinsic motivation and goal orientation in formal education

There has been a lot of research on the aspects of motivation affecting learning processes and outcomes in the field of formal education during the past decades, and goal orientation has proven to be a particularly robust motivation construct (e.g. Baranik et al., 2010). According to Deci and Ryan (1985; Ryan & Deci, 2000) human motivation is based on three psychological needs, namely self-determination, competence, and interpersonal relatedness. They developed the much-quoted *self-determination theory*, which defines processes and structures of self-determination and competence that people use to organize cognitive, affective, and behavioural variables. In short, when learners sense that they possess freedom of choice, they are given the possibility to fulfil their psychological need to experience competence, self-determination, and interpersonal relatedness and, thus, they gain energy from within themselves to direct their behaviour towards achieving the learning objective; in other words, intrinsic motivation is being aroused. The theoretical framework

derives from a philosophical perspective in which human beings are active agents who act on and are acted upon by their social and physical environments. From this point of view, internal psychological structures reflect and anchor the external ones, such as the social and political structures. In their work, Deci and Ryan (1985) present a vast number of empirical studies in which the learners vary from preschool children to college students and adults.

According to self-determination theory (Deci & Ryan, 1985), when children and adolescents are given optimal challenges, a large variety of stimuli, and a context of autonomy, their curiosity and interest (i.e. intrinsic motivation) energizes them to achieve their learning objectives and even surpass them. However, there are quite a few learning objectives in schools' curricula that are not intrinsically motivational or engaging; therefore, extrinsic support is also needed.

Learning is a multilayered and multifunctional process, which includes both cognitive and motivational structures and processes and their interplay (Deci & Ryan, 1985). Motivation involves energy, direction, persistence, and perception of a variety of means in reaching one's objective (Ryan & Deci, 2000). Moreover, motivation concerns activation and intention, and it is essential in an individual's cognitive, biological, and social regulation. In other words, it's the core element in human behaviour and functioning. Motivation to learn is influenced by students' attribution of their abilities to complete the task and perception of the benefits of doing so (e.g. Eccles et al., 1993; Pajares, 1996; Wigfield & Eccles, 2000).

The assessment of motivational factors by research instruments MSLQ and PMLQ (see Sections 3.3.2 and 3.3.3) in this study are based on Pintrich's (1988) motivational expectancy model. In that model, three components of motivation are introduced. Firstly, there are **value components**, which involve learner–goal orientation and the task value of learning. The learner can be mostly internally goal-oriented; he or she experiences curiosity, challenge, joy, or increased self-worth through learning (Pintrich & McKeachie, 2000). Learners who are more externally goal-oriented are mostly motivated by good grades, rewards, or acceptance. The task value of learning describes learners' perceptions of the importance, utility, or intrinsic interest of a task or a course (Pintrich & McKeachie, 2000). Task value and goal orientation interact with each other, as well as with the intensity of behaviour (Pintrich & McKeachie, 2000).

Secondly, there are two kinds of **expectancy components**: control beliefs and self-efficacy beliefs. Learners who experience that they have control over their own behaviour and can influence their environment tend to achieve better learning outcomes than learners who don't believe that they have control. A learner's self-

efficacy consists of beliefs about performance capabilities when conducting a certain learning task and beliefs about achieving grades. Self-efficacy refers to a learner's beliefs of their cognitive abilities. Both of these expectancy components affect the student's performance in a positive way via cognition, self-regulation, and metacognition. Both control beliefs and self-efficacy beliefs are linked to skills in planning, monitoring, and regulating cognition (Pintrich & McKeachie, 2000). As stated by Pintrich and McKeachie (2000):

> That is, students who believe they can perform a task and influence the outcome on a task should be more likely to check their progress and try different cognitive strategies if unsuccessful. Students' skill in self-regulation and their control and efficacy beliefs should be linked synergistically, each component building upon and supporting the other. In this way, it may be difficult to separate them empirically, but conceptually they can be distinguished. (p. 37)

Thirdly, there are **affective components**, such as test anxiety (Pintrich & McKeachie, 2000). Test anxiety indicates that learners with poor cognitive skills may suffer from interfering anxious thoughts and feel anxiety during a test situation, which reduces the cognitive capacity of the learner. On the other hand, learners who are well prepared and possess good cognitive skills are not equally distracted during a test as they have more cognitive capacity to apply (Pintrich, 1988). Several motivational components, such as self-efficacy, internal goal orientation, and test anxiety correlate with the use of cognitive and metacognitive strategies (Pintrich et al., 1993).

Moreover, Bandura's (1989) and Elliott and Dweck's (1988) ideas about self-efficacy beliefs and goal-orientation lay the foundation for the personal achievement goal orientation research instrument (Middleton & Midgley, 1997; Midgley et al., 2000) that was applied in the third case study. Self-efficacy affects thought patterns that may be self-aiding or self-hindering (Bandura, 1989), since much of human behaviour is regulated by forethought embodying goals, and personal goal setting is influenced by the self-appraisal of capabilities. The stronger the perceived self-efficacy of the learner is, the higher goals they set for themselves and the firmer their commitment to them is (Bandura, 1989).

Achievement goals refer to the type of mindsets individuals hold when engaging in achievement-related behaviour (Elliott & Dweck, 1988). Learners' goal-setting seems to have either **mastery goal orientation**, **performance goal orientation**, or a mixture of both. Mastery-oriented learners' goal is to develop their competence (Elliott & Dweck, 1988). Learners aim to deepen and broaden their understanding, learning is perceived as interesting as such, and learners' focus is fixated on the task.

Performance-oriented learners aim to demonstrate their competence to the teacher and to other students, and their focus is fixated on the self (Elliott & Dweck, 1988). The mastery goal orientation approach has been associated with adaptive patterns of learning, whereas the performance approach goal orientation has been associated with both adaptive and maladaptive patterns of learning (Pintrich, 2003). Adaptive processes refer to, for example, learners' abilities to calibrate their behaviour and cognition and not to constantly over- or underestimate their capabilities and then lose motivation as a result of negative feedback.

Furthermore, the two goal orientation profiles mentioned above were complemented with **performance avoidance goal orientation**, thus introducing a trichotomous achievement goal framework (Elliot & Church, 1997). The trichotomous framework suggests that learners' goal orientation can also entail avoiding the demonstration of incompetence or appearing stupid (Elliot & Church, 1997; Middleton & Midgley, 1997; Pintrich, 2003). As with performance-oriented learners, learners' attention is focused on the self, and their orientation is associated with maladaptive patterns of learning (Pintrich, 2003). According to the literature (e.g. Baranik et al., 2010), empirical research on this trichotomous framework has yielded strong support, and it was considered to fit well for the third case study's research design. Also, a four-dimensional achievement goal orientation framework, with a second avoidance orientation—**mastery avoidance goal orientation**, has been introduced (Elliot & McGregor, 2001). Learners with mastery avoidance goal orientation strive to avoid misunderstanding or failing to learn course material or to avoid leaving a task incomplete; thus, the focus is on avoiding a negative possibility (Elliot & McGregor, 2001). Perfectionists who strive to avoid making any mistakes or doing anything wrong are the ones who possess this particular avoidance goal orientation profile (Elliot & McGregor, 2001). Due to the literature bringing forth the discrepancies in the goal orientation research such as inconsistencies in definitions and dimensions of the constructs (e.g. DeShon & Gillespie, 2005), it was decided not to include the fourth goal orientation profile into the research design of this study.

2.6 Changes in conceptual constructs

The third case study investigated whether inquiry learning in a cross-curricular context induced changes in learners' conceptual structures. Conceptual change is identified as a learning process that, in addition to accumulation of knowledge,

entails changes in concepts, conceptual constructs, and ways of acting (e.g. Hakkarainen et al., 2004; Hewson, 1981). In this study, conceptual construct changes which entail adding new information to existing conceptual structures are referred to as **enrichment** (Vosniadou, 1994) and can also be called subsumption (Ausubel, 1968; Novak, 2010), where existing concepts (subsumers) interact with newly learnt information. The subsuming concept (subsumer) creates movement of relevant information through the perception barrier, thus enabling the acquisition of new information. **Belief revision**, which is regarded as a change in the learner's beliefs or in the perception of a theory (Vosniadou, 1994), was also investigated. Beliefs are tightly connected to learners' ontological and epistemological presuppositions (Vosniadou, 1994). Therefore, beliefs instead of smaller fragmented structures create a uniform structure.

Because there were six different school subjects involved in the third case study, we were particularly interested in the idea of "ontologically organized associative trees" (Chi, 1997). This model suggests that people store concepts on ontologically distinct associative trees. A category means a set of objects that are perceived to belong together. When new objects are encountered, they are considered as members of a certain category and labelled accordingly. Thus, people have a cognitive advantage when they use categories that they are familiar with, because it reduces the demand for processes such as storing and reasoning (Chi, 1997). A **conceptual shift** can occur among the branches of the same ontological tree, which is regarded in this study as either enrichment of the concept or belief revision (Vosniadou, 1994) if the change is related to the whole belief construct.

These "trees" can form barriers restricting understanding and creativity; thus, learners should be able to cross these barriers in a flexible way (Chi, 1997). When a person re-represents something in a new way, a switch is made from one ontological multi-branched tree of concepts and categories to another. When the entire ontological tree to which the concepts belong gets changed to another, it requires changes in a vast number of attributes linked to the concepts. Consistent with Chi's (1997) definition, **conceptual change** is defined in this dissertation as shifting a concept from one ontological tree to another, and this, too, was under investigation in the cross-curricular case study.

Conceptual change is considered the most difficult and most creative shift, as concepts and their attributes shift across entire ontological trees (Chi, 1997). The sudden "aha moment" can be seen as a phenomenon of creativity, where every piece suddenly falls into place, and this phenomenon can be viewed as an ontological shift because a concept that moves from one ontological tree to another inherits all the

attributes of the first tree (Chi, 1997). Moreover, what may seem like trivial conceptual shifts from one person's perspective may be ontologically significant from another person's perspective (Chi & Brem, 2009). When a person detects a paradox concerning a new concept and its categorization, it can trigger conceptual change (Bereiter, 1985; Chi, 1997; Chi & Brem, 2009). Anomalies can be left unchanged in learners' concept categories if the learner is extremely committed to their current theories. In that case, conceptual changes do not happen. One can explain and accept these anomalies, thus expanding the current theory, as suggested by Ohlsson (2009), or one can make a belief revision or a conceptual change to avoid the problematic contrast.

Moreover, possible **threshold concepts** were investigated. A threshold concept is considered as fundamentally transformative, which means that it changes one's understanding or interpretation of something (Meyer & Land, 2003). Threshold concepts are gateways to understanding the critical content of a discipline. Threshold concepts transform learners by allowing them to view matters as biologists, philosophers, artists, and so on; perceiving a threshold concept involves both an ontological and a conceptual shift (Meyer & Land, 2003). A threshold concept can be detected as a kind of gateway to the challenging content of a certain discipline, such as "genetic variation" in biology, or "personhood" in philosophy (Batzli et al., 2016; Land et al., 2010). Many learners tend to get stuck with threshold concepts and need support from the teacher to overcome this obstacle and learn the subject matter. Schwartzman (2010) suggested that crucial elements behind the difficult experience are unrelated to the disciplinary context. Instead, experiences of difficulty are based on reflective and defensive responses to rupture, which results from encountering existentially unfamiliar constructs. In other words, the foundation of a threshold concept is discipline-independent by nature. The time frame following the encounter with the threshold concept can be viewed as Heidegger's "dynamic of rupture", as the learner's response is constructed in an explicit form by either reflectiveness or defensiveness. This results in a time frame of confusion and uncertainty for the learner. We investigated whether enrichment, belief revision, conceptual change, or threshold concepts emerged by analysing learners' diaries, portfolios, and concept maps and by conducting narrative interviews in the third case study.

3 METHODOLOGY AND METHODS

AR is sometimes considered to be the same as practitioner research (McAteer, 2013), but in this dissertation it is considered to differ from it in a significant way. Practitioner research refers to in-service teacher training where teachers engage themselves with research to improve their teaching practices, often as a part of an in-service training programme. In AR, you cannot separate theory from practice, as the researcher explores, theorizes, and changes practice and provides a platform for criticizing ideologies (McAteer, 2013). Hence, as the researcher considers what to develop in practice and how to have a positive effect on learners, they bring a moral and an epistemological dimension to the research. As the researcher is at the centre of both practice and research, it belongs more to the category of critical knowledge than hermeneutic knowledge in phenomenological method (McAteer, 2013). In hermeneutic knowledge, the researcher focuses repeatedly on a dialogue and critical reflection that aims at understanding individuals' otherness and becoming liberated from one's self-centredness at different stages of the research (Laine, 2018). In this perspective, hermeneutic dialogue is subsumed into the phenomenological method to proceed stepwise with a critical awareness of the subjectivity of the researcher (e.g. Giorgi, 2009; Laine, 2018; Smith et al., 2009). AR is a cyclical reciprocal process of research and action, the findings of each cycle informing the planning and execution of the next (McAteer, 2013; Stringer, 2004; Zuber-Skerritt, 1996); thus, the action researcher is both practical and theoretical in approach.

All case studies of this dissertation together with their inquiry learning teaching and learning models, were designed by the author of this dissertation. The first and second case studies were conducted in 2013–2016 (Table 2). The circumstances of formal education were quite different with the third case study, which took place in 2020–2021 during the Covid-19 pandemic (e.g. Chen et al., 2022).

3.1 Ontological and epistemological background

Ontological and epistemological presuppositions form the foundations of our knowledge base (Vosniadou, 1994). Ontology and epistemology, tied to the scientific

research tradition of educational research, directed the study design of all three case studies. Ontology is a branch of philosophy that deals with different world views and the nature of reality; for example, do we focus on the social relationships of the surrounding world or the physical objects and their features, such as mass or density? (e.g. Guba & Lincoln, 2005). The social reality involves a socially negotiated network of meanings; thus, ontologically it exists in a different way than the physical world (what is real; the nature of reality). Epistemology is the branch of philosophy that seeks to define what knowledge is and where it comes from, i.e. it defines the structure and origins of knowledge (what is our knowledge about reality) (e.g. Novak, 2010). This applies to the way we construct knowledge as individuals and how knowledge is being constructed in different disciplines (e.g. Novak, 2010). Knowledge includes concepts and propositions. As meaningful learning results in new knowledge construction by integrating thinking, feeling, and acting in a typically human way, this can be epistemologically regarded as human constructivism (Novak, 1993). Human constructivism explains both the way humans learn usable knowledge and the way they construct knowledge.

Kuhn (1996) formulated the idea of the scientific paradigm in the 1960s, which consists of formal theories, classic experiment, and trusted research methods. His reasoning was based on the observation of how much more disagreement there was in the social sciences about the valid research questions and methods of scientific research compared to the natural sciences. In educational research, there are two paradigms that are sometimes considered to be opposites to each other: constructivism and positivism (Lincoln & Guba, 1985). For example, qualitative inquiry, such as ethnography and autobiography, is grounded in constructivism and quantitative research in positivism. These two paradigms represent two different conceptions of knowledge, one that aims to understand human experiences, norms, and purposes and another that strives to discover and explain phenomena by statistical inference of relationships between dependent and independent variables (Alexander, 2006).

Underneath the positivist paradigm lays the idea of aiming for objectivity in scientific research, and underneath the constructivist paradigm is the idea of relativism. Ontological objectivity means that we see things the way they exist and reveal their actual features in their ontological state (e.g. Eisner, 1992). The purist advocators of the quantitative approach claim that research should entail time- and context-free generalizations, and ensure that the observer is separate from the entities that are subject to observation (Nagel, 1986). The scientific classical realist paradigm claims that science can make possible knowledge of the world beyond its

accessible empirical manifestations (Leplin, 1984). In educational research, positivist orientation usually considers education as an object of investigation, and the knowledge gained is seen as objective and quantifiable as the reality is stable, observable, and measurable (Merriam, 1998). The purist advocators of constructivism or the qualitative approach, on the other hand, consider the observer as a subjective, value-bound participant in the research and inseparable from the informants, as they are the only source of reality (Guba, 1990), since multiple realities are constructed by social interaction between participants (Merriam, 1998). From the point of view of constructivist or interpretive orientation, education is seen as a process and network of lived experiences and knowledge comprised of understanding the meanings of the process or experiences (Merriam, 1998).

Even though some researchers in the field of education take a purist's stand, suggesting that one research study can only consist of one of the two paradigms (Alexander, 2006) mentioned above, there has, for some time, been an orientation for taking a pluralistic stand in combining the quantitative and qualitative paradigms if the research design and its research questions call for it, thus constituting a third paradigm (Johnson & Onwuegbuzie, 2004, p. 17). This mixed methods approach integrates quantitative and qualitative methods (e.g. Creswell & Creswell, 2018; Sieber, 1973). According to Pintrich (2003), scientific perspective entails the use of empirical evidence to support knowledge claims, and it is irrelevant whether the data is qualitative or quantitative as long as the study design is well done, data collection and analysing procedures are well explicated, and the inferences drawn from the data are well reasoned and in line with the knowledge claims.

This study shares aspects of critical realism (**CR**) in its philosophical framework. CR is mostly applied in the social sciences to understand, critique, and suggest solutions for social conditions (Fletcher, 2017), but it has been used in educational research as well (Luke, 2008; Scott, 2005). Some studies in both social sciences and educational research, such as this study, share the pragmatic interest of knowledge (Habermas, 1987). This study seeks to present solutions for pedagogical practices in promoting deeper thinking skills based on the identified tendencies and causal mechanisms of the case studies. CR arose from the "paradigm wars" between constructivism and positivism in the 1980s (Denzin & Lincoln, 2011), and it uses components of both paradigms to form its own branch of philosophy of science, with its own ontology and epistemology (Brown et al., 2002; Denzin & Lincoln, 2011; Fletcher, 2017). CR refuses to reduce ontology to epistemology, by stating that human knowledge can only capture a limited section of a much vaster reality (Fletcher, 2017). With this notion, CR differentiates itself from both positivist and

constructivist perspectives of reducing reality to human knowledge; the former by suggesting that knowledge is the container of reality, and the latter by suggesting that knowledge acts as a lens for reality (Bhaskar, 1998; Fletcher, 2017). CR sees the surrounding world as theory-laden but not theory-determined (Fletcher, 2017). According to CR, some theories succeed to explicate knowledge that is closer to reality than other theories; thus, some theories are more truth-like than others (Danermark et al., 2002, p. 10). These theories, which help us to get closer to reality, are the ones that explicate causal mechanisms involved in social phenomena, activities, and events (Archer et al., 1998; Fletcher, 2017). Such theories are formed by using rational judgement of the investigated social events (Archer et al., 1998). Because CR does not focus on merely describing the empiric data but underlines the causal analysis and explanation instead, it fits well for analysing social phenomena and suggesting solutions within an educational context.

The first case study, which investigated the cognitive and affective learning outcomes of student groups that were taught in two different teaching and learning models, falls into the quantitative research paradigm and is complemented with two case studies aiming to describe the experiences of different kinds of learners and to understand these experiences. The quantitative case study aims to produce generalizable information about the inquiry learning model being studied, and the two qualitative sub-studies focus on describing the experiences and the process and understanding them. Thus, the qualitative studies seek to bring forth the variety of how the different learners make sense of their world, the process in question, and the meanings they construct based on their experiences (see Merriam, 1998). Hence, the perspective of the participants is essential, even though the researcher is an active participant in the process. All three sub-studies of this dissertation are empirical studies. Especially in the field of educational research, leaning on empirical evidence together with well-reasoned argumentation are of vital importance, compared to epistemologies in other disciplines (Mayer, 2000; 2001).

3.2 Argumentation for selected methods

As the matters under investigation in this study relate to motivation to learn, self-regulated learning skills, ways of instruction, learning environments, and domain specific and cross-curricular subject matter in the context of formal teaching and learning, there isn't a single unambiguous research method to provide answers to the research questions. This study explores the multifaceted interface between

educational psychology, cognitive psychology, educational sciences, information sciences, and statistics. According to Donald E. Polkinghorne (1995), there are three different kinds of research data: numerical, short answer, and narrative data. Numerical data can be collected, for example, with self-report questionnaires of Likert scale ratings from one to five, like the data sets in the first case study. Short answers can be easily converted into lists and categories, such as nationalities, hobbies, or most liked subjects in school. Polkinghorne considers narratives, such as the ones collected for the second and third case studies, to be data collected by interviews, or written answers to open-ended questions, diaries, or autobiographies, in which participants provide their responses in their own words. Narrativity can be of oral or written origin. All these three different forms of data can be present in one single study, as long as their different nature is carefully considered and taken into account when analysing and interpreting the data (Heikkinen, 2015; Polkinghorne, 1995). As elaborated by Heikkinen (2015, p.160), narrative data can't be presented by numbers or categorized unambiguously, but instead its processing requires an interpretive approach. This is evident in the third case study. The overview of data gathered for the case studies is presented in Table 2.

Table 2. Overview of data gathered for the case studies.

	Date	**Number of participants (*n*)**	**Research method**
case study I middle school upper secondary school	2013- 2016	 152 (75 intervention/ 77control group) 101 (46 intervention/ 55 control group)	quantitative, quasi-experimental: pre-test/post-test, PMLQ, MSLQ
case study II middle school	2013- 2014	13	qualitative: narrative interview
case study III upper secondary school	2020- 2021	10	mixed methods: qualitative: narrative interview, content analysis of learning diaries, portfolios, and concept maps and quantitative: PALS

Note. The unpublished study to answer SRQ3 (regarding the role of the digital learning environment and digital tools) used the data collected by narrative interviews in case studies II and III.

3.3 Quantitative research orientation

Statistical description does not usually present unambiguous facts in the behavioural sciences, but indicative data that can be used to understand and predict phenomena that occur in a large number of people, the so-called population from which the sample originates (Komulainen & Karma, 2002). Statistics seek to determine whether the observed phenomena are coincidental or whether regularity is found in them, which is expressed in terms of statistical significance (Creswell & Creswell, 2018). The phenomena or facts to be studied do not necessarily appear in one or a few people, but in a larger group of people (i.e. in a larger sample), so the use of statistical mathematics in the humanities is justified (Komulainen & Karma, 2015).

The aim of the first case study was to investigate possible statistically significant differences between the learning outcomes and motivation levels of student groups that were taught either with a conventional teacher-centred procedure or with inquiry learning; thus, an experimental research design was applied. The most important difference between the control groups and the intervention groups is that the learners in control groups did not follow the question-driven procedure of the progressive inquiry model, and they did not use educational technology tools to implement the collaborative studying approach in practice. As the students were not randomly selected into studied groups from the whole population of Finnish middle school and upper secondary school students, the study can be defined as quasi-experimental (e.g. Creswell & Creswell, 2018; Dimitrov & Rumrill, 2003; Table 2). In this study, a nonrandomized control group pre-test/post-test (see Section 3.3.1) and survey design (see Sections 3.3.2 and 3.3.3) were used (e.g. Dimitrov & Rumrill, 2003). We were not able to choose participants randomly into the test groups and control groups, but we accepted all the groups that volunteered and replied to the request made by the researcher across the Pirkanmaa region in Central Finland. There are no groups of special education or groups formed by any special characteristics, such as language or mathematical skills, so it can be said that the groups were equally heterogeneous by nature. In this kind of design, investigating intact groups reduces the reactive effects of experimental procedure, which increases external validity (Dimitrov & Rumrill, 2003). There were 6 middle school geography teachers, 152 middle school students, three upper secondary school geography teachers, and 101 upper secondary school students involved in the first case study quantitative research (Table 2). The research was cross-sectional, since the informants took the tests or answered the surveys at a certain time point.

3.4 Measuring cognitive learning outcome in the first case study

The research instruments used in the first case study were self-reporting questionnaires and tests (Table 2), and these lean on the positivist and scientific realist research paradigm. They are both typical types of measures in behavioural sciences such as educational or cognitive psychology (Jackson, 2006). Pre-test and post-test research instruments were designed for the first case study to assess recollection of facts, understanding the geographical phenomena and skills to apply information creatively to given situations (Bloom et al., 1981). This is in line with meaningful learning (Ausubel, 1968; Novak, 2010), which entails that information that is learnt meaningfully and is thereby associated with subsumers in cognitive structure can usually be recalled for a much longer time period compared to rote learning. When time passes, recalled information may vary from the original version, but the remaining enhanced ideas in cognitive structure may facilitate learning in future, when learning something that is closely related to the concepts and their attributes learnt earlier. Neurologically, the physiological explanation is that meaningful learning entails more synapses between neurons storing the new concept and neurons storing previously learnt, related, concepts compared to rote learning (Novak, 2010, p. 71).

A pre-test and post-test were designed according to Bloom's taxonomy (Bloom et al., 1981) to measure the cognitive learning outcome according to the subject matter of the geography course in question. The tests had similar structures for students in both educational levels (middle school and upper secondary school), including 20 multiple choice questions that were designed to measure the students' recollection of factual knowledge (maximum score of 20 points), and 5 open-ended questions designed to measure the participants' understanding and abilities to apply, analyse, synthesize, and assess knowledge (maximum score of 10 points). The content of the pre-test and post-test was similar, but the formulation of questions differed as well as the order of choices given as answers, to avoid the set response effect (Jackson, 2006). The tests' content validity was assessed by a university teacher of geography didactics and two middle school and upper secondary school teachers before the pilot study. The means (and standard deviations) for the pre-test and post-test completed by the middle school participants were 22.4 (SD = 4.0) and 20.9 (SD = 5.3), respectively. The means (and standard deviations) for the pre-test and post-test completed by the upper secondary school participants were 19.0 (SD = 3.4) and 20.4 (SD = 3.4), respectively. The maximum score for the tests was 30 points; thus, the items were challenging without being excessively difficult.

Pre-test/post-test designs are commonly used in behavioural research, and the objective is to compare groups and/or measure change resulting from experimental interventions (Dimitrov & Rumrill, 2003). Test groups with experimental intervention and control groups who were not exposed to interventions take the same tests. When taking the pre-test, all individuals in all the participating groups are at the same starting level, as there have not been any interventions at that point. During the investigation period, some groups are introduced to the interventions with inquiry learning and some are not and, by comparing the change in pre- and post-tests, the possible effects of intervention can be detected. The simplest way of a quantitative pre/post design is to calculate the difference between post- and pre-test scores (actual gain). However, this is not always appropriate because if a student, for example, achieves an extremely high score in pre-test, they cannot achieve very high absolute gain. One solution to the described problem is the average normalized learning gain (Hake, 1998), where the gain value is calculated based on the original pre-test and post-test scores in a way that normalizes the progress in the learning outcome results; in other words, the gain value measures more accurately students' improvement between the pre-test and post-test. The average normalized gain value (G) was calculated as G = Posttest% - Pretest% / 100%-Pre-test% (Hake, 1998).

The reliability of pre- and post-tests was tested by Cronbach's α. This detects whether the items in the test measure the same thing, in this case the competence in the field of geography. For the middle school participants in Sample 1 (n = 152), the Cronbach's coefficients were α = .76 for the pre-test and α = .84 for the post-test. This verified that the tests were reliable as the coefficient was over .60 (Jackson, 2006). For the upper secondary school participants in Sample 2 (n = 101), the Cronbach's coefficients were α = .56 for the pre-test and α = .63 for the post-test. Hence, the tests of Sample 2 were considered satisfactory. All of the data analyses were carried out with SPSS, and the numeric data were systematically observed for outlier detection. In middle school dataset, both the pre-test and post-test scores were skewed toward the high end of the scale, whereas in the upper secondary school dataset, the distribution of the pre-test was normal and the post-test score showed high kurtosis and was slightly skewed towards high scores. Nevertheless, the skewed values were below one; therefore, the distributions were considered close enough to normal for parametric tests to be applied.

3.4.1 Measuring the level of motivation in the first case study

The first case study aimed at investigating how the students' motivation level changed during the geography course. The intervention groups studied with progressive inquiry and control groups with more teacher-centred teaching and learning model. Motivation level was measured at three time points with a self-reporting instrument, the Pedagogically Meaningful Learning Questionnaire (**PMLQ**; Table 2), which was originally designed according to instructivism, constructivism, and behaviourism as the underlying design paradigms (Nokelainen, 2006). Motivation was measured over time as suggested by Järvenoja and her colleagues (2018) in order to capture its fluctuation.

There are ten categories in the original version of the PMLQ, but only the motivation section, with four items, was used for this study. The items were assessed on a five-point Likert scale ranging from one ("totally disagree") to five ("totally agree") with no specific labels for the responses in between. The four items were summarized into one summative motivation variable. Participants answered this self-assessment questionnaire three times, at the very beginning of the investigation period, in the middle, and at the end of the course after specific geographical issues had been studied.

The motivation that is studied with the PMLQ self-assessment in the present study derives from both cognitive (Wilson & Myers, 2000) and motivational theories (Deci & Ryan, 1985). Motivation is operationalized in the PMLQ with four items. These items measure dimensions of intrinsic goal orientation, extrinsic goal orientation, and meaningfulness of studies. These items were summarized into one summative motivation variable. According to the theoretical background, motivation supports the direction of a person's general behaviour and can be consciously or subconsciously goal-oriented (Ruohotie, 1998). Motivation affects all learning. Motivation is an umbrella term for incentives, learning goals or objectives for performance, self-regulation, expectations, and attributions of failure and success, as well as intrinsic and extrinsic goal orientation (Ruohotie & Nokelainen, 2003). A person with intrinsic goal orientation strives to reach learning goals because the learning material and subject matter is interesting in itself. A person with extrinsic goal orientation strives to reach better results than others, to achieve an external reward, such as a good grade or grant, or avoid punishment. Levels of motivation are categorized as contextual and general; thus, it can vary according to the subject matter or topic dynamically. On the other hand, general level motivation is more static (Ruohotie, 1998). The more static type of motivation changes over the

different stages of life. Moreover, motivation can be distinguished from attitude, as attitude affects the quality of a person's performance and learning outcomes, while motivation affects alertness and vigour in the learning situation (Ruohotie, 1998).

The Cronbach's alpha varied between the measurements of three time points from .55 to .68 (Sample 1, middle school) and .63 to .72 (Sample 2, upper secondary school). Hence, the PMLQ measurements for motivation were considered satisfactory (Jackson, 2006). All data analyses were conducted with SPSS, and the numeric data were systematically observed for outlier detection.

3.4.2 Measuring the self-regulated learning skills in the first case study

In order to explore the SRL skills among students who were taught with either inquiry learning or a more teacher-centred method, the Motivated Strategies for Learning Questionnaire (**MSLQ**; Table 2) instrument (e.g. Pintrich et al., 1993) was partially used in the first case study, focusing on specific categories that measure the regulatory activities of academic learning. For the present study, five scales were selected from the motivation/affect area (see Section 2.4; mastery self-talk, extrinsic self-talk, relevance enhancement, situational interest enhancement, and self-consequating) and one scale from behaviour scale (environmental structuring). The MSLQ version's 6 categories included 31 items. The length and structure were designed to keep the length of the questionnaire manageable for adolescents of 13 to 19 years of age, and to focus the investigation of SRL skills on the motivational components of learning.

Participating adolescents answered this self-assessment questionnaire once, at the very beginning of the investigated course. MSLQ is a self-reporting instrument that measures SRL skills by using a seven-point Likert scale ranging from one ("totally disagree") to seven ("totally agree"), with no labels for the responses in between. SRL applies the general models of regulation and self-regulation to learning (Wolters et al., 2003), and in the present study it takes place specifically in the classroom and school context, among a student demographic that has, to date, been investigated very little: from 14 to 15 (middle school, 8th grade) and 16 to 19 (upper secondary school) of age.

The MSLQ has been widely used and empirically validated since the 1990s in middle schools, junior high schools, colleges, and universities, whereas it is recommended not to be used with children below third grade because of developmental considerations. It was originally used as a research instrument in the

United States, and it has been translated into many languages including Arabic, Dutch, Finnish, French, German, Greek, Hindi, Hungarian, Italian, Japanese, Norwegian, Spanish, and Swedish (Wolters et al., 2003). In this study, a summative scale was calculated for the 31 items and discretized into 5 classes (weak, sufficient, satisfactory, good, excellent) to group students based on their motivational regulation. The reliability of the 31 variables was high in both samples (Sample 1, α = .95; Sample 2, α = .94; Jackson, 2006). This indicates that all the variables measured the same construct: strategies for the regulation of motivation. All data analyses were carried out with SPSS, and the numeric data were systematically observed for outlier detection.

3.5 Qualitative research orientation

3.5.1 Qualitative narrative interviews in the second and third case studies

According to constructivism, each person creates knowledge subjectively by integrating their prior experiences and conceptions with new ones. This way, conceptions and ideas on oneself as well as of the surrounding world are always changing (Bakhtin, 1986; Guba & Lincoln, 2005); hence, all individuals construct their own transforming narrative. From the point of view of relativism, knowledge can be regarded as a network of these narratives. Qualitative interviews enable the collection of data directly from the participants, such as students in a classroom, and they can lead to in-depth understanding of events and objects that are involved in learning and teaching processes. This explains the popularity of the qualitative interview, since it has become the most common qualitative research method in the field of education (Glesne, 2010; Merriam, 1998).

Narrative interviews can be used for many purposes, such as understanding the past, constructing and defining a person's identity, orientating participants towards future events, disseminating an experience and making it understandable, building trust, and communicating silent knowledge and shared beliefs (Hyvärinen & Löyttyniemi, 2005). In this dissertation, the objective of the narrative interview was to understand the past events of a certain geography and cross-curricular course and to induce the adolescents into reshaping their experiences into an understandable format of narrative (Table 2). It was regarded as an extra benefit if the interviewing process led to self-reflection by the learner and they became able to acknowledge

their strengths in the learning process. The interviewer was equipped to support the interviewees if any unpleasant topics arose during the interviews, which did happen in some of the interviews of the upper secondary school students.

Narrative inquiry underlines the process of in-depth understanding; thus, it is very close to hermeneutic and phenomenological research (Heikkinen, 2015). In this study, narrative inquiry is considered, as suggested by Heikkinen (2015), more as an approach than a specific research method, as there are constructivist assumptions of knowing and knowledge underlying it, along with a strongly interpretative approach. As is typical in phenomenological research, when analysing the interview data the researcher's goal was to make insightful observations and understand the events and phenomena that were being narrated (Abbott, 2008). Furthermore, the conceptualization of the narrated events and phenomena are central to phenomenological research, and, in this study, conceptualization was based on the theoretical background of the study. Phenomenology explores the reciprocal relationship between an individual and their surrounding world, and the focus is to find out what is the phenomenon that manifests itself in the perceived world at that particular time (e.g. Giorgi, 2009; Smith et al., 2009). A teacher perceives classroom events in a different way compared to the students. Nevertheless, the focus of the narrative inquiry was not purely phenomenological, since even though the aim was to discover and depict the nature of learners' learning experience, the philosophical essence of existence of the learners was not the focus of this study.

The one-question narrative interview, introduced by Fritz Schütze (Hyvärinen & Löyttyniemi, 2005; Rosenthal, 2003, 2004; Wengraf, 2001), was applied in this study. Students were asked one question to guide them into storytelling. After a narrative or short answer, the second phase of the interview followed, with questions derived from the previous answer. The last phase of the interview involved asking questions that were in the interest of the researcher for the current study if these topics had not been addressed already. In this way, the interviewer cannot be regarded as an objective bystander but as an active participant in the interview process. Furthermore, the students were regarded as experts of learning and, to avoid alienating adolescents from their experiences through a formal question-answer setting, it was decided not to use a structured or semi-structured interview but instead to give students more freedom to express themselves in their own words in a narrative interview.

A narrative involves both the story and narrative discourse (Abbott, 2008). Furthermore, a story is comprised of events and existing entities or existents. Events can be either intentional (acts) or unintentional (happenings), and existents can

involve characters and settings for the events. Narrative discourse refers to the traditional and cultural conventions of storytelling, such as the structure and style of a novel, poem, theatre play, or choice of words, or being an active participant or a distant observer in the narrative. Narrative is never just stating facts but always encompasses personal experiences (Hyvärinen & Löyttyniemi, 2005). According to Bakhtin (1981), verbal discourse is always a social phenomenon. Thus, the narrative of one's self, one's life, and one's worldview is constantly changing, and it is being influenced by personal and others' experiences and their interpretations. As Bakhtin explicates this (1986, p. 91): "Each utterance refutes, affirms, supplements, and relies on the others, presupposes them to be known, and somehow takes them into account." Experiences are reconstructed into new narratives every time that they are being narrated; thus, a narrative is reconstructed with the interpretation of the researcher and once more with the interpretation by the reader.

In our research, the narratives have two-dimensional characteristics because they are both the target of research (thematic analysis of narratives) and its outcome (narrative analysis). The orientation of our study was cross-sectional, since we focused on investigating what kinds of narratives interviewees would produce at the end of the course. An autobiographical approach was chosen because we focused on the events of the story—more precisely, what happened and why—rather than investigating the structures and forms of these narratives with a more linguistic approach (Abbott, 2008). Therefore, both the scientific classical realistic paradigm and constructivist interpretative paradigm are equally present. Recruiting the interviewees based on their freewill, that is to say, all students in the middle school intervention group and in the cross-curricular study unit were invited to the interviews. All who volunteered (13 students from the total of 75 middle school students and all 10 out of 10 in the cross-curricular study unit) were accepted to be interviewed.

A narrative analysis of the narrative interviews was carried out by formulating composite narratives (Kuisma, 2018; Willis, 2019). First, thematic analysis was used to categorize individual narratives according to the themes of the research questions (see Section 1.2). Second, the most frequently detected narrative was identified and labelled as the dominant narrative, and the others were labelled as counternarratives.

The interviews were conducted and transcribed in the students' mother tongue, Finnish. After the transcripts were read through for the third time, a summary was made of each interview by extracting the key quotations. These individual narratives were translated into English, aiming for the most valid interpretation of the narrative rather than an accurate word-for-word translation with the finest semantic and

linguistic details (Nikander, 2008), since the analysis of this study is more content-oriented than interaction-oriented. Next, composite narratives were made by combining individual summaries sharing the same theme. Translation and combining were done to secure the precision and accuracy of the narratives and to ensure the readers of analytic transparency. The composite narratives are presented in Section 4.2.

3.6 Mixed methods research orientation

3.6.1 The relationships between personal goal orientation profiling, learning diaries, portfolios, and concept maps in the third case study

The research methods for the third case study are selected based on the aim to explore experiences of the applied inquiry learning teaching and learning model and to develop it further. Thus, it leans on the CR and mixed methods paradigm (Table 2).

Students kept learning diaries to make notes for their portfolios about how well they felt they had learned the subject matter, what concepts they had learned, and which questions they wanted to find answers to. In this way, we gathered data about students' individual learning goals and the achievement of these objectives. Students were instructed to ponder the meanings of the concepts, other ideas, and observations of their learning process in their portfolios. The portfolios were graded by the six teachers on a scale ranging from one to three.

At the beginning of the study unit, the students answered a questionnaire about their personal achievement goal orientations. The questionnaire was used to categorize the relationships between students' goal orientation, learning outcomes (learning diaries, portfolios, and concept maps), and the conceptual changes expressed in the narrative interviews. The questionnaire belongs to the Patterns of Adaptive Learning Scales (**PALS**; Table 2), developed by Midgley and colleagues (2000). The questionnaire is based on goal orientation theory (e.g. Bandura, 1989; Elliot & Church, 1997; Elliott & Dweck, 1988; Middleton & Midgley, 1997; see Section 2.5), which tackles the relationship between the learning environment and students' motivation, affect, and behaviour. We chose the questionnaire to assess students' learning outcomes according to their mastery, performance approach, and

performance avoidance goal orientation profile. The questionnaire uses a five-point Likert scale (1 = not at all true, 3 = somewhat true, 5 = very true).

To explore what the learners perceived as key concepts and their connections, they were asked to draw a concept map of the most meaningful concepts they had encountered in the study unit. In this way, learners' conceptual structuring was made visible (Novak, 2010; Novak & Cañas, 2008). Concept maps were analysed through content analysis by listing the three most meaningful concepts and the number of their links (propositions) (excluding the link to the main concept). The more links to a concept, the more meaningful it is for the learner (Åhlberg, 2018). As the concept map was made hierarchically, the higher the concept was situated the more meaningful it was for the learner.

A qualitative narrative inquiry approach was chosen for this study because it focuses on a constructivist in-depth understanding of the events (Abbott, 2008) as well as scientific realistic comprehension of the events. The narrative interviews were analysed with three aspects: (a) the most challenging concepts; (b) the most interesting concepts mentioned by the interviewees; and (c) threshold concepts, conceptual change, enrichment, or belief revision narrated in the interviews. These results were compared to the results of the PALS questionnaire, the teachers' assessments of the portfolios, and the analysis of the students' concept maps. This way, it was possible both to explore the goal orientation profiles and to better understand their meanings for learners. Without the rich data gathered by narrative interviews, all other results would have remained as unattached details with quite ambiguous meaning.

4 RESULTS

4.1 Designed teaching and learning models (Case study I–III)

This section presents the results for **MRQ (How did the designed models support students' learning?)** by introducing the inquiry-based teaching and learning models that were designed for a domain-specific and cross-curricular study units**.** The basis of the teaching and learning model for middle school and upper secondary school geography courses investigated in the first two case studies (Table 1) was very similar: the programme, pedagogical aspects such as student tasks, and timetable of the geography course were planned together between the researcher and the teachers. The objective was to obtain the following key elements which define geographic inquiry in the context of the human and physical geography of Europe in middle school and in the context of geographical hazards in the upper secondary school geography course: (1) human and physical phenomena and their associated relations; (2) geospatial reference systems such as events, places, and regions; (3) the spatial perspective; and (4) geographic vocabulary (Favier, 2011, p. 100). Progressive inquiry was applied to the geographic inquiry approach in order to investigate the geographical phenomena by collecting, processing, and understanding the data (Chang et al., 2012). Data comprised of texts, animations, maps, and diagrams.

The participants from the upper secondary school differed from the participants from the middle school because they voluntarily chose to carry out their studies in this particular educational setting and were selected to attend the school based on their previous school performance. With this in mind, together with the developmental differences between the two age groups, the content and design of the geography courses differed between the middle and upper secondary schools. However, the intervention groups' progressive inquiry teaching and learning models were quite similar, and the way the intervention groups used information and communication technology (ICT) had similar objectives.

The teaching and learning model designed for the third case study refined the inquiry learning model based on the results gained from the previous case studies. Once again, according to the progressive inquiry (see Figure 1; e.g. Muukkonen et

al., 1999), learning proceeded cyclically as the learners formulated questions according to their previous knowledge. Six teachers planned the cross-curricular study unit's timetable, objectives, and content with shared themes. They decided not to give a numerical grade for the course but a mark of "approved" to reduce performance pressure.

4.1.1 Inquiry learning model for middle school geography course

The middle school students in the first and second case study applied the inquiry learning model, where they proceeded cyclically by formulating research questions and finding answers (Figure 1; Kuisma, 2018; Kuisma & Nokelainen, 2018). The teacher presented the outline of the course on the human and physical geography of Europe including its main contents, objectives, and assessment. Then each student was asked to choose one European country for his or her project work, and the students with the same country formed a pair. Next, each pair wrote down what they already knew about their country and why they had chosen it, and made a study plan with questions. The digital learning platform Moodle was used for writing the study plans, commenting on them, asking questions, and disseminating the best information sources to other peers. The project work proceeded progressively by searching for information by seeking answers to the questions in the study plan and inventing new questions (see Figure 1). The project work on European countries involved a task to draw maps of certain geographical topics, such as topography and livelihoods, and write down how the map related to other maps and phenomena of the project work.

In addition to their progressive investigation, the adolescents were asked to design simple digital games for their peers about two different topics (Figure 3). Their peers then played each game by solving the geographical dilemmas. The teacher used an interactive whiteboard during the geography course, and the students used it when playing the interactive games.

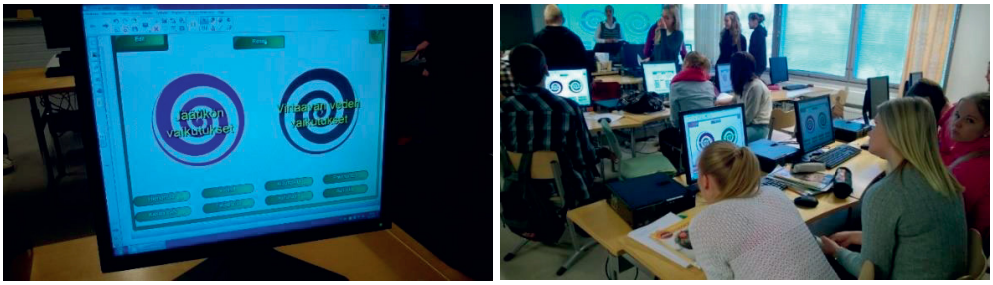

Figure 3. Vortex-games in the field of erosion designed by middle school students.

At the end of the course, a tourism fair took place in the classroom (Figure 4). Half of the student pairs first played the role of experts advertising their country to the visitors, and then they switched roles. Maps and diagrams were presented at the fair with drawings, pictures, or souvenirs that the students chose to display (Figure 4). The students were guided to compare their original study plans to their project work outcomes in order to make their learning visible.

Figure 4. Student experts advertising their country to the visitors in a tourism fair.

4.1.2 Inquiry learning model for upper secondary school geography course

The upper secondary school students in the first case study applied the inquiry learning model, where they proceeded cyclically by formulating research questions and finding answers (Figure 1; Kuisma & Nokelainen, 2018). The subject of the course was geographical hazards in the field of human and physical geography. The events for the intervention group were designed to take place as follows. The teacher presented the outline of the course, including the main contents, objectives, and assessment. Then, each student was asked to choose one geographical hazard for his or her project, and the students with the same hazards formed a pair. Next, each pair wrote down what they already knew about the hazard and why they had chosen it, and developed a study plan with research questions. The digital learning platform,

Moodle, was used to write the study plans, comment on them, ask questions, and disseminate the best information sources to peers. The project proceeded progressively, starting with searching for information, followed by seeking answers to the questions in the study plan, negotiating, and finally inventing new questions (see Figure 1).

The project work involved drawing at least one picture of the hazard and adding augmented reality in the form of a video clip or audio file to the drawing (Figure 5). Each pair wrote a report about their hazard and attached a drawing that including augmented reality. Finally, a course leaflet was created with the various hazards, which supported the students when studying for the exam.

Figure 5. A course leaflet with augmented reality about geographical hazards created by upper secondary school students.

In addition to their progressive investigation, the adolescents designed a simple digital game for their peers about two climatic hazards. Their peers played each game by solving the geographical dilemmas. The teacher used an interactive whiteboard during the geography course, and the students used it when playing the interactive games.

At the end of the course, each pair gave a presentation of their work and displayed their videos or other supplementary material. The students used tablet computers and the technology that was attached to their devices to present their work. Finally, the students were asked to compare their original study plans with the outcomes of their projects to make their learning visible.

4.1.3 Inquiry learning model for cross-curricular upper secondary study unit

The upper secondary school students in the third case study applied the inquiry learning model, where they proceeded cyclically by formulating research questions

and finding answers (Figure 1; Kuisma & Ratinen, 2021). During their cross-curricular study unit they were introduced to views on humans in the context of biology (senses, taxonomy and evolution, and humans as animals), psychology (higher-order thinking skills), physical education and physics (measuring and modelling exercises), philosophy (naturalism–culturalism and essentialism–existentialism), and arts (joint artwork expressing and exhibiting different views about humans). They were guided to monitor their own learning by setting research questions for themselves, assessing the level of attainment of their learning objectives, writing down the lessons' key concepts in their learning diaries, and pondering key concepts and learning experiences in their portfolios.

Inquiry learning took place at two levels. At the first level, the students' ongoing task was to write down research questions according to their points of interest in their learning diaries using Microsoft Office OneNote. The teachers responded to these questions by either talking with the student in question or writing to them in OneNote. Thus, there was an ongoing scientific dialogue over the course of the study unit. At the second level of inquiry learning, each teacher planned the lesson tasks constituting inquiry learning if it was considered possible and useful for learning.

Three lessons were held in each subject. Physical education and physics lessons were combined and led jointly by two teachers for all six lessons. During the first lesson, the students were given instructions regarding the whole study unit, the researcher informed them about the study, and the procedure of the two-level inquiry learning model with instructions for the learning diary and portfolio was explained to them.

4.2 Student narratives (Case study II and III)

This section presents the results for **SRQ1: What kind of narratives did middle school and upper secondary school students formulate from the viewpoint of self-regulated learning?** (Table 1)**.** One dominant narrative and two counter-narratives were identified in narrative interviews with students from both educational levels. The number of narratives to be identified from the dataset of middle school or upper secondary school had not been decided in advance; thus, it was a coincidence that one more general narrative and two less common ones emerged from both. As expected, due to their higher developmental stage the narratives of the upper secondary school students entailed a lot more self-reflection compared to the middle school students' narratives.

4.2.1 Dominant narratives of middle school and upper secondary school students

Most of the middle school informants (8/13) described the geography course as beneficial for learning the subject matter and subject-related skills as well as enhancing their self-regulated learning skills. As these students negotiated matters actively and experienced the talkative atmosphere as a positive factor, this dominant narrative was labelled as "**the negotiating master of self-regulation**". Below is a short quotation from the composite narrative (Kuisma, 2018):

> I find the atmosphere more pleasant when people are talking to each other and it's not totally silent. (…) I like it when you are given the responsibility for your own work; you get to search for information and learn according to your own activity. And, even though you are studying things independently, you get to check if you got things right, and if you don't know something, ask someone who knows better. (p. 91)

Most upper secondary school students (6/10) narrated that they achieved their learning goals well and enjoyed the autonomy of the course assignments (learning diary and portfolio); thus, the dominant narrative was labelled as "**learning deepened by autonomy**". Below there are short quotations from the composite narrative (Kuisma & Ratinen, 2021):

> I liked the learning diary and portfolio tasks as I could do them at my own pace and in my own way. The diary was a means to proceed with the portfolio. It was good as we all learn things in different ways and our points of interest differ, so the freedom of choice was a good thing. (…) It was quite laborious to pick up the concepts from the teachers' talks or slides, and I missed some of them as I was taking notes at the same time. But this way, I really had to focus and stay alert during each lesson, and I liked that the students were made to actively ponder things. You have more time to think about things and do the task. It's a well-organised way to proceed, and it's nice to design the look of the portfolio. I stayed well on schedule when making the portfolio. At first, it was difficult to compose the research questions, but I quickly got the hang of it. I took the time and effort to find the answers, especially in biology, but I didn't write everything down. It [formulating questions] was nice and challenged me to think and reflect on things. (…) Right at the beginning of the course, I named different main categories for the concepts: biological, social, physical, and mental and spiritual, then I identified and combined different concepts under those categories, so I could better understand concepts and their meanings when I knew which area they belonged to. I also use colour-coding to memorise notes that I take. Yes, I feel that I now [after this class] have a clearer idea of how I think, how my world of thought might work, what my presuppositions are, so the emphasis is on how much I learn and remember after all. It's good to write things down right away because I know that otherwise I wouldn't remember it later.

Students who generated dominant narratives in both educational levels expressed all four phases of SRL: planning, monitoring, controlling, and reacting/reflecting on their cognition, motivation, and behaviour; thus, these narratives could share the same label. More precisely, they both manifested good skills in effort regulation, time management, controlling their study environment, and, in middle school, also help-seeking. Learners who narrated the dominant narrative expressed high task value, high general motivation levels, and positive and realistic self-efficacy beliefs concerning their learning abilities. In the middle school and upper secondary school settings, maps and portfolios, respectively, enhanced these students' metacognitive skills through elaboration as well as learning the subject matter.

4.2.2 Counter-narratives of middle school and upper secondary school students

The first of the middle school counter-narratives depicts a learner who preferred to do the project work alone instead of negotiating with peers, would have preferred more teacher-led lessons, and did not stay on schedule. This counter-narrative was narrated by four out of the thirteen informants and was labelled as "**solo learner in need of support**". Below is a short quotation from the composite narrative (Kuisma, 2018):

> Well, it's pretty hard work, as it takes a lot of time, and you need to do it at home as well. It's hard because I have physical training exercises four times a week, and yet I have to find time to study. (…) I felt that time flew by mysteriously quickly. I feel that the deadline came all too soon for me. Sometimes it was very difficult to find information, and I had to skip one topic altogether! I did it too hastily, and I'm afraid it's not in the same level as my outputs usually are. (p. 92)

The first counter-narratives in both educational levels resemble each other as both depict a learner who struggles with SRL skills at all three levels (cognition, motivation, and behaviour). Below is a short quotation from the composite narrative named as "**struggling with motivation and schedule**" narrated by three out of ten upper secondary school informants (Kuisma & Ratinen, 2021):

> Especially making that portfolio was maybe a bigger job than I had thought. On the other hand, because I did it in three days at the end of the course, it could have made it feel a lot heavier than if I had done it one topic at a time after each lesson. I'm actually the kind of person who really does not do those things just when they should be done, but I will make them a week behind, which is really bad. (…) It was good that it [the portfolio] replaced the course exam, but then it was forgotten after the

> lessons when I went home, to work, or somewhere right away, and I no longer remembered when I had left the school that it should be done.

The students narrating the first counter-narrative fell behind schedule and found forming research questions relevant to oneself especially difficult. These narratives suggest that the teacher failed to support these students' self-regulatory process through the clarity and pace of instruction, and by supporting their feeling of control over their learning (Loyens, Magda, & Rikers, 2008). These students seemed to possess an impersonal orientation (Deci & Ryan, 1985), which gives the sense that their learning outcomes are beyond their control. This can lead to a sense of helplessness and demotivation; hence, they either felt incapable of coping with the forces of the surrounding world or the forces of drive and emotion (Deci & Ryan, 1985). Some of these students narrated features of anxiety, which is often linked to impersonal orientation (Deci & Ryan, 1985).

The second middle school counter-narrative depicts a learner who prefers to study alone and has high SRL skills; hence, it was labelled as "**solo master of self-regulation**". This learner managed to control their cognition, motivation, and behaviour well, even under challenging conditions. They controlled their motivation, for example, by situational interest enhancement, as depicted in the following narrative (Kuisma, 2018, p. 92): "I like to do chores which involve organizing things and putting small pieces together, so I enjoyed the kind of work where I got to take care of the tiny details on each page, draw maps, and all." This learner is autonomy-oriented (Deci & Ryan, 1985), as experience of choice is a key factor in their learning, and they applied SRL skills when aiming for self-selected goals. Drawing thematic maps stimulated this learner to apply elaboration as a metacognitive skill and induced creative reasoning as they explained how they understood the geographical phenomena. They also used organizing subject matter as a metacognitive skill to learn. This narrative depicts a learner who is more creative than control-determined and has creative and flexible self-determined behaviour, an internal perceived locus of causality, and a high perceived competence (Deci & Ryan, 1985).

The second counter-narrative varied a lot between middle school and upper secondary school. In both groups, only one student narrated the second counter-narrative; however, in middle school, it depicted a learner with very high SRL skills but poor social and negotiating skills, while in upper secondary school, it depicted a learner with excellent negotiating skills but poor effort regulation skills. Below, there is a short quotation from the upper secondary school's second counter-narrative named as "**active communicator with poor effort regulation**" (Kuisma & Ratinen, 2021):

> I have a personal problem with tasks like the portfolio and learning diary, as they are easily left undone; I didn't fill them up much. They are really difficult for me for some reason. I can write an essay in a week if it's an assignment, and it goes quite easily, but when I have to write something like a progressive portfolio, I can't. For me, such a free-form portfolio is somehow really difficult. I'm like, "What am I now actually writing here?" and although I have the lesson topic, I'm still like, "Yeah, you should write something about this, but what?" In my opinion, I'm a pretty good conversationalist; I know how to carry on conversations with other people, interesting discussions, and bring a new point of view. It all goes easily. But then when that conversation should, like, take place with myself, then my mind somehow goes blank and I can't challenge myself in the same way. And because of that, it was really hard for me to come up with research questions, which shows in the diary as there aren't many of them. And then all those concepts and so on, basically I deal with them pretty much in my head. But then I forget to write them down. And that feels like, "So damn, I failed again."

The middle school student achieved her learning goals excellently, but the upper secondary school student did not get the portfolio done. She herself did not know why she always misses creating a portfolio. This learner was unable to complete the course due to missing assignments. The nature of the counter-narratives varied in different datasets, and further research may reveal more different narratives depicted by diverse learners.

4.3 Learning outcomes (Case study I and III)

This section presents the results for **SRQ2: How did inquiry learning affect cognitive and affective learning outcomes?** (Table 1)**.** First, the results of the quantitative research in the first case study on cognitive and affective learning outcomes are presented (Kuisma & Nokelainen, 2018). In this case study, the motivation level is considered as an affective learning outcome, variation in which was investigated by the PMLQ research instrument (see Section 3.3.2) at three different time points during the studied geography course. Second, the learning outcomes of the mixed methods research in the third case study are presented.

Cognitive learning outcomes were investigated in the first case study in middle school (Sample 1) and upper secondary school (Sample 2) geography courses by comparing the post-test scores and calculating the average normalized gain value that measured students' improvement between the pre-test and post-test (see Section 3.3.1). First, we investigated if there was any statistically significant difference between the intervention group's (progressive inquiry method and specific ICT) and control group's cognitive learning outcomes by testing the null hypothesis:

H0: CoLOInt = CoLOContr

(CoLO = cognitive learning outcome; Int = intervention group; Contr = control group).

We tested the data set of middle school students (Sample 1) and upper secondary school students (Sample 2) separately.

The middle school students in the intervention and control groups scored similar results on the pre-test (t = -.647, df = 150, p = .519), and Levene's test for homogeneity of variances indicated equal variances (F = .152, p = .697). It is noteworthy that the middle school students in the intervention group scored higher points (M = 22.0, SD = 4.4) on the post-test compared to the control group (M = 19.4, SD = 6.1). An independent samples t-test was executed to investigate the statistical significance between these mean values. The difference was statistically significant (t = 3.0, df = 139, p = .003). According to Levene's test, the difference between the variances in the intervention and control groups was statistically significant (F = 10.0, p = .002). The deviation in the post-test score was higher in the control group (SD = 6.1) than in the intervention group (SD = 4.4). Similarly, there were no statistically significant differences in the pre-test scores between the upper secondary students in the intervention and control groups (t = -1.413, df = 99, p = .161), and Levene's test indicated equal variances (F = 1.207, p = .255). Yet again, the students in the intervention group scored statistically higher points (M = 21.4, SD = 2.9) on the post-test compared to students in the control group (M = 19.6, SD = 3.6, t = 2.761, df = 99, p = .007). The equal variances were assumed based on Levene's test (F = 1.016, p = .316).

Furthermore, the average normalized gain value was used to measure students' improvement between the pre-test and post-test. In this study, the variance in the gain values was tested by applying the Mann–Whitney U-test to the nonparametric independent samples because of the skewed values and high kurtosis in the distribution of the variables. The results showed a statistically significant difference (p < .0001) in absolute gain values between the intervention group (M = -0.15, SD = .65) and the control group (M = -0.59, SD = 1.15) among middle school students. A similar result was also found from the upper secondary school sample (intervention group: M = 0.22, SD = .31; control group: M = -0.03, SD = .34). This indicates that in both samples the intervention group students' cognitive geographical skills improved more than of those in the control group.

Additionally, in the same case study I, we tested the null hypothesis that there were no differences in the variances between the different groups of teaching and learning methods and in the levels of SRL skills when investigating these groups' relations to post-test results in both samples (Kuisma & Nokelainen, 2018). The differences between the variances were not statistically significant. The post-test scores were higher among the middle school students with weak, sufficient, satisfactory, or good self-regulation skills when the progressive inquiry method was used. Students with high self-regulation skills scored slightly higher points on the post-test when they received teacher-centred instruction. Moreover, among upper secondary school students, the post-test scores were higher for every level of self-regulation skills when the progressive inquiry method was used, but again, these differences were not statistically significant. To summarize, the self-regulated learning skills that the student possessed before the course did not affect their cognitive learning outcome in a statistically significant way in either the middle or upper secondary schools. Hence, the students were able to attain the necessary self-regulation skills during the course, and students with poorer SRL skills had equal possibilities to succeed when either the progressive inquiry method or teacher-centred method was applied.

Motivation level did not vary in a statistically significant way during the study unit in either educational level between the three different time points (Kuisma & Nokelainen, 2018). However, it did differ in a significant way between the intervention and control groups in the middle school students' sample ($F_{1,150} = 7038.8, p < .0001$), showing that motivation was higher when teaching with inquiry learning at all measurement time points. In contrast, in the upper secondary school sample, a more teacher-centred method resulted in a higher level of motivation at the first two measurement points ($F_{1,99} = 5859.8, p < .0001$). At the last measurement point, the motivation level of the intervention and control group was the same. In both samples, the teaching and learning models explained most of the variation in the students' motivation levels ($\eta^2 = .98$). To summarize, the positive effect of inquiry learning on motivation level was evident in the middle school context but not in upper secondary school.

In the third case study, we found evidence of changes in conceptual constructs but with vast individual differences (Kuisma & Ratinen, 2021). Most students (seven out of ten) expressed a profile of mastery goal orientation (Table 3); they aimed to deepen and broaden their understanding, perceived learning as interesting in itself, and expressed an adaptive learning pattern. Learners with a mastery goal orientation manifested conceptual change, belief revision, and

threshold concepts the most. The results shown in Table 3, together with data from the narrative interviews, indicate that all ten students were likely to possess adaptive learning patterns in an academic learning context. Additionally, the two students with the highest scores in the mastery approach (Sofia and Pilvi; see Table 3) scored poorly in their portfolios, which was explained by their narrative interviews. These students were so immersed in pondering new ideas that instead of formulating them as parts of their portfolio, they preferred discussing these topics with others and letting their own thoughts mature. Thus, good external performance in the task was not very important for these students.

Moreover, the upper secondary school students possessed weak abilities to reflect on their own learning processes and outcomes, which emerged as inconsistencies in their interviews. Some students did not consider the deepening of their concept perception or understanding the same phenomenon from the viewpoints of different disciplines to be relevant (e.g. Susanna). Instead, excelling in the matriculation exam (e.g. Leena) or enhancing their competence in their future profession (e.g. Marja) were considered as more important. However, some students (Sofia and Pilvi) identified deepening and broadening their own understanding of the topic, humans and humanity, as their main objective.

Table 3. Upper secondary school learners' mean scores for personal achievement goal orientation (five-point Likert scale), teachers' assessment of the portfolios (scale of 1–3), and composite narratives (n = 10; names are pseudonyms) (Kuisma & Ratinen, 2021).

	Mastery approach *M* (*SD*)	Performance approach *M* (*SD*)	Performance avoidance *M* (*SD*)	Portfolio *M* (*SD*)	Narrative type
Susanna	4.3 (1.21)	4.4 (0.89)	2.8 (1.33)	2.6 (0.5)	Counter 1
Tiina	3.8 (0.98)	3.4 (1.52)	2.5 (0.55)	1.6 (0.8)	Dominant
Marja	3.5 (1.05)	3.6 (1.14)	1.8 (0.98)	1.5 (0.7)	Dominant
Johanna	4.2 (1.17)	2.2 (0.84)	2.5 (0.84)	-	Counter 2
Leena	4.3 (0.82)	3.8 (1.64)	2.5 (1.05)	2.4 (0.5)	Dominant
Mari	4.0 (1.10)	4.4 (0.89)	1.8 (1.33)	2.8 (0.4)	Dominant
Sofia	4.8 (0.41)	1.8 (1.10)	1.8 (0.75)	1.8 (0.6)	Dominant
Pilvi	4.7 (0.52)	3.8 (0.84)	1.7 (1.63)	1.9 (0.6)	Dominant
Jannika	3.5 (0.55)	2.6 (1.82)	1.5 (0.84)	1.4 (0.5)	Counter 1
Katriina	3.2 (0.75)	2.2 (1.79)	1.5 (0.84)	1.0 (0.0)	Counter 1
Total	4.0 (0.97)	3.2 (1.49)	2.1 (1.08)	1.9 (0.8)	

From the six school subjects of the cross-curricular study unit, physics concepts were identified as the most challenging by nine out of ten students. Students mentioned

having too many exercises and too little time to analyse the physical education and physics phenomena. These results refer to a need to lessen the amount of subject matter and give students more time to gain an understanding of the phenomena and their concepts. Data triangulation suggests that an enrichment of concepts took place in all sections of the study unit, even though the narratives were inconsistent. In physics, there was significantly less enrichment; only one student narrated having learned to understand new phenomena or the phenomena in a new way. A lot of belief revision was detected in the philosophy section, but most adolescents failed to describe the concepts in more detail, which can be a sign of defensive responses to unknown conceptual constructs. It would be interesting to investigate these possible anomalies in learners' concept categories further.

Some students (Sofia and Pilvi) vividly narrated how their perception of the world changed when they encountered the concept "fully human", which was regarded as a threshold concept. Sofia pondered what is regarded as fully human and what is incomplete: if a person is blind and deaf or has a developmental disorder, is that person regarded as fully human? In this way, she manifested both a threshold concept and conceptual change when moving concepts across the ontological trees of biology, philosophy, and psychology. At the same time, she realized how we use familiar concepts, such as human, without really being aware of their meanings. She also pondered whether "cumulative knowledge" changes the whole human species and what the future might look like, again manifesting a threshold concept as well as conceptual change. Also, Sofia narrated that she found it extremely fascinating when there were teachers of different school subjects present in the lessons and they offered differing views on topics. For example, the philosophy teacher suggested that *Homo sapiens* is the most advanced species, and the biology teacher challenged this by stating that different species are adapted to different environments; hence, some bacteria can be seen as more advanced than humans when studying organisms living in hot springs. This made Sofia revise her belief of humans as a species, and there was a conceptual change as she moved the concept with its many attributes from the ontological tree of biology to the ontological tree of philosophy. The key finding was that the mastery approach does not relate to the in-depth reasoning in portfolios and concept maps, but it seems to relate to the occurrence of threshold concepts and conceptual change shown in the narrative interviews.

4.4 The role of the digital learning environment (Case study II-III)

In this section, **SRQ3: What was the role of the digital learning environment and digital tools in goal-setting and proceeding with course tasks in an inquiry learning context?** (Table 1) is examined. In both the second and third case studies, the narrative interview study (Table 2) yielded similar results: students in both educational levels under-use available technology in their course assignment. Middle school students were advised to use Moodle as a platform for writing down their research questions and study plans, to disseminate best information sources to their own team as well as to other teams and the teacher, and to discuss matters or ask for help when needed (see Section 4.1.1; Kuisma, 2018). Instead, they used, for example, WhatsApp with their mobile phones for disseminating their ideas or photos of the maps that they had drawn to their team members. They did use Moodle for writing down research questions and for describing what they already knew about the country they had chosen to investigate. However, they did not comment on each other's plans, nor did they write comments on how their thoughts or understanding had changed after finishing the project work. They did, however, reflect on the matter verbally at the end of the course, when the teacher asked about it. Data from the narrative interview suggested that under-using Moodle was due to a lack of time, a lack of familiarity using Moodle, or a perception of the application as clumsy or time-consuming.

Moreover, most of the middle school students (12 out of 13) narrated enjoying creating and solving digital games, and they were considered beneficial for learning the subject matter (Kuisma, 2018). In addition, they enjoyed using the interactive whiteboard to play a few games in the topic summary. Neither teachers nor students used the various tools of the interactive whiteboard other than instructed by the researcher for any other activities during the course. Hence, both the students and teachers seemed to need more guidance and time to learn different ways of using Moodle and the interactive whiteboard (Kuisma, 2018).

The upper secondary school students used Microsoft Office Teams OneNote as their digital learning platform (see Section 4.1.3; Kuisma & Ratinen, 2021). All students described the digital learning platform as well-suited for the cross-curricular study unit (Table 4). This entails that the learning diary and portfolio were easy to find and make and that learning materials and assignments were easy to find. Some teachers used the MS Teams Files section for sharing learning material and assignments, which was considered as an unsatisfactory choice. Students found it

easy to adapt to different teachers' various ways of using Teams OneNote, and it did not matter much if some of the teachers used the content library and some used the collaboration space. However, one learner mentioned that it took some time to adapt to the different ways of using OneNote; thus, a more unified approach is recommended.

Learners considered the learning diary as a useful tool for making their portfolios (Table 4). Most of the students (seven out of ten) considered picking up concepts as easy, and five of ten considered formulating research questions as easy. A couple of students mentioned picking up concepts as difficult, and four students narrated formulating research questions as challenging. One student described formulating research questions as hard at first, but it become easier when one gained experience of doing it. When comparing these results to the portfolio assessment by teachers, it is evident that many upper secondary school students have difficulties in self-assessment of their learning, as they scored poorly on the assignment even though they considered the assignment as easy. Some students explained this conflict by their manner of not writing down their thoughts in the portfolio.

Table 4. Upper secondary school learners' perceptions of the digital learning environment and tools in a cross-curricular study unit according to narrative interview.

	Narrated benefits	Narrated problems and disadvantages	Effects on goal-setting
Susanna	It was very helpful that diary and portfolio were so easy to find in Teams OneNote. Even though teachers may use different parts of OneNote (content library and collaboration space), material and assignments are easy to find. Making a diary was effortless on this platform. Picking up concepts was hard, but manageable. Also formulating research questions was difficult. Altogether, diary helped to concentrate and ponder things. Making the portfolio was quite stressful as one could not stay on schedule. Did not write down her thoughts on the concepts, even though pondered them. Liked the way of working, in which the students were put to reflect on things themselves.	Not mentioned	The structure or other properties of Teams do not affect goal setting.
Tiina	The structure of Teams is clear (materials and tasks are easy to find) and familiar throughout upper secondary school. Noticed the importance of quick notes and wrote down concepts and research questions in her learning diary. Formulating research questions was easy and she took the time and effort to find the answers and ponder the concepts. Additionally, picked up	Problems with loading physics programs (LoggerPro and GeoGebra)	Not mentioned

	some interesting research questions from other students. Enjoyed making portfolio as it was perceived as systematic way of working. Considered portfolio to be better than a course exam.		
Marja	The good thing about Teams is that one can go back to the notes later. It was beneficial for storing slides provided by teachers, and students' own diary and portfolio which they could share to teachers in real time. Through Teams, they were able to attend the lessons remotely when needed. Making the diary and portfolio at one's own pace felt good. Formulating research questions was hard at first but quickly became easier. Considered diary as a good tool for making the portfolio. A portfolio is a good way to individualize teaching, as everyone can move forward the way they want and invest in what they feel is important. The portfolio with its concepts will continue to serve as a good summary of course issues.	It would be nicer to take notes by hand and not with a digital application. She did not have enough time to invest in the portfolio.	Teams does not affect goal setting
Johanna	Teams and OneNote were well suited for this study unit, although overall she does not like them much. Materials and assignments were easy to find. Making a diary and portfolio was effortless on this platform, on OneNote's personal space. The formation of research questions was overwhelming. Pondered the concepts in her mind but could not write anything down. Did not make a portfolio; thus, failed to complete the study unit.	Not mentioned	Not mentioned
Leena	Teams and OneNote were well suited for this study unit. Materials and assignments were easy to find and making a diary and portfolio was effortless on this platform. Considered diary as an excellent tool for making the portfolio and it helped to focus during the lessons. Enjoyed the autonomy attached to the assignment and found making the portfolio easy. Perceived formulating research questions of one's own interest as highly meaningful.	Not mentioned	Not mentioned
Mari	Teams and OneNote were well suited for this study unit. They were easy to use and everything was easy to find. Making a diary and portfolio was effortless on this platform. Learning diary was surprisingly easy to do and she took a habit of writing one or two research questions and some concepts after each lesson. Considered diary as an excellent tool for making the portfolio. Found formulating research questions and picking up	Teachers used Teams OneNote in different ways (some used content library, some collaboration space), which took some time to get used to.	When research questions are regarded as learning goals, achieved them very well.

	concepts easy and took the time and effort to find answers and ponder them thoroughly.		
Sofia	The good thing about Teams is that one can easily go back to the notes later to ponder them more. It was beneficial for storing learning material and notes. It is valuable that through Teams one was able to attend the lessons remotely when needed. Colour coding to indicate the level of learning and writing down research questions and concepts was nice, quick, and easy. Enjoyed making the diary. Formulated a lot of research questions for which many do not even have an answer. The concept assignment made her really consider the topics and their relationships. Considered the thinking process more valuable than actually writing these ideas in the portfolio.	Not mentioned	Teams itself does not guide goal setting. It was nice to use colour codes as indicators of achieving the learning objectives in learning diary.
Pilvi	Preferred teachers using Teams OneNote compared to teachers loading learning material into the Teams Files section and expressed a wish that in future all teachers would only use OneNote. Diary and portfolio were easy to use and easy to find as they were in OneNote. Diary was quick and easy to do and a good tool for self-reflection to indicate how well they had learnt things in real time. Formulating research questions supported learning the subject matter. Also, picking up concepts helped to learn and recollect matters.	Teachers using Teams Files for storing learning material.	Not mentioned
Jannika	Teams and OneNote were familiar and well suited for this study unit. Materials and assignments were easy to find and making a diary was effortless on this platform. Formulating research questions was hard and did not succeed in it, but picking up concepts was easy and the quick assessment of achieving the learning objectives by colour coding. Forgot to make the portfolio on time and returned it late.	Not mentioned	Teams itself did not guide goal setting or achieving the learning objectives, yet it did not complicate them either.
Katriina	Teams and OneNote were familiar and well suited for this study unit. Materials and assignments were easy to find, and making a diary was effortless on this platform. Formulating research questions was hard and did not succeed in it, but picking up concepts was easy and the quick assessment of achieving the learning objectives by colour coding. The last entries to diary were late due to technical problems. Forgot to make the portfolio on time and returned it late.	Not mentioned	Teams itself did not guide goal setting or achieving the learning objectives, yet it did not complicate them either.

Moreover, learners narrated that real-time monitoring of one's learning achievements by colour coding was beneficial (Table 4). They realized the importance of quick note taking, as one tends to forget even the most intriguing ideas quite quickly; thus, the use of systematic note taking with easy access for future use was highlighted. The other quick assignments of the diary (picking up concepts and formulating research questions) were considered to support concentrating during the lessons. Also, the fact that teachers saw the progress of the diary and portfolio in real time and were able to comment on them was mentioned as a useful feature.

Many upper secondary school students found it hard to understand what was meant by learning goals in the interview, which can be seen in Table 4 by missing information. This suggests that they are not used to consider what their learning objectives are and how they could achieve them. When explained in more detail, many narrated that when considering research questions as learning goals, they achieved them well. According to the interviews, the functions of the Teams system from the viewpoint of facilitating learning (Nokelainen, 2006) did not support or hinder goal setting in any way.

5 RESEARCH ETHICS, VALIDITY, RELIABILITY, AND LIMITATIONS

This study complies with the ethical principles of research with human participants and the recommendations on research integrity provided by the Finnish National Board on Research Integrity TENK (Finnish Advisory Board on Research Integrity, 2012; Finnish National Board on Research Integrity TENK, 2019). Research is always an intervention from the participant's viewpoint, regardless of the research method (Vilkka, 2018). For example, both face-to-face interview and survey distract the informant, and it is the researcher's responsibility to make sure that data collection or any other research stage does not cause harm for any of the participants or people near to them. To minimize the possible harm for the participants, the study plan of this study was sent to the Ethics Committee of the Tampere region, and they gave their consent. Additionally, a request for asking teachers and their students to participate in the research was sent to the chief education officer and schools' headmasters together with an information letter. An information letter and permission request were given to the teachers and students, and the researcher met the teachers and students face-to-face to clarify the aims and procedure of the research and to answer their questions. Additionally, the information letter together with the request to sign a consent form was sent to the middle school students' parents or guardians. According to the *Medical Research Act 1999* s. 488, a 15-year-old has the right to decide for themself to participate in the research, but the guardian must be notified of the young person's participation. Some of the participants were under 15 years old, and we wanted these young students to discuss the matter of participation together with their guardians; therefore, parental or guardian consent was asked for as well. Teachers and students were also given a detailed privacy notice via email. As a researcher, I am bound by professional secrecy (*Data Protection Act 2018* s. 1050; *Personal Data Act 1999* s. 523), and I cannot, under any circumstances, reveal the personal information of the people involved in the research to others (Kuula, 2011). Potential partners and funding bodies are clearly identified in the reports such as scholarly articles.

When planning this research, a carefully considered decision was made to measure a phenomenon that is qualitative in nature (changes in various components

of motivation of the learners) with a quantitative approach. This choice was largely research ethical and required the researcher to become familiar with the specific issues and traditions of research ethics, statistics, and educational research (e.g. Nummenmaa, 2010). The researcher should always determine what the phenomenon to be studied in the target population is and what perspective one is using and why. In this study, studied phenomena of teaching and learning were both physiological and social by nature, since social-cognitive constructs were studied (e.g. Pintrich, 2003). If qualitative phenomena are studied by qualitative methods, there is no contradiction in the choice of method. But if one wants to get generalizable information that strives for objectivity, one gets caught up in tough questions (Nummenmaa, 2010). When looking at human learning from a quantitative perspective, choices and trade-offs inevitably have to be made. Even if we examine the numbers, for example the differences between the initial and final tests between groups using different teaching methods, this is not purely a ratio scale phenomenon, because in non-mathematical subjects the evaluator interprets the answers as they are scored, and there is no absolute truth to measure. The researcher pondered whether the measurement scale was of ordinal or interval scale by nature, by questioning whether, for example, the Likert scale intervals between options such as one and two and two and three were equivalent, when the self-assessment scale was made on the scale 1 = not at all true, 3 = somewhat true, 5 = very true (e.g. Kuisma & Ratinen, 2021; Nummenmaa, 2010). The scale was considered as an interval scale because the options 1, 3, and 5 were all identified verbally.

The significance of the problem of a qualitative variable with quantitative properties decreases as the sample size increases (Nummenmaa, 2010). In this case, the differences between the assessments of individuals are reduced, and the use of interval scale measures and analysis methods in measuring and analysing the phenomenon can be justified. The sample size of the quantitative first case study (n = 253) was considered as large enough and, together with data properties (e.g. skewness and kurtosis), was considered as fulfilling the requirements to justify the use of pre- and post-tests, MSLQ and PMLQ as research instruments, statistical research methods, and statistical inference (Murphy et al., 2014). Because the researcher prepared for each case study carefully and spent time identifying and delineating the research problem and discussing it with more experienced fellow researchers and representatives of the target group, the choice of the research instruments can be regarded as well organized. As the phenomena in question had been studied before, albeit with a different target group, and there were already pre-tested and validated instruments for them, it was decided to use those instruments

(Nummenmaa, 2010). This way, it was also possible to compare the research results with previous studies. These premises were taken into account when deciding to apply the research instruments MSLQ, PMLQ, and PALS. Validity was also enhanced by pilot-testing the study and discussing the instrument with both subject teachers and experienced researchers, which removes vague or unnecessary questions or claims from the research instruments, such as pre- and post-test (e.g. Nummenmaa, 2010).

The MSLQ is a popular measurement instrument in educational psychology research, and it has been used in hundreds of educational research projects to assess student motivation and the use of learning strategies (Hilpert et al., 2013; Panadero, 2017). When the entire latent factor structure of this 81-item-instrument has been investigated, several weaknesses have been found (e.g. Hilpert et al., 2013; Panadero, 2017). However, the six dimensions with 31 items of motivation and behaviour regulation investigated in this study's MSLQ version belong to the strongest and most valid section of the instrument and thus have been recommended to be used in scientific research (Hilpert et al., 2013). The dimensions used in our study were: (a) regulation of value, (b) regulation of performance goals, (c) self-consequating, (d) environmental structuring, (e) regulation of situational interest, and (e) regulation of mastery goals (see Section 2.4; Kuisma & Nokelainen, 2018). They belong to the most valid section of the instrument consisting of three latent factors (expectancy, value, and self-regulation), with six indicators: intrinsic goals, task value, self-efficacy, control beliefs, metacognitive regulation, and effort regulation (Hilpert et al., 2013). Therefore, the MSLQ was chosen, although there were also other research instruments to choose from (Panadero, 2017). Additionally, the motivation level measured by PMLQ comprised of dimensions of intrinsic goal orientation, extrinsic goal orientations and meaningfulness of studies, which were derived from the MSLQ (Kuisma & Nokelainen, 2018). As the extrinsic goal orientation dimension has been found to have weaknesses (Hilpert et al., 2013), this should be considered when assessing this study.

As described above, validity was carefully taken into account already when choosing the research methods, for instance by considering whether the research method or instrument was good for studying and measuring just the desired phenomenon or whether it studies or measures something else. In the first and third case studies, it was essential that the measurement scale of the quantitative study was internally consistent (Punch, 2003, p. 60). This means that the items which make up the variables are consistent with each other. This was ensured by measuring the coefficient alpha for content validity, as described in Section 3.3. In the case of

qualitative research, internal validity was examined by the question of whether the research strategy had been chosen according to the nature of the object to be studied.

External validity was considered when planning and conducting the quantitative study. It relates to how applicable the results are in the real world, i.e. in the investigated population. According to Official Statistics of Finland (OSF, 2012), the number of 8th graders studying in Finland in the academic year 2011–2012 was about 60,000, and with a margin of error of 5%, we aimed for a sample size of 400 middle school students in order to gain generalizable results (Murphy et al., 2014). However, despite of our hard effort, we did not manage to gain the target amount but had to settle with a smaller sample size (n = 152). Therefore, this limitation must be taken into account when interpreting the results of the first case study. Similarly, the number of students in upper secondary schools in Finland in 2012 was about 110,000 (OSF, 2019), and our sample size (n = 110) was quite small (Murphy et al., 2014). We did not have the possibility for random sampling and an experimental design, but a quasi-experimental design was applied instead (see Section 3.3). This needs to be considered when assessing the external validity of the results. The invitation to take part in the research was sent to all middle schools and upper secondary schools in Central Finland's Pirkanmaa region. All student groups whose teachers and students volunteered were chosen to participate. The schools were homogeneous in terms of the students' school performance, and there were no statistically meaningful differences between the self-reported evaluations of students' school success (Kuisma & Nokelainen, 2018). Furthermore, no classes required special admission criteria. Thus, these student groups can be regarded as representing fairly well groups of students from different parts of Finland, and although students have not been randomly selected from all over Finland, the results can be seen as indicative of the whole target group. When investigated further, random sampling should be applied in order to enhance the external validity.

This study aimed for an assessable research process, and the reader of both the attached articles and the summary should be able to follow the researcher's reasoning. It should be clear that the results are not based solely to the personal intuition of the researcher. Therefore, the researcher has put emphasis on describing the research methods, solutions, data, and interpretations as clearly as possible. The analysing method was considered to suit the nature of the data. While the concepts of reliability and validity were essential criteria for quality in the quantitative study, in the qualitative research the terms credibility, neutrality or confirmability,

consistency or dependability, and applicability or transferability were considered as the essential criteria for research quality (Lincoln & Guba, 1985).

Reliability means, in general, that respondents answer the same questions in the same way when the study is repeated (Punch, 2003, p. 42). The stability of responses was made as high as possible by keeping the study environment and guidelines for the informants as consistent as possible through all case studies. The researcher was always the same, and the studying procedure stayed the same. Nevertheless, the respondents' mood and state of mind can always differ between different time points. In qualitative research, reliability was considered when choosing the most appropriate approach. For example, the approach of narrative interview was considered to be consistent across different researchers and different studies (Creswell & Creswell, 2018, p. 250). The reliability of the study was improved by discussing the questions of the narrative interviews with experienced researchers.

In the humanities, as in other disciplines, ethical issues must be pondered upon at every stage of research and even when people are not met face-to-face but research is conducted using documentary material. In interview situations, people are dealt with directly, and here the ethical issues are the most diverse (Hirsjärvi & Hurme, 2015; Kvale & Brinkmann, 2009). Research ethical norms are based on the principles developed in medical research: the principles of benefit, avoiding harm, respect for autonomy, and justice (Kuula, 2011). Ethical dilemmas were considered in every phase of the second and third case studies' narrative interviews. Firstly, before conducting the interviews, the objectives, meaning, and consequences were considered (Kvale & Brinkmann, 2009). Besides the three aspects of AR discussed in Section 1.2, enhancement of learners' knowledge and skills about the subject matter and SRL were also regarded as more significant than the possible inconveniences to the participants. Secondly, the consent of the interviewees was requested, and the confidentiality of the investigation and the anonymity of the interviewees were guaranteed (Hirsjärvi & Hurme, 2015). It was ensured that the interviewee received sufficient information about what it entailed when asked to participate in the interview study (Hirsjärvi & Hurme, 2015). Everyone requested to participate was able to refuse to participate in the study, even if it happened after the interview. Ethical considerations were also taken into account in the interview situation itself (Kvale & Brinkmann, 2009). The possible consequences of the situation on the interviewee, such as stress or a change in self-image, were taken into account. Also, the possibility of a therapeutic interview and how close to it we were was considered. On some occasions, after finishing the interview with the student, the teacher-researcher took the time to discuss any worrisome issues that came to

the fore during that interview. Next, in the transcription phase, confidentiality continued to be considered and attention paid to the equivalence of the transcript with oral statements (Kvale & Brinkmann, 2009). These individual transcripts were translated from Finnish to English, aiming for the most valid interpretation of each narrative, thus not striving for an accurate word-to-word translation with the semantic and linguistic details (Nikander, 2008), because the analysis was more content-oriented than interaction-oriented in the present study. In the analysis phase, ethics was also present in how deeply and critically the interviews were analysed. Lastly, the confidentiality and the possible consequences of the published articles for the interviewees and the groups or institutions associated with them were taken into account.

SRL has many characteristics that are reciprocally related to each other (Loyens, Magda, & Rikers, 2008), for example students' interest and teacher's effect. The teacher affects students' self-regulatory processes in many ways, such as through the clarity and pace of instruction and by affecting the students' feeling of control level over their learning. Also, the teacher's enthusiasm, humour, and fairness along with the teacher's expectations on students' capacities affect SRL processes (Boekaerts & Cascallar, 2006). From a vast meta-analysis of 800 studies, John Hattie (2009) found the teacher's effect to be the most important factor in successful education:

> Teachers need to be directive, influential, caring, and actively engaged in the passion of teaching and learning. Teachers need to be aware of what each and every student is thinking and knowing, to construct meaning and meaningful experiences in light of this knowledge, and have proficient knowledge and understanding of their content to provide meaningful and appropriate feedback such that each student moves progressively through the curriculum levels. (p. 238)

There were several teachers teaching the study groups of this study, and they each have their own educational practices and theoretical frameworks from which these practices derive. In order to avoid the teacher's effect disturbing the results of the quasi-experimental study in the first case study, two or three other teachers, in addition to the researcher, gave lessons to both the intervention and control groups in middle school. It was not possible to do the same in upper secondary school due to the course being held only once a year, therefore the researcher was the only teacher to teach the intervention groups and two other teachers taught the control groups. Additionally, all teachers were interviewed with a semi-structured elite interviewing procedure to explore the teaching method and the procedure of the course in detail. Also, the teacher's effect was investigated through narrative

interviews with students in the second and third case studies, as well as a survey for the teachers in the third case study. There were no indicators that the teacher´s effect would have affected the results of this study in an adverse way, but it should be taken into account.

6 CONCLUSIONS

This dissertation aimed to fulfil the research gap in the scientific literature about didactic models for inquiry learning among middle school and upper secondary school students. More precisely, this dissertation had four aims (Table 1) when investigating certain aspects of inquiry learning in the context of Finnish middle school and upper secondary school geography and cross-curricular education. First, the objective was to investigate how students' learning could be supported by designed inquiry based pedagogical models. Second, to further elaborate the first objective, the aim was to build an understanding of the students' perceptions of these inquiry learning models by narrative interviews. Moreover, the aim was to investigate the statistical relationships between inquiry learning and cognitive and affective learning outcomes in the context of geography education. Cognitive learning outcomes were studied by measuring students' improvement between the pre-test and post-test, whereas the motivation level was considered as an affective learning outcome. Lastly, the aim was to understand the role that digital learning platforms have when used in inquiry learning. The main findings of the dissertation were presented by answers to four research questions which articulate the four above mentioned research aims.

Three collaborative inquiry-based teaching and learning models were designed for three case studies, that followed each other in an AR process, where stages followed each other in spiral manner (Figure 6; McAteer, 2013). These models are key results of this study thus they are described in detail in section 4.1.1-4.1.3. Case studies I and II took place quite close to each other, and the interviewed middle school students of case study II also took part in the quantitative study of case study I. After case studies I and II, the results were analysed and the researcher reflected these results with previous studies and theories, planned next phases of research, pondered different pedagogical possibilities for the next case study's model and designed the practices for the cross-curricular teaching and learning model. Pedagogical practices were discussed with the teacher colleagues and supervising researchers before the case study took place.

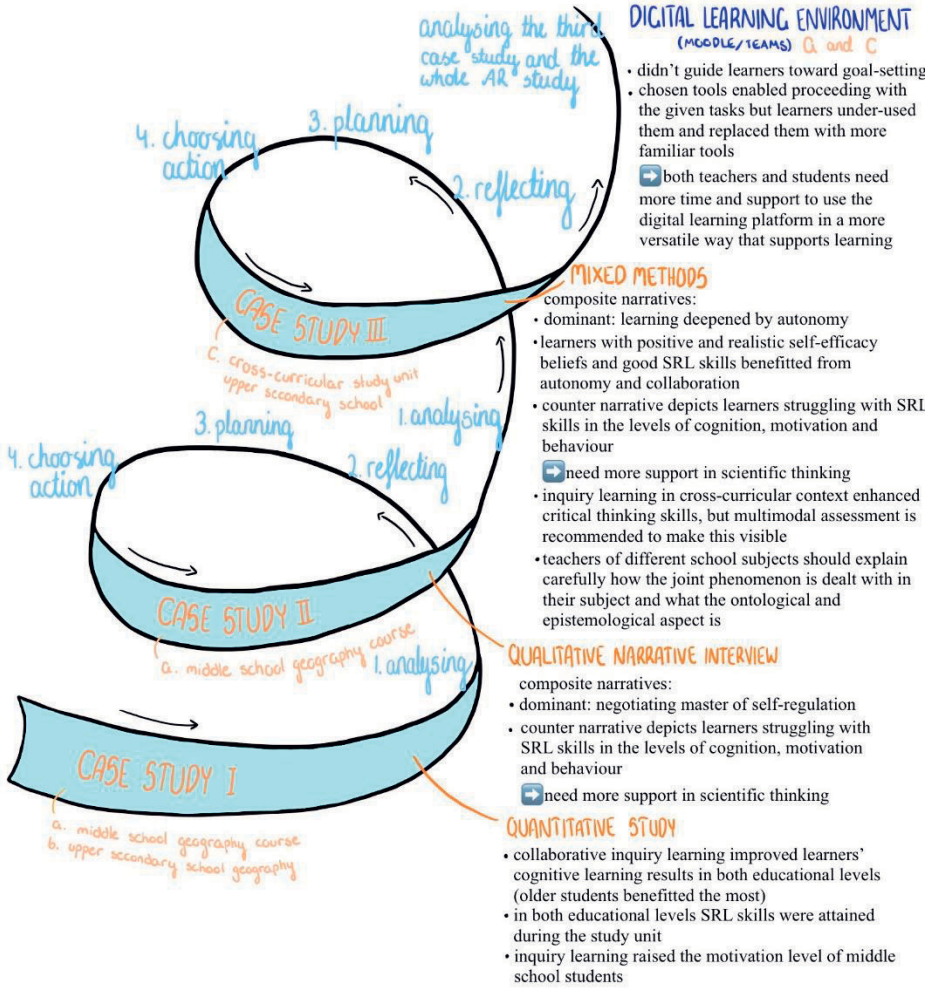

Figure 6. The spiral stages of AR with main findings of each case study. The designed three inquiry-based teaching and learning models are marked with letters a, b, c (a=middle school geography, b=upper secondary school geography, c= cross-curricular study unit; see section 4.1.1.- 4.1.3).

MRQ "**How did the designed models support students' learning?**" was firstly addressed by depicting the teaching and learning models that were designed regarding inquiry learning for a domain-specific and cross-curricular study units. The first model was designed for middle school geography education and the second one for geography education in upper secondary school (Case studies I and II; Kuisma, 2018; Kuisma & Nokelainen, 2018). The third model was designed for a cross-curricular study unit of six school subjects in upper secondary school (Case study

III; Kuisma & Ratinen, 2021). All three models implemented the cyclic model of progressive inquiry (Figure 1; Muukkonen et al., 1999; Paavola & Hakkarainen, 2005) where the learners proceeded with the nine steps of the model during the whole course.

The designed inquiry learning models supported students' learning as follows: In the geography education context, the learners worked in pairs and reported their questions and working theories to other pairs and their teacher via Moodle's digital learning platform. Middle school students pondered upon the phenomena by illustrating them in maps in their portfolios, and upper secondary school students illustrated their geographical topic by a drawing that was supported with augmented reality. The openness level of these and other course assignments or tasks was based on the amount of information and autonomy given to the student by their teacher (Bell et al., 2005; Novak, 2010). In the two models designed for geography education, the openness levels were "guided inquiry", where students investigated a question provided by their teacher using procedures designed or selected by themselves, and "open inquiry", where students formulated their own questions to investigate the given topic using procedures designed or selected by themselves (Bell et al., 2005). The "open inquiry" was considered to represent a holistic approach (Scardamalia & Bereiter, 1991), where neither the teacher nor the student could anticipate beforehand what the results would be.

In the third case study, with the cross-curricular context, inquiry learning was implemented in an upper secondary six-subject study unit "Human being—What am I?" in two levels. Firstly, by structuring a course task in the form of a learning diary to write down research questions and key concepts and a portfolio to ponder and reflect on these issues. These tasks proceeded during the whole study unit, and teachers commented on them in Teams OneNote. Similarly to the geography education context, this task was considered as "guided inquiry" as well as "open inquiry" (Bell et al., 2005). Secondly, learners were given small short-term research tasks in biology, physical education and physics, psychology, and arts to apply the first two openness levels of inquiry learning: "confirmation" and "structured inquiry" (Bell et al., 2005).

Furthermore, teaching and learning models designed for this study were identified as congruent with the basis of progressive inquiry (Paavola & Hakkarainen, 2005). They included active learning activities with learner-centred teaching strategies (Bereiter, 2002; Scardamalia, 2002). They entailed a question-driven process of understanding by formulating and revising research questions (Hintikka, 1982, 1985). Learning was an expansive process, where activities produced new

activities (Engeström, 1999) and collaborative communities induced innovations (Nonaka & Takeuchi, 1995).

SRQ1 "**What kind of narratives did middle school and upper secondary school students formulate from the point of view of self-regulated learning?**" further elaborates the MRQ. It was answered by short quotations and analysis of the composite narratives presented in the second and third scientific publications (Kuisma, 2018; Kuisma & Ratinen, 2021). The main results for this sub-research question (case studies II and III) were in line with previous studies suggesting that, in middle school and upper secondary school, learners with positive and realistic self-efficacy beliefs and good SRL skills benefitted from the high level of autonomy and informal collaboration provided by inquiry learning. This was suggested by the composite narrative that was identified as dominant in both datasets. The first counter-narrative in both educational levels (middle school and upper secondary school) resembled each other, as both depicted a learner struggling with SRL skills at all three levels, namely cognition, motivation, and behaviour. These students fell behind schedule and found forming research questions relevant to oneself difficult. Teachers of these students failed to support the students' self-regulatory process. This result suggests that both middle school students and secondary school students need more practice to engage in scientific thinking. The second counter-narrative varied a lot between the two datasets: in middle school it portrayed a learner who had excellent SRL skills but insisted on studying alone, whereas in upper secondary school it depicted a learner with excellent negotiating skills but poor effort regulation skills.

As the data for the third case study was collected from October 2020 to December 2020, the study unit took place during the Covid-19 pandemic when the schools were once again in face-to-face teaching mode. Nevertheless, the students had experienced school closures and distance education together with other major changes in their everyday life (Chen et al., 2022), which may have affected adolescents' psychological well-being (Holzer et al., 2021; Maestrales et al., 2022). According to the self-determination theory (Deci & Ryan, 1985), as the learners may not have met their needs for competence, autonomy, and relatedness that are the requirements for the experience of well-being, their ability for positive emotion and intrinsic motivation may have diminished (Holzer et al., 2021). This may have affected the results and especially explain the poor effort regulation depicted in the second counter-narrative in the upper secondary school.

Moreover, in middle school, the use of maps together with a portfolio and an exhibition in a tourism fair, and in upper secondary school, a course leaflet and

portfolio, enhanced the learners' metacognitive skills through elaboration as well as learning the subject matter. This is in line with progressive inquiry that suggests that collaboratively created, shared knowledge-laden artifacts can induce learning (Paavola & Hakkarainen, 2005).

SRQ2 "**How did inquiry learning affect cognitive and affective learning outcomes?**" also elaborates the MRQ further. It was answered firstly by the main results from the quantitative case study I (Kuisma & Nokelainen, 2018). A quasi-experimental design was applied to compare cognitive learning outcomes and motivation level of student groups taught by inquiry learning with student groups that were taught with a more teacher-centred method. The results show that cognitive learning outcomes were improved at both education levels, but the older students benefitted even more than the middle school students. This can be seen as a consequence to the more advanced SRL skills of the older students as these skills are developmental by nature (Loyens, Magda, & Rikers, 2008; Wolters et al., 2003). This can lead to more efficient collaboration as not only their individual SRL skills but also the complex and demanding skills of shared regulation are more matured (e.g., Malmberg et al., 2015). Positive impact of inquiry learning on the academic learning outcomes is in line with previous research (Andrini, 2016; Furtak et al., 2012), but one should maintain a critical view on the meta-analyses of this field as the definition of inquiry learning varies a lot (Furtak et al., 2012). This dissertation in congruent with the results of Furtak and her colleagues (2012), that the learning outcomes are enhanced when the students are first being explained why inquiry learning is applied, that is, how it is expected to strengthen their SRL skills. Moreover, the positive impact on learning outcomes seems to apply when the openness level of inquiry learning is of medium level: not too open and not too guided (Jerrim et al., 2019), thus the openness level of the teaching and learning models introduced in this dissertation seems to have succeeded well. As students in both educational levels gained better cognitive learning outcomes when taught by inquiry learning than a more teacher-centred method, this study suggests that there is no reason to avoid applying inquiry learning for fear of poorer cognitive learning outcomes; on the contrary, the results encourage the use of it.

Additionally, previous SRL skills had no effect on cognitive outcomes; hence, the necessary regulation skills were adopted during the course. Inquiry learning affected motivation levels positively in the middle school context, but in upper school this was not the case. In contrast, in the upper secondary school sample, a more teacher-centred method resulted in a higher level of motivation at the first two measurement points of the study unit.

Furthermore, learning outcome was investigated by a mixed methods approach in the third case study within a cross-curricular context in upper secondary school (Kuisma & Ratinen, 2021). Through the findings on changes in the conceptual constructs of learners with different goal orientations and SRL skills, this dissertation aims to contribute to the discourse on curriculum integration. The inquiry learning model fit the cross-curricular context well, since learners studied a common theme, humans and humanity, from six school subjects' perspectives, and learners were advised to write down new research questions in their learning diaries as a section with new perspective of a new school subject began. This study suggests that this kind of cross-curricular inquiry learning enhanced critical thinking skills of upper secondary school students as they started to think about how we name things and do we really mean what those concepts entail. The key finding, that the mastery approach does not relate to the in-depth reasoning in portfolios and concept maps but to the occurrence of threshold concepts and conceptual change, is consistent with previous research (e.g. Bardach et al., 2020; Elliot & McGregor, 2001) that suggests that the mastery approach does not predict performance outcomes but seems to predict a reduction in worry cognition. Therefore, educators should design cross-curricular study unit assessment in a multimodal way that allows students to showcase their thinking processes and ideas in forms other than writing. This is in line with another item included in the Finnish upper secondary school curriculum reform: the validity and reliability of assessment. For example, at the end of the investigated study unit, students created a joint artwork, which helped to bring forth ideas that otherwise would have been left invisible and to synthesize different disciplines' views. This is congruent with research on the connection-building strength of the visual arts (Scott & Twyman, 2018). Writing or drawing one's ideas and, thus, elaborating the subject matter in one's own manner helps students learn better; hence, it is a beneficial SRL skill. Furthermore, there is a need for more research-based guidance for pedagogical practices to improve upper secondary school students' academic writing skills in various school subjects in the cross-curricular context (Hertzberg & Roe, 2016).

Some upper secondary school students seemed to understand the essential view in science that beliefs and presuppositions are not absolute facts but theoretical interpretations which are subject to falsification (Vosniadou, 1994), but many found this confusing and contrary to their ontological and epistemological beliefs (Muis et al., 2018). Discontinuities in the students' narratives may derive from years of studying school subjects within more traditional institutional structures (de Freitas & Bentley, 2012). Hattie (2009) addresses the importance of teachers' awareness of

knowledge construction: that it is not the knowledge or ideas but the students' construction of this knowledge and these ideas that is the key element of teaching and learning. Vermunt and Verloop (1999) name teaching as process-oriented when it takes into account both the nature of the knowledge to be studied and thinking strategies. They also stress the importance of teachers not to take over learning and thinking activities from students too often, which supports the idea of applying different openness levels of inquiry learning in teaching.

The last sub-question to further elaborate the MRQ in this dissertation, **SRQ3** "**What was the role of the digital learning environment and digital tools in goal-setting and proceeding with course tasks in an inquiry learning context?**", was investigated by the second and third case studies. In other words, it was studied in both the domain-specific context of geography education in middle school and a cross-curricular context in upper secondary school. Narrative interviews suggested similar results in both educational levels: students under-use available technology in their inquiry learning course tasks.

Middle school data suggested that under-using Moodle was due to a lack of time, lack of familiarity in using Moodle, or a perception of the application as clumsy or time-consuming (Kuisma, 2018). Moreover, most of the interviewed middle school students narrated enjoying creating and solving digital games, and they were considered beneficial for learning the subject matter. Also, they enjoyed using the interactive whiteboard to play the games. As neither teachers nor students used the various tools of the interactive whiteboard other than as instructed by the researcher for any other activities during the course, both the students and teachers seemed to need more guidance and time to learn different ways of using Moodle and the interactive whiteboard (Kuisma, 2018).

Upper secondary school students used Microsoft Office Teams OneNote as their digital learning platform (Kuisma & Ratinen, 2021). The students found the digital learning platform well-suited for the cross-curricular study unit. This showed that the learning diary and portfolio were easy to find and make and that learning materials and assignments were easy to find. Learners considered the learning diary as a useful tool for making their portfolio and real-time monitoring of one's learning achievements by colour coding as beneficial for learning. Students perceived taking notes quickly and systematically and making them easy to access as highly meaningful. Picking up concepts and formulating research questions were considered to support concentration during the lessons. Also, the fact that teachers saw the progress of the diary and portfolio in real time and were able to comment on them was mentioned as a useful feature. Students found it easy to adapt to

different teachers' various ways of using Teams OneNote, and it did not matter much if some of the teachers used the content library and some used the collaboration space.

Upper secondary school students were not used to considering what their learning objectives are and how they could achieve them; thus, there seems to be a need to make learning processes more visible (Hattie, 2009; Jahnke et al., 2017). When explained in more detail, many narrated that, when considering research questions as learning goals, they achieved them well. In other words, learners can be educated to consider their learning objectives as research questions that they can achieve by finding answers to them. According to the interviews, the functions of the Teams system from a viewpoint of facilitating learning (Nokelainen, 2006) did not support or hinder goal setting in any way.

7 DISCUSSION

Teachers have been identified as the most influential factors in educational change (e.g. Duffee & Aikenhead, 1992), and even though there are vast differences among teachers concerning their effect on student achievement, most teachers have a positive effect on student achievement (Hattie, 2009). A change in teachers' pedagogical skills requires long-term training (van Driel et al., 2001). For example, learning in networks, peer coaching, collaborative AR, and the use of cases have been discovered to be the most successful ways to make changes in teachers' practices and enhance their pedagogical knowledge (van Driel et al., 2001). It would have been interesting to monitor changes in participating teachers' pedagogical knowledge during the case studies of this dissertation, and it is an important area for future research. Moreover, the suggested pedagogical models of inquiry learning with their theoretical framework can easily be implemented in teacher training programmes. The evolution of these models (i.e. modifications made by teachers in the years to come) would also be worth investigating.

Many researchers have tried to delimit the factors that facilitate or hinder SRL by adopting either a metacognitive or a motivational perspective, and there has been an attempt to combine different theoretical frameworks in order to capture the complexity of the SRL processes (e.g. Efklides et al., 2018). Many researchers suggest that the reasons students have for striving to gain control over their learning process are mediated by their epistemological beliefs—specifically their beliefs about the nature of knowledge and the ways of knowing and learning (e.g. Hofer & Pintrich, 1997; Muis et al., 2018). Thus, belief about knowledge may affect study strategies, which was evident in the third case study, as learners' beliefs in the nature of knowledge in the field of physics was a demotivating factor. Also, a lot of belief revision was detected in the philosophy section of the same cross-curricular study unit. Most adolescents failed to describe the concepts of philosophy in more detail, which can be a sign of defensive responses to unknown conceptual constructs. Therefore, in a cross-curricular study unit, teachers of different school subjects should explain carefully how the joint phenomenon is dealt with in this particular subject and what the ontological and epistemological aspect of this particular school subject is. It might be helpful to explain the four dimensions that can be seen as

constructing the epistemological theories—certainty of knowledge, simplicity of knowledge, source of knowledge, and justification for knowing (Hofer & Pintrich, 1997)—as a way to help clarify the thinking and nature of knowledge in the school subject in question.

The mechanisms of how emotions affect and are affected by the elements of SRL (cognition, motivation, and behaviour) and learning outcomes are difficult to investigate, but nevertheless have been investigated by some researchers (e.g. Ahmed et al., 2013). The effects of emotions on learning have traditionally been associated with motivation (Efklides et al., 2018). However, the literature suggests that affect has a significant impact on learning processes before, during, and after learning occasion, and affect, motivation, and metacognition interact with each other (Efklides et al., 2018; Järvenoja et al., 2020). This study claims that middle school students' motivation is higher when taught with inquiry learning than with a more traditional, teacher-centred method. It would be interesting to investigate students' emotions and their explanatory factors further. On the other hand, the interesting opposite result from upper secondary school suggests that, in that context, motivation level is higher when taught with a more traditional, teacher-centred method. It would be worth investigating whether this is connected to affect dealing with the sense of security and familiarity or what other explanatory factors underlie this result. Furthermore, this suggests that autonomy is not something that the majority of upper secondary school students want from their studies, but quite the opposite.

Most students in both educational levels benefitted from a high level of autonomy of inquiry learning in a domain-specific context (see Section 4.2.1), since they expressed good SRL skills. Thus, this dissertation suggests that inquiry learning is well suited for training students with SRL skills. This claim is supported by the result that most students' previous SRL skills did not have a significant role in their academic success in both middle school and upper secondary school (Section 4.3); thus, most learners seemed to evolve the required SRL skills during the study unit. On the other hand, two counter-narratives (see Section 4.2.2) identified in both education levels strongly suggest that in both education levels, many students need support to learn to use SRL skills. Therefore, teachers need more resources such as training to support these skills and to identify learners in need of support. This study also brings forth the dilemma that some learners need help beyond their teachers' expertise to gain help in resolving, for example, traumas that hinder them from proceeding with project work, such as developing a portfolio, that require greater SRL skills, such as effort regulation.

This dissertation's results of the cross-curricular study unit encourage teachers to enable students to encounter unfamiliar, educationally critical content of different disciplines (Schwartzman, 2010) by carefully selecting common themes for cross-curricular study units to strengthen learners' higher-order thinking skills. While carrying out cross-curricular studies, similarities, differences, and relationships between subjects need to be addressed (Kleve & Penne, 2012) to strengthen students' discipline awareness. Furthermore, to enhance students' motivation, they should be aware of the contextual goals of each discipline a well as the whole study unit to be able to set their personal achievement goal in the mastery-performance and mastery-avoidance axis (Bardach et al., 2010; Elliot & Church, 1997; Elliot & McGregor, 2001; Hattie, 2009; Jahnke et al., 2017; Wolters et al., 2003).

As the cross-curricular study units are being added to each upper secondary school's curriculum in Finland from autumn 2021 onwards, it would be interesting to know if students choose them and, if so, why. Is novelty a strong agent? Or do the four preceding epistemic emotions (control, value, complexity, and achievement or impasses of epistemic aims) play a role (Muis et al., 2018)? In light of the findings from this study, students strongly prefer the study units that are needed for the matriculation exams that give them the best possible scores for their future studies. In other words, this constitutes the basis for their valuing the study units. There is a possibility that these well-planned cross-curricular study units will not get chosen because they do not distinctly train for any school subject's matriculation exam. It would be worth investigating whether making it compulsory to choose at least one cross-curricular study unit during students' upper secondary school career and/or giving additional credits for postgraduate studies from completing such a study unit would make a difference.

Many teachers have listened to the words of praise for new technology and its revolutionary effects on learning, and yet have found that pedagogy has remained the same despite the new devices and software. Hence, many have wondered what pedagogical methods could be used to make these new tools more conducive to student learning. Section 4.1 suggests three pedagogical models of inquiry learning including student assignments to be used in the Moodle or Microsoft Teams digital learning environments. This study claims that both middle school and upper secondary school students need more guidance and experience to learn to take advantage of these platforms (see Section 4.4). Social networking software has changed the fundamental ways we communicate, receive information, learn, and work with others, while high-speed wireless networks, mobile personal devices, and cloud computing have dramatically changed our everyday lives (Tan & Lee, 2018).

Information and communication technologies are evolving in unpredictable ways, to which teachers can adapt by innovative teaching practices, which poses challenges for both teachers and students (Cerratto-Pargman et al., 2012). Researchers have articulated their concern over the misunderstanding that because learners are familiar with new technologies, they can learn by themselves to apply them in a manner most beneficial for their learning (Cerratto-Pargman et al., 2012; Hakkarainen et al., 2004; Laurillard, 2012). Instead, as also suggested by this study, the teacher's role is even more important in scaffolding students' thinking and supporting them in learning digital literacies.

According to the upper secondary school interviews, the functions of the Teams system from the viewpoint of facilitating learning (Bakhtiar, 2018; Järvenoja et al., 2020; Nokelainen, 2006) did not support or hinder academic goal setting in any way. It would be interesting to develop the widely used digital learning platforms Moodle and Teams in terms of pedagogical usability, utility, or navigational and signalling aids (Nokelainen, 2006; Sung & Mayer, 2012). Additionally, it would be interesting to investigate whether the effects on goal setting or other SRL processes would be enhanced by these improvements. Maybe these commonly used platforms could be developed more towards the direction of collaborative pedagogy similar to CSILE (Computer Supported Intentional Learning Environments) and its revised version, known as Knowledge Forum (Scardamalia, 2004), and Personal Learning Environment (PLE), where the learners would both collaborate with peers and use personalized tools allowing them the opportunity to combine learning from different institutions or make links between formal and informal learning by, for example, wiki or blog texts (Milligan et al., 2006).

Already by the 1980s there was a growing movement of teacher professionalism that pursued providing teachers more opportunities to engage in curriculum theorizing and educational research (Carr & Kemmis, 1986, p. 1). Unfortunately, this pursuit seemed to fail, as two decades later new teacher generations were almost oblivious to the opportunities of extending their professionalism by educational research (Carr & Kemmis, 2005). As Carr and Kemmis (1986) suggest, teachers' possibilities to do anything else but educational work is very limited, since teaching requires a wide range of skills, and they have not only students as their "clients" but also the parents, the local community, government, and employers making claims that education should meet. Thus, it seems that teachers have no possibilities to engage themselves with scientific research. In fact, the research process has been demanding and cumbersome not only because of its broad theoretical and philosophical background and methodology but also because of the uncertain

timelines of journal publication and financial matters. Nevertheless, it has been professionally rewarding by offering new aspects about teaching and learning processes and deepening and broadening knowledge of qualitative, quantitative, and mixed-method research methodologies. This dissertation achieved its aims to implement AR in all three aspects (Carr & Kemmis, 1986): **Technical** AR was met as both the effectiveness of educational practice and the teacher-researcher's and her teacher colleagues' professional development were enhanced. The researcher also engaged herself in collaboration with other participants (students, teachers, and researchers) and encouraged others to self-reflect; hence, this study also has features of **practical** AR. Additionally, this study entails **emancipatory** AR, as it also liberated the participants from previous traditions of education and transformed the educational system, especially in the third case study when planning and executing a joint cross-curricular study unit. All three case studies empowered the participants to solve complex educational problems collaboratively (Carr & Kemmis, 1986).

According to self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000), every person needs competence, autonomy, and relatedness. According to this study, in both middle school and upper secondary school some learners need long-term support, others manage with less support, and many are able to fulfil these basic needs while studying with collaborative inquiry learning without direct adult support measures. This dissertation considers viewpoints of teaching *and* learning (Vermunt & Verloop, 1999) and provides a means to fulfil the above-mentioned needs of various learners while learning the subject matter and strengthening one's SRL skills through collaborative inquiry learning. Simultaneously, it brings forth a need to differentiate teaching so that the teacher identifies learners with weaker SRL skills and gives more support to these learners for enhancing these skills. This is congruent with the idea of teacher as a **diagnostician** (Vermunt & Verloop, 1999), and it goes without saying that teachers should be provided resources to achieve these kinds of skills and understanding.

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Effects of progressive inquiry on cognitive and affective learning outcomes in adolescents' geography education

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Abstract

Adolescents need skills to acquire information and compare, analyze, transform, and experiment with knowledge. However, little research has been conducted on the content and pedagogical practices that are necessary to achieve these skills. This article seeks to contribute to this discussion because geography enables the attainment of the so-called higher-order thinking skills, and the progressive inquiry model provides suitable pedagogical practices. This study provides empirical evidence on the effects of the progressive inquiry teaching method and learning model on cognitive and affective learning outcomes. This paper focuses on learning outcomes among 253 Finnish middle and upper secondary school students. This comparison between different developmental stages reveals the effects of the teaching and learning method in question. The results indicate that the progressive inquiry method improves cognitive learning results at both educational levels in the context of geography education. The research provides evidence that older students benefit more from the learning model. Additionally, the self-regulated learning skills that the students possess at the beginning of the course do not affect their cognitive learning outcomes. Progressive inquiry clearly enhances the motivation levels of middle school students; however, the effect on the motivation level was more ambiguous among the upper secondary students.

Keywords: active learning; computer-supported collaborative learning; inquiry learning; learning outcomes; progressive inquiry

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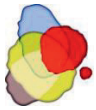


1. Introduction

Inquiry-based learning, such as the progressive inquiry method, requires a great deal of effort from students and teachers, especially when information and communication technology (ICT) is used as a learning tool (Cerratto-Pargman, Järvelä, & Milrad, 2012; Winne, 1995). Nevertheless, the benefits of inquiry-based learning surpass its drawbacks. One of these benefits is the enhancement of essential citizenship skills in the 21st century societies (Banchi & Bell, 2008; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). Although the novelty of many of these skills is controversial, certain skills are commonly seen as necessary for coping with and succeeding in a knowledge- and information-based society (Pauw, 2015). Learners in 21st century societies need skills to acquire information, as well as inquire, analyze, transform, construct, compare, and experiment with knowledge (e.g., Cerratto-Pargman et al., 2012). Despite studies that scrutinize the definitions of these skills, little research has focused on the content that should be used to teach these skills (Pauw, 2015). This article seeks to contribute to this discussion by introducing geography as a context for higher-order thinking and progressive inquiry as a pedagogical model. Research was conducted using a carefully planned quasi-experimental design that compared intervention and control groups, and investigated intact groups to reduce the reactive effects of the experimental procedure, thus increasing external validity (see Dimitrov & Rumrill, 2003). Since the first author of this paper was in a position to act immediately when data was missing (e.g., a survey response), the data was completed right away by asking the student to fill in the missing form. The research design was made in such a way that it enabled the researchers to investigate two different developmental stages of learners in order to find differences in learners' self-regulated learning skills, especially related to motivation, and their effects on learning outcomes. Since self-regulated learning processes are developmental by nature (Loyens, Magda, & Rikers, 2008), we compared two data sets: one from middle school and one from upper secondary school.

According to Wolters, Pintrich and Karabenic (2003, p. 5), "self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment." Based on an analysis of major research trends (Wolters & Taylor, 2012), it encompasses four phases (forethought/planning, monitoring, control/management, reaction/reflection) and four related areas of self-regulation (cognition, motivation, behavior, context) for each phase. In the current study, our focus is on the motivational aspects of self-regulated learning in control (or management) phase (Pintrich, 2004; Wolters, Pintrich, & Karabenic, 2003; Wolters & Taylor, 2012; Zimmerman, 2000; Zimmerman & Schunk, 2008).

One of the key features of geography as a school subject is that it provides content that can mediate the attainment of higher-order thinking skills, such as analyzing, synthesizing, and problem solving (Leat, 1997; Nagel, 2008; Pauw, 2015). Therefore, geography differs from other school subjects due to its analytic and synthetic nature. Learners are challenged with questions about who, why, where, when and how this happen, as well as finding causal relationships within and between phenomena of human and physical geography (Leat, 1997; 1998). As geography provides excellent possibilities for improving learners' 21st century skills, courses of geography were chosen for this study. The following sections present the theories that underlie the research design of this study, followed by a description of the methods.

1.1 Geographical thinking skills

Geography plays a central role in school curricula that educates adolescents for the future (Pauw, 2015). Geography deals with complex issues, such as globalization and global warming, which are included

in the geography curricula of middle schools and upper secondary schools (Finnish National Board of Education, 2015; Pauw, 2015). Moreover, thinking geographically is a skill that helps adolescents understand where something is, how the location affects its characters, and its relations to other phenomena (Nagel, 2008). Adolescents need knowledge about different cultures in order to understand global and local issues. In our study, pre-tests and post-tests were designed according to Bloom's taxonomy to determine students' abilities to recollect factual knowledge, analyze information, and thinking synthetically (Bloom, Hastings, & Madaus, 1981). Moreover, multiple choice questions were designed to measure students' abilities to recollect factual knowledge, and open-ended questions were created to measure their understanding and abilities to apply, analyze, synthesize, and assess knowledge.

In order to succeed in their future careers and personal lives, adolescents require innovative and creative thinking skills, problem solving skills, and communication and collaboration skills that can be taught via geographic studies (Leat, 1997; Nagel, 2008). These skills were implemented into the design of the geography courses of this study. According Nagel (2008, p. 354), "Geography provides students an inexhaustible context for creativity in an interdependent world." Additionally, geography can teach metacognitive skills, thus making the learning processes visible to the learner, which can be transferred to other subject domains (Leat, 1997; 1998).

In this study, middle and upper secondary school students studied human and physical geography. The middle school students studied the geographical phenomena in the European context, while the upper secondary school students studied these phenomena from a global perspective. Both age groups were expected to execute geographical thinking, and analyze and synthesize different phenomena collaboratively through a type of inquiry-based learning called progressive inquiry.

1.2 Progressive inquiry as a teaching and learning model

Progressive inquiry is a teaching and learning model that falls under the umbrella of the active learning approach where students construct knowledge themselves (Prince & Felder, 2006). Active learning activities involve learner-centered teaching strategies that seek to activate students, while progressive inquiry introduces students to a new way of creating knowledge that resembles the scientific inquiry process (Paavola & Hakkarainen, 2005). This is a cyclic process of creating a context for learning, determining the research questions, constructing working theories, seeking and deepening knowledge, conducting a critical assessment of knowledge advancement, and sharing expertise (Muukkonen, Hakkarainen, & Lakkala, 1999). The theoretical framework of progressive inquiry consists of the following theories and models: (1) the knowledge-building theory of intentional learning and expertise (Bereiter, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 1994); (2) the interrogative model of inquiry (Hintikka, 1982, 1985), (3) the theory of expansive learning (Engeström, 1999), and (4) the model of knowledge-creating companies (Nonaka & Takeuchi, 1995).

The knowledge-building processes involved in the progressive inquiry model include monologic ("knowledge acquisition"), dialogic ("participation") and trialogic ("knowledge creation") levels of learning (Paavola & Hakkarainen, 2005). Knowledge acquisition represents a subjective or mental view of human learning, participation represents an inter-subjective or social view of learning, and knowledge creation represents an interaction between individuals, communities, and shared knowledge-laden artifacts being developed (Hakkarainen, 2009). The progressive inquiry approach underlines the key role of the active learner and collaboration when directing one's behavior. It also presupposes that inquiry is a question-driven process of understanding what is needed for knowledge creation, that mediating artifacts can induce learning, and that learning is an expansive process where activities produce new activities.

Progressive inquiry provides learners with a high level of autonomy. To be successful in such a learning process, the learner requires various forms of support from the teacher, as well as self-regulated learning skills (Winne, 1995). According to Zimmerman (1998), the learner's behavior should be intrinsic rather than extrinsic (e.g., regulated by the teacher, parents, or peers) because it enables self-regulated learning to take place. Self-regulated learning skills become fortified as the learner gains experience with controlling

his or her cognition, motivation, behavior (especially effort regulation), physical learning environment, and study schedule (Winne, 1995; Wolters, Pintrich, & Karabenick, 2003). Self-regulatory skills are not fixed individual characteristics as they involve contextual, developmental, and individual constraints (Pintrich, 1999; Wolters, Pintrich, & Karabenick, 2003). When participating in collaborative learning, regulative processes can become even more complex through the interaction between self-regulative, co-regulative, and socially shared regulation processes (Järvelä & Hadwin, 2013).

From the competence research perspective, all these three levels of learning contribute to the holistic development of the individual (cognitive, metacognitive) and subject-related (conceptual, functional) competences (Le Deist & Winterton, 2005). Self-regulation relates to metacognitive ("learning to learn") competence development (Nokelainen, Kaisvuo, & Pylväs, 2016) and is, therefore, a prerequisite of inquiry-based pedagogy because it is needed at the monologic level of knowledge-building processes in technology-mediated learning. Co-regulation relates to the dialogic level and socially shared regulation is needed at the trialogic level. This study focuses on the motivational aspects of regulation. Self-regulated learning processes are developmental by nature (Loyens, Magda, & Rikers, 2008); therefore, we aim to compare the effects of progressive inquiry on the learning outcomes of two different age groups of adolescents.

The progressive inquiry teaching and learning method—with its collaborative way of working—suits the pedagogical framework of geography education because geographical thinking involves question-making, multiple resources to seek answers, analytic and synthetic thinking, and creative problem solving. Our first research question investigates whether this is true and whether it applies to different age groups of adolescents by scrutinizing the cognitive learning outcomes of the method. The second research question investigates the level of self-regulation skills and its relationship with cognitive learning outcomes. Finally, we scrutinize the motivation level of the learners during the geography course.

1.3 Research questions and hypotheses

We wanted to know how progressive inquiry affected the attainment of cognitive learning goals and motivation levels of learners. Motivation level is regarded as an affective learning ability. We also aimed to investigate the relationship between self-regulated learning skills and cognitive learning outcomes. Another study used qualitative interviews to examine what kinds of learning narratives existed among learners (Kuisma, 2018). In this study, we addressed the following research questions:

- RQ1. Does progressive inquiry affect cognitive learning results when studying geography at different levels of the education system?
  - (1a) Does the progressive inquiry method affect cognitive learning results when studying geography?
  - (1b) Do the cognitive learning results differ between middle school and upper secondary school students when they are taught using the progressive inquiry method?
- RQ2. How do cognitive learning outcomes relate to self-regulated learning, specifically regulation of motivation?
- RQ3. Does the progressive inquiry method affect the motivation levels of students?

First, we investigated if there was any statistically significant difference between the intervention group (progressive inquiry method and specific ICT) and control group's cognitive learning outcomes by testing the null hypothesis: H_0: $CoLO_{Int} = CoLO_{Contr}$ (CoLO= Cognitive Learning Outcome; Int= Intervention group; Contr = Control Group). We tested the data set of middle school students (Sample 1) and upper secondary school students (Sample 2) separately.

Second, we investigated the relationship between self-regulated learning skills, and teaching and learning methods with cognitive learning outcomes. We tested the null hypothesis, that there are no differences in variances between different groups of teaching and learning method, and levels of skills in self-regulated

learning when investigated these groups' relations to post-test results. Additionally, we tested the null hypothesis H_0: β1, β2, β3 = 0 for the regression equation CoLO = β0 + β1*TLM + β2*SRL +β3*TLM*SRL + ε (CoLO = cognitive learning outcome as post-test score, β0 = constant, TLM = teaching and learning method, SRL = self-regulated learning skills, ε = random error).

Third, we investigated the effect of the progressive inquiry method on the level of motivation by null hypotheses that there are no differences in variances between different teaching and learning groups in motivation level. We investigated this matter at three different time points (t_0, t_1, and t_2).

2. Method

2.1 Participants

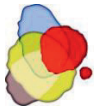
All of the participants (N = 253) participated voluntarily, and their schools were located in an urban area in Central Finland. We sent out invitations via email to participate in this study to all the middle school and upper secondary geography teachers and head masters in Pirkanmaa region (area in Central Finland), and accepted all the volunteers. One hundred fifty-two informants (Sample 1) studied at the middle school of the comprehensive school, and 101 informants (Sample 2) studied at the upper secondary school. Middle school participants of this study took part in a course on the human and physical geography of Europe, the course topic for the upper secondary school students was geographical hazards.

Seventy-five students, among the younger participants of Sample 1, were part of the intervention group that studied using the progressive inquiry method and specific information and communication technology. Seventy-seven students were part of the control group that received teacher-centered training and a learning method that was different from ICT used in the intervention group. Students were taught by six different teachers in nine groups at two schools with an average group size of 18 students. Most (86.8%) of the middle school students in Sample 1 were 14 years of age, and there were slightly more girls (55.3%) than boys (44.7%). The schools were homogeneous in terms of the students' school performance, and there were no statistically meaningful differences between the self-reported evaluations ($F_{1,150}$ = .926, p = .873). Furthermore, no classes required special admission criteria.

Forty-six students were part of the intervention group that studied with the progressive inquiry method and specific ICT in the upper secondary school in Sample 2, and 55 students were part of the control group that received teacher-centered teaching and a learning method that did not use specific ICT tools. They were taught by three different teachers at three different schools in five groups, with an average group size of 22 students. Sixty-two percent of the students were 17 years old, 16% were 18 years old, 13% were 16 years old, and 9% were 19 years old.

There were more male students (72.3%) than females (27.7%) among the upper secondary school participants. This shows that the voluntary course of geographical hazards attracted more boys than girls. There were no statistically significant differences between the students in the intervention and control groups in terms of academic success ($F_{1,99}$ = .028, p = .866). Furthermore, there were no statistically significant differences between the three different schools in terms of academic success ($F_{2,98}$ =1.446, p = .240).

The participants from the upper secondary school differed from the participants from the middle school because they chose to carry out their studies in this particular educational setting and were selected to attend the school based on their previous school performance. Therefore, the content and design of the geography courses differed between the middle and upper secondary schools. However, the intervention groups' progressive inquiry teaching and learning model was similar, and the way the intervention group used the ICT had similar objectives, even though developmental levels of the participants differed.



2.2 Research instruments

The research instruments used in this study included self-report questionnaires and tests. The timeline of these instruments is displayed in Appendix 1. A pre-test and post-test were designed according to Bloom's taxonomy (Bloom, Hastings, & Madaus, 1981) to measure the cognitive learning outcome. The tests had similar structures for both age groups, including 20 multiple choice questions that were designed to measure the students' recollection of factual knowledge (maximum score of 20 points), and five open-ended questions designed to measure the participants' understanding and abilities to apply, analyze, synthesize, and assess knowledge (maximum score of 10 points). The full upper secondary school pre-test is presented in Appendix 2. The multiple-choice questions are formulated according to the following example: "Which of the following concepts refer to an astronomical body that falls onto the surface of Earth? a. asteroid, b. comet, c. meteorite, d. shooting star." One example of the open-ended questions is as follows: "Compare the threats of volcanic eruptions and climate change. What differences are there in the nature of these threats?" A university teacher of geography didactics and two middle school and upper secondary school teachers assessed the tests. Finally, a pilot study was conducted with 21 middle and 18 upper secondary school students.

The means (and standard deviations) for the pre-test and post-test completed by the middle school participants were 22.4 (*SD* = 4.0) and 20.9 (*SD* = 5.3), respectively. The means (and standard deviations) for the pre-test and post-test completed by the upper secondary school participants were 19.0 (*SD* = 3.4) and 20.4 (*SD* = 3.4), respectively. The maximum score for the tests was 30 points, which assured that the items were challenging without being excessively difficult.

For the middle school participants in Sample 1 (n=152), the Cronbach's coefficients were $\alpha = .76$ for the pre-test and $\alpha = .84$ for the post-test. This ensured that the tests were reliable. For the upper secondary school participants in Sample 2 (n=101), the Cronbach's coefficients were $\alpha = .56$ for the pre-test and $\alpha = .63$ for the post-test.

Regulation of motivation was measured with a 31-item survey developed by Wolters and his colleagues (Wolters, Pintrich, & Karabenick, 2003; Wolters & Benzon, 2013). It extends previous instruments (e.g., MSLQ, Pintrich, Smith, Garcia, & McKeachie, 1993) by focusing on (Wolters, 2003, p. 190) "the activities through which individuals purposefully act to initiate, maintain, or supplement their willingness to start, to provide work toward, or to complete a particular activity or goal (i.e., their level of motivation)." The instrument investigates motivation regulation with six dimensions: 1) Regulation of value; 2) Regulation of performance goals; 3) Self-consequating; 4) Environmental structuring; 5) Regulation of situational interest; 6) Regulation of mastery goals. Students responded to the survey with a five-point Likert scale (1=Totally disagree, …, 5=Totally agree). A sample item from the Self-consequating factor is as follows: "I make a deal with myself that if I get a certain amount of the work done I can do something fun afterwards." According to Wolters and Benzon (2013), bivariate correlations among six motivation regulation strategies have shown to be positive and fairly strong (.15-.75). In this study, a summative scale was calculated for the 31 items and discretized into five classes (Weak, Sufficient, Satisfactory, Good, Excellent, see Table 1 for details) in order to group students based on their motivational regulation. The reliability of the 31 variables was high in both samples (Sample 1, $\alpha = .95$; Sample 2, $\alpha = .94$). This indicates that all the variables measure the same construct, strategies for the regulation of motivation.

The learners self-assessed their levels of motivation on a five-point Likert scale (1=Totally disagree, …, 5=Totally agree) at three time points: at the beginning (t_0), in the middle (t_1), and at the end (t_2) of the geography course. Items were derived from Pedagogically Meaningful Learning Questionnaire (PMLQ, Nokelainen, 2006) that was originally designed to measure experiences on the ten categories of learning connected to the usability of learning material: 1) Learner control; 2) Learner activity; 3) Collaborative learning; 4) Goal orientation; 5) Applicability in other contexts; 6) Added value of the learning method; 7) Motivation; 8) Valuation of previous knowledge; 9) Flexibility in certain time points during the investigation period; 10) Feedback. In this study, only category for the motivation was applied. It is based on MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1993) and measures dimensions of intrinsic goal orientation, extrinsic goal orientations and meaningfulness of studies with four items. These items were summarized into one

summative motivation variable. One example of these items is as follows: "The topics to be learnt at school are interesting to me." The first measurement (t_0) took place in the first lesson of the geography course. The second measurement (t_1) was done after the first digital game took place in the intervention groups; and the third measurement (t_2) took place after the second digital game (Sample 1, middle school) or after the interactive leaflet was finished (Sample 2, upper secondary school). Based on the time point, the Cronbach's alpha varied from .55 to .68 (Sample 1, middle school) and .63 to .72 (Sample 2, upper secondary school).

2.3 Procedures

The rationale for this quasi-experimental study was sent to the Ethics Committee of the Tampere Region for revision. The committee approved this investigation as planned. All of the students answered the pre-tests at the beginning of the course and completed the post-test at the end of the course. They also filled in a self-report survey about their strategies for the regulation of motivation during their first lesson. Furthermore, a survey measuring their motivational level was filled out at the beginning, in the middle, and at the end of the course.

2.3.1 Instruction for middle school participants in the intervention group

The researcher and teachers jointly planned the events in the geography course, and the subject was the human and physical geography of Europe. The events of the intervention group were designed to take place as follows: The teacher presented the outline of the course, including its main contents, objectives, and assessments. Then, each student was asked to choose a European country for his or her project work, and the students with the same country formed a pair. Next, each pair wrote down what they already knew about the country and why they chose it, and were asked to develop a study plan including research questions to be answered. The digital learning platform, Moodle, was used to write the study plans, comment on them, ask questions, and disseminate the best information sources with peers. The project work proceeded progressively by searching for information and seeking answers to the questions in the study plan and inventing new questions. The project also involved drawing maps for certain geographical topics, such as topography and livelihoods, and writing down how the map related to other maps and phenomena.

In addition to their progressive investigation, the adolescents were asked to design simple digital games for their peers on two different topics. Their peers then played each game by solving the geographical dilemmas. The teacher used an interactive whiteboard during the geography course, and the students used it when playing the interactive game. The task of the first game was to design a pair of vortexes for two different types of weathering (e.g., physical and chemical weathering), and in the second game to design a vortex pair for two types of climate (e.g., Mediterranean and subarctic climate).

At the end of the course, a tourism fair was organized in the classroom. Half of the student pairs played the role of experts advertising their country to visitors, and then they switched roles. The maps and diagrams were presented at the fair along with drawings, pictures, and souvenirs that the students chose to display. The students were then asked to compare their original study plans with the outcomes of their work in order to make the learning visible.

2.3.2 Instruction for upper secondary participants in the intervention group

The researcher and teachers jointly planned the events in the geography course. The subject of the course was geographical hazards in the field of human and physical geography. The events for the intervention group were designed to take place as follows: The teacher presented the outline of the course, including the main contents, objectives, and assessment. Then, each student was asked to choose one geographical hazard for his or her project, and the students with the same hazards formed a pair. Next, each pair wrote down what they already knew about the hazard and why they chosen it, and developed a study plan with research questions. The digital learning platform, Moodle, was used to write the study plans, comment on them, ask questions, and disseminate the best information sources to peers. The project would proceed progressively,

starting with searching for information, followed by seeking answers to the questions in the study plan, and finally inventing new questions.

The project work involved drawing at least one picture of the hazard, and adding augmented reality in the form of a video clip or audio file to the drawing. Each pair wrote a report about their hazard and attached a drawing that including augmented reality. Finally, an interactive leaflet was created with the various hazards, which supported the students when studying for the exam.

In addition to their progressive investigation, the adolescents designed a simple digital game for their peers about two climatic hazards (climate change and ozone depletion). Their peers played each game by solving the geographical dilemmas. The teacher used an interactive whiteboard during the geography course, and the students used it when playing the interactive game.

At the end of the course, each pair gave a presentation of their work and displayed their videos or other supplementary material. The students used tablet computers; therefore, they used the technology that was attached to their devices to present their work. Finally, the students were asked to compare their original study plans with the outcomes of their projects in order to make the learning visible.

2.3.3 Instruction for the control groups

The teacher presented the outline of the course, including its main contents, objectives, and assessments. Then, the teacher introduced each topic, followed by exercises that were executed individually or with a peer. The students did not complete a project on a specific topic throughout the entire course. Moreover, they did not use a digital learning platform, such as Moodle, for planning or disseminating their ideas or information sources. They did not design a digital game in pairs, and the upper secondary school participants did not create a leaflet. In other words, the students in the control groups were not guided to work collaboratively to the same extent as the students in intervention group. Moreover, they did not have the same autonomy in their learning exercises, which meant they received more teacher-centered instruction without as many technological tools. The most important difference when compared to the intervention groups is that these learners did not follow the question-driven procedure of the progressive inquiry model and they did not use educational technology tools to implement the collaborative studying approach into practice.

2.4 Data analyses

All of the data analyses were executed with SPSS, and the numeric data was systematically observed for outlier detection. In middle school data set, both the pre-test and post-test scores were skewed toward the high end of scale, whereas in the upper secondary school data set, the distribution of the pre-test was normal and the post-test score showed high kurtosis and was slightly skewed toward high scores. Nevertheless, the skewed values were below one; therefore, the distributions were considered close enough to normal for parametric tests to be applied.

3. Results

3.1 RQ1: Effects of the teaching and learning model on cognitive outcomes

The following phrasing was used when presenting the results: The intervention groups comprised students who studied with progressive inquiry and specific ICT tools, as described in Chapters 2.3.1 and 2.3.2, whereas students in the control groups received teacher-centered instruction, as described in Chapter 2.3.3. The middle school students in the intervention and control groups scored similar results on the pre-test (t = -.647, df = 150, p = .519) and Levene's test for homogeneity of variances indicated equal variances (F = .152, p = .697). The middle school students in the intervention group scored higher points (M = 22.0, SD = 4.4) on

the post-test compared to the control group (M = 19.4, SD = 6.1). An independent samples t-test was executed to investigate the statistical significance between these mean values. The difference was statistically significant (t = 3.0, df = 139, p = .003). According to Levene's test, the difference between the variances in the intervention and control groups was statistically significant (F = 10.0, p = .002). The deviation in the post-test score was higher in the control group (SD = 6.1) than in the intervention group (SD = 4.4).

Similarly, there were no statistically significant differences in the pre-test scores between the upper secondary students in the intervention and control groups (t = -1.413, df = 99, p = .161), and Levene's test indicated equal variances (F = 1.207, p = .255). The students in the intervention group scored statistically higher points (M = 21.4, SD = 2.9) on the post-test compared to students in the control group (M = 19.6, SD = 3.6, t = 2.761, df = 99, p = .007). The equal variances were assumed based on Levene's test (F = 1.016, p = .316).

The gain value was calculated based on the original pre-test and post-test scores because it normalized the progress in the learning outcome results. For example, when a student who scored high points on the pre-test, scored high points once again on the post-test, they did not receive the highest points of improvement. The absolute gain value (G) was calculated as G = Posttest% - Pre-test% / 100%-Pre-test%. In other words, the gain value measured students' improvement between the pre-test and post-test. In this sample, the variance in the gain values was tested by applying the Mann-Whitney U-test to the nonparametric independent samples because of the skewed values and high kurtosis in the distribution of the variables.

Mann-Whitney U-test was used to examine the difference between the gain values of the middle school and the upper secondary school intervention and control groups. Results showed a statistically significant difference ($p < .0001$) in absolute gain values between intervention group (M = -0.15, SD = .65) and control group (M = -0.59, SD = 1.15) among middle school students. Similar result was also found from the upper secondary school sample (intervention group: M = 0.22, SD = .31; control group: M = -0.03, SD = .34). This indicates that in both samples the intervention group students' cognitive geographical skills improved more than of those in the control group.

3.2 RQ2: Relationships between regulation of motivation and cognitive learning outcomes

A summative variable was constructed from the score that was derived from the 31 variables measuring strategies for the regulation of motivation. As the observations of the original variable were normally distributed (N = 253, M = 127.9, SD = 27.5, Mdn = 129, Mo = 129), it was decided to reconstruct five groups of equal relative frequencies. The group in the middle included the mean, median, and mode values (Table 1). The variable of different teaching and learning groups in different educational levels was recoded into a new dummy variable, where a value of 1 equaled the progressive inquiry and a value 0 equaled the teacher-centered approach.

Table 1

Relative frequencies of motivation regulation skills in five categories (N = 253)

Score of strategies for the regulation of motivation, in points	Relative frequency, %	Labeling of the motivation regulation level
≤ 107	19.2	Weak
108 – 127	19.6	Sufficient
128 – 134	19.2	Satisfactory
135 – 151	20.0	Good
≥ 152	18.0	Excellent

We tested the null hypothesis that there were no differences in the variances between the different groups of teaching and learning methods, and the levels of self-regulated learning skills when investigated these groups' relations to post-test results in both samples. In Sample 1 (middle school), Levene's test showed that the error variance of the dependent variable (post-test score) was equal across the investigated groups ($F_{9, 141} = 1.813$, $p = .071$), and the results from the regression analysis suggested that in this model ($CoLO = \beta_0 + \beta_1*TLM + \beta_2*SRL + \beta_3*TLM*SRL + \varepsilon$; CoLO = cognitive learning outcome as post-test score, TLM = teaching and learning method, SRL = self-regulated learning skills), the teaching and learning methods did not explain the post-test score ($F_{1, 141} = 3.866$, $p = .121$) in a statistically significant way. Neither the self-regulated learning skills alone ($F_{4, 141} = .329$, $p = .847$) nor scrutinized together with the teaching and learning method ($F_{4, 141} = 2.148$, $p = .078$) had any statistically significant relationship with the post-test score. The ANOVA showed that the teaching and learning models explained only a part of the success on the post-test ($\eta^2 = .056$, $p = .005$), while self-regulated learning skills explained even less ($\eta^2 = .020$, $p = .589$).

In Sample 2 (upper secondary school), Levene's test showed that the error variance of the dependent variable (post-test score) was equal across the investigated groups ($F_{9, 89} = 1.714$, $p = .097$). The results of the regression analysis suggested that in this model ($CoLO = \beta_0 + \beta_1*TLM + \beta_2*SRL + \beta_3*TLM*SRL + \varepsilon$) the teaching and learning methods explained the post-test score ($F_{1, 89} = 13.367$, $p = .017$, $\eta^2 = .74$) in a statistically significant way. Neither the self-regulated learning skills alone ($F_{4, 89} = 1.088$, $p = .468$, $\eta^2 = .52$) nor scrutinized together with the teaching and learning methods ($F_{4, 89} = .641$, $p = .634$, $\eta^2 = .03$) had any statistically significant explanatory effect on the post-test score. The ANOVA suggested that this model failed to explain much of the variation in the post-test scores because the teaching and learning methods explained only some of the success on the post-test ($\eta^2 = .090$, $p = .004$), and self-regulated learning skills explained even less ($\eta^2 = .030$, $p = .596$).

Even though the differences between the variances were not statistically significant, Figure 1 shows how the post-test scores were higher among the middle school students with weak, sufficient, satisfactory, or good self-regulation skills, when the progressive inquiry method was used. Students with high self-regulation skills scored slightly higher points on the post-test when they received teacher-centered instruction. Additionally, Figure 1 shows that among upper secondary school students, the post-test scores were higher for every level of self-regulation skills when the progressive inquiry method was used.

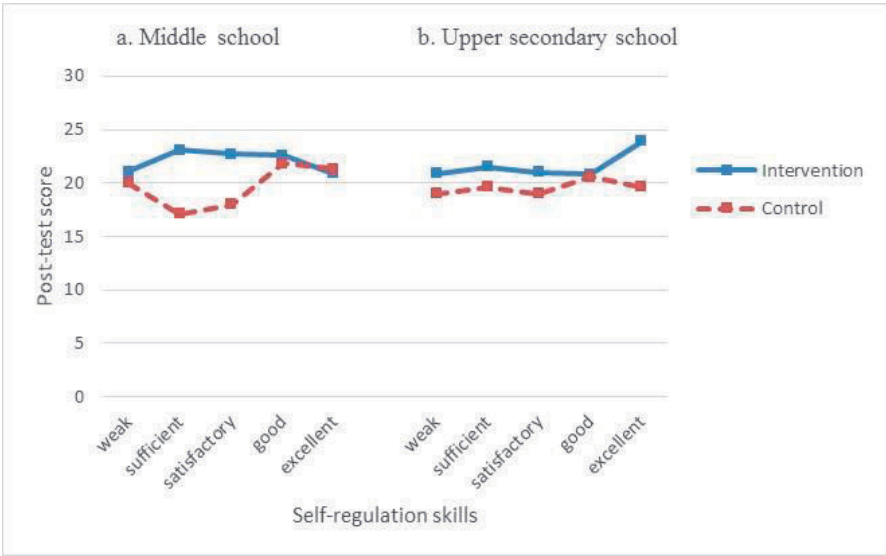


Figure 1. Self-reported self-regulation skills in relation to post-test scores in the intervention and control groups at both education levels.

3.3 RQ3: Relationship between the level of motivation and the teaching and learning methods

In Sample 1 (middle school), Levene's test showed that the error variance of the dependent variable (level of motivation) was equal across the middle school students in the investigated groups (t_0: $F_{1,150} = 1.056$, $p = .306$; t_1: $F_{1,150} = .435$, $p = .511$; t_2: $F_{1,150} = 1.699$, $p = .194$) and in Sample 2 (upper secondary school) (t_0: $F_{1,99} = .36$, $p = .549$; t_1: $F_{1,99} = .003$, $p = .958$; t_2: $F_{1,99} = 4.838$, $p = .030$). In the upper secondary school sample, the last measuring point (t_2) showed that equal variances could not be assumed between the intervention and control groups. This should be recognized when interpreting the results.

When analyzed using Wilks' Lambda test, the results showed that the motivation level did not differ in a statistically significant way between the different time points (Sample 1, $p > .05$; Sample 2, $p > .05$); however, it did differ in a significant way between the teaching and learning models used with the middle school ($F_{1,150} = 7038.8$, $p < .0001$) and upper secondary school ($F_{1,99} = 5859.8$, $p < .0001$) students. In both samples, the teaching and learning models explained most of the variation in the students' motivation levels ($\eta^2 = .98$). Figure 2 visualizes the motivation levels at three different time points.

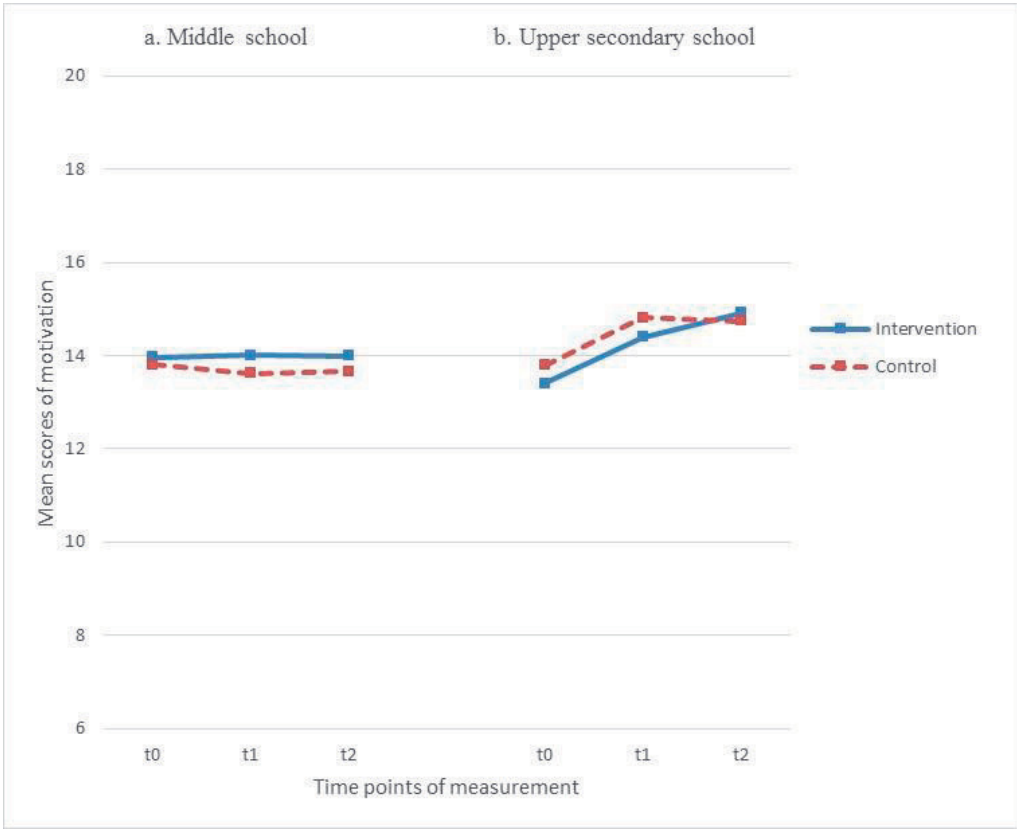
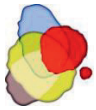


Figure 2. Self-reported motivation levels in the intervention groups that used the progressive inquiry learning model compared to the control groups, which received teacher-centered instruction in middle school and upper secondary schools (measured at time points t_0, t_1, and t_2).



4. Discussion and conclusions

According to this study, the progressive inquiry learning model fits well with geographical studies both at the middle and upper secondary school levels. When investigating RQ1, the students at both educational levels showed higher post-test scores when taught with the progressive inquiry method, and their cognitive learning outcomes improved significantly more than the control group. As the skills to analyze data and make syntheses were also being measured in pre- and post-tests, the results suggest that this type of progressive inquiry teaching and learning model, which enhances the higher-order thinking skills, fits well both education levels. This result was in line with previous research on computer-supported collaborative learning (CSCL), which suggests that CSCL technologies trigger positive changes in group dynamics by enhancing learning interactions and enabling sharing and constructing knowledge among team members (Ludvigsen, Lund, Rasmussen, & Säljö, 2011). It was also congruent with the finding that learning complex and challenging science topics improves when students are repeatedly trained to use their self-regulatory skills in hypermedia environments (Greene & Azevedo, 2007). Since collaborative learning has become more common (O'Donnell & Hmelo-Silver, 2013), research on engagement in learning has broadened from the context of individual learning to collaborative groups (Järvelä, Järvenoja, Malmberg, Isohätälä, & Sobocinski, 2016). We require more information on the cognitive and socio-emotional interactions between team members in order to support different kind of learners, and the ways that self-, co-, and socially shared regulation affect the collaborative learning process.

Furthermore, this study provided evidence that supported the following claim: since students in upper secondary school are older and have undergone a selection procedure to attend the school, it is understandable that the progressive inquiry method would suit them better than younger students because their self-regulated learning skills would be more developed. This conclusion is derived from upper secondary school students' higher absolute gain values, as well as the higher probability that the gain values would differ between the group that studied using the progressive inquiry method and the group that received teacher-centered instruction.

The results from RQ2 suggested that the self-regulated learning skills that the student possessed before the course did not affect their cognitive learning outcome in a statistically significant way in either the middle or upper secondary schools. This meant that the students were able to attain the necessary self-regulation skills during the course, and students with poorer self-regulated learning skills had equal possibilities to succeed when either the progressive inquiry method or teacher-centered method was applied. There was an interesting tendency suggesting that middle school students with the strongest self-regulatory learning skills scored the highest points on the post-test when they received teacher-centered instruction. The result was not statistically significant, but it would be useful to investigate, whether the students with a high level of self-regulation skills do not benefit from the progressive inquiry method as much as students with weaker self-regulation skills.

It would be useful to measure students' self-regulated learning skills in terms of regulation of motivation at the end of the course as well, in order to get more insight about whether the progressive inquiry method enhances these skills. However, since the progressive inquiry method enhances student autonomy when making choices about the order of tasks, proceeding with tasks, or scheduling their studies (Kuisma, 2018), good results in cognitive learning outcomes point to potential improvement in these learning outcomes as well. This finding is in line with Wolters and Benzon (2013, p. 218) as they state that "efforts to improve students' self-regulated learning may benefit from including motivational strategies into the instructional plan." In future studies, we intend to use six factor structure of motivation regulation instead of a summative score, as Wolters and Benzon (2013) concluded after their empirical study that correlations of motivation regulation factors were not substantial enough to indicate a single underlying construct.

The results from RQ3 clearly show the positive effect of the progressive inquiry method on learners' motivation levels in middle school. Wolters and Pintrich (1998) found in their study that students' motivation level varied across several disciplines (mathematics, social studies, and English), but not their regulatory

strategy use. Although current study had no variance in discipline and did not measure change in regulatory processes, motivation levels were higher throughout the geography course compared to the control group. The collaborative activities in the form of designing and playing the digital games, along with the progressing project work, seemed to increase the motivation level of the middle school students. However, in the upper secondary school, the motivation levels of the intervention group were lower than those of the group that received teacher-centered training. The motivation levels of the intervention group continued to rise from one time point to another. Finally, the motivation levels at the end of the course rose to the same levels as the control group. Altogether, the upper secondary school students seemed to be less motivated by the progressive inquiry method than the younger students.

Inquiry learning can be used in classroom practices with or without ICT, but it has been shown that learners' abilities for scientific research and collaboration skills are fortified when ICT is included (Banchi & Bell, 2008; Hakkarainen et al., 2004). It has been suggested that the gap between the every-day use of ICT and the way it is utilized at school can affect students' motivation in higher education (Hietajärvi et al., 2015). Although socio-digital participation has proven to be a tangled web of relationships, it is suggested that complex technology-mediated knowledge practices can be useful for learning in educational settings when striving for deep learning. It would be interesting to investigate this web of causal relationships among middle and secondary school students.

Keypoints

- The progressive inquiry method and learning model suits geography education because it improved students' cognitive learning outcomes and motivation levels.
- Cognitive learning outcomes were improved at both education levels, i.e., middle school and upper secondary school.
- Upper secondary school students profited more from the progressive inquiry method in terms of cognitive outcomes compared to middle school students.
- Previous self-regulated learning skills had no effect on cognitive outcomes; therefore, the necessary regulation skills could be adopted during the course.
- The positive effect on motivation levels was evident in the middle school context.

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Appendix 1

Research design

Geography of Europe / Geographical Hazards			
Intervention group 1	Progressive inquiry: learner-centered	*n*=75	
Control group 1	Teacher-centered	*n*=77	
Intervention group 2	Progressive inquiry: learner-centered	*n*=46	
Control group 2	Teacher-centered	*n*=55	

t_0	t_1	t_2
Pre-test Regulation of motivation survey Motivational level survey	Motivational level survey	Motivational level survey Post-test

Group 1: Sample 1, Middle school students
Group 2: Sample 2, Upper secondary school students

Appendix 2

Pre-test in upper secondary school

Circle the option that you think is correct. (Only one of the options is correct!)

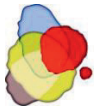
1. Which of the following concepts refer to an astronomical body that falls onto the surface of Earth?

   a. asteroid
   b. comet
   c. meteorite
   d. shooting star

2. During the sunspot cycle when the Sun is the most active,

   a. Earth's magnetic field changes, so that a magnetic storm may destroy transformers, electronic devices and satellites.
   b. the movement of tectonic plates strengthens and volcanic activity causes threats to human activities.
   c. the slowing down of sea currents may cause global warming.
   d. the ozone layer in the upper atmosphere thins down significantly.

3. How large a portion of all earthquakes on Earth take place in the Pacific Ocean and its surrounding areas?



a. 10 %
b. 25 %
c. 50 %
d. 80%

4. Loss of human lives caused by earthquakes can be decreased

a. by building a large undivided space under an apartment building, e.g. a parking hall.
b. by making large buildings as complex in shape as possible.
c. by attaching the floors of apartment buildings (ceilings) properly to the building's load-bearing walls by using steel reinforcement structures.
d. by decreasing the use of adjusting structures.

5. A tsunami **usually** begins from an earthquake which

a. is caused by an asteroid crash.
b. is caused by human activities, e.g. building of dams.
c. takes place in the inner parts of the continental lithosphere plate.
d. raises the water mass above the whole earthquake area, causing a giant wave advancing in all directions.

6. The magnitude of an explosive volcanic eruption depends on

a. the composition of magma.
b. the steepness of the volcano's slope.
c. population density on the slopes of the volcano.
d. the location of the area with respect to the equator.

7. Volcanic activity is useful to local people because

a. geysers and craters attract tourists.
b. a volcano that has erupted once will not erupt a second time, and it is possible to build a tourist resort in the crater.
c. the volcanic mud slides from volcanos would make a luxurious spa treatment for tourists.
d. it is easy to predict volcanic eruptions, and volcano eruption watching attracts tourists.

8. How does a cyclone form?

a. It is formed when strong winds combine together.
b. It is formed from warm seawater from a strong low pressure area.
c. It is formed when a rain front approaching from the sea meets a continent.
d. It is formed when a tsunami meets a continent.

9. Which of the following countries have suffered the most from tropical cyclones?

a. Japan
b. Bangladesh
c. United States
d. Australia

10. What are twisters?

a. Strong hurricanes which kill hundreds of people in the United States every year.
b. Tornado-like whirlwinds which occur in Finland, for example.
c. Splinters of stones thrown into air during a volcanic eruption.
d. Earthquake waves.

11. Floods cause

a. less damage in Ostrobothnia than in Finnish Lakeland.
b. half of all deaths in the world caused by natural catastrophes.
c. depletion of soil nutrients in the floodplains of rivers.
d. more damage in natural rivers than in rivers that have been turned into straight canals.

12. Hot weather can be a threat to human lives because

a. air-conditioning devices are ineffective.
b. hot weather is difficult to predict and there are no advance warnings.
c. hot weather disrupts railway schedules.
d. the temperature regulation system in a human body is working at its limits when the surrounding temperature rises to 40°C.

13. Erosion, the wearing away of the soil, is accelerated

a. if terrace plantations are built on steep slopes instead of fields that naturally follow to the shape of the slopes.
b. if treeless areas are forested.
c. due to logging of forests, agriculture and animal husbandry.
d. due to thickening of the plant cover.

14. The most significant harmful effects from an unbalanced diet

a. are more common in the population of working age than in children.
b. are less significant than the harmful effects of excessive eating.
c. are caused by lack of proteins, minerals, vitamins and fibre.
d. are caused by insufficient caloric intake.

15. Which disease spreads through dirty drinking water?

a. typhoid fever
b. malaria
c. AIDS
d. Ebola

16. Which of the following statements related to natural biodiversity **is correct**?

a. Biological diversity has increased over the last centuries.
b. Climate change decreases the natural biodiversity in arctic areas.

c. Genetic diversity is not part of biological diversity.
d. Out of all ecosystems, wetlands have suffered the least from decrease of biodiversity.

17. Which one of the following statements related to climate change **is incorrect**?

a. The average temperature on Earth is estimated to rise 1–5 degrees Celsius in a hundred years.
b. The strengthening of the greenhouse effect is mainly due to carbon dioxide and other greenhouse gas emissions from usage of fossil fuels.
c. Climate change makes it easier to cultivate grain in regions around the equator.
d. The surface level of oceans will rise due to climate change.

18. Climate change can be slowed down

a. by planning the infrastructure of an area so that motor vehicles are used as little as possible.
b. by increasing one's own carbon footprint.
c. by increasing methane emissions.
d. by increasing consumption of fossil fuels in developing countries.

19. Ozone depletion is

a. less often noticeable above the Antarctica than in the North Pole area.
b. a significant environmental problem in the lower levels of the atmosphere.
c. a significant environmental problem in the upper atmosphere, the stratosphere.
d. decreased due to freon and halon emissions.

20. The problem with urbanization is

a. formation of smoke fog, or smog.
b. decrease of floods as rain water is directed to storm water drains.
c. merging of the residential areas of the well off and the disadvantaged people.
d. increasing biodiversity.

Answer the following questions in writing:

21. Compare the threats of volcanic eruptions and climate change. What differences are there in the nature of these threats?

22. How can slowing down of climate change be useful in Sub-Saharan Africa?

23. There are regular floods in a certain area.

a. What could cause the floods?

b. How could the inhabitants decrease flood damages?

c. Which kind of damage caused by floods is the most harmful, in your opinion? Explain briefly.

PUBLICATION 2

Narratives of inquiry learning in middle school geographic inquiry class

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Narratives of Inquiry Learning in Middle School Geographic Inquiry Class

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Narratives of Inquiry Learning in Middle School Geographic Inquiry Class

This study aimed at modifying a teaching and learning model for a geographic inquiry to enhance both the subject-related skills of geography and so-called 21st century skills in middle school students (14–15 years old). The purpose of this research is to extend our understanding of the user experiences concerning certain tools for learning such as maps and information and communication technology when they are used alongside the inquiry learning model by examining the narratives produced by the students in one compulsory middle school geography course. The data comprised interviews with students from three different classes in the same school. The narrative of the "negotiating master of self-regulation" was identified as the dominant narrative of the experiences of the progressive inquiry model. This narrative depicts a learner who benefits from progressive inquiry and has the appropriate communication and collaboration skills to cope and succeed in the 21st century. Two counter-narratives—the "solo learner in need of support" and "solo master of self-regulation" narratives—in which the skills for self-regulated learning and negotiation varied from high to low, were also identified. The results also indicate experiences of under-using the available technological applications.

Keywords: collaborative inquiry learning; geographic inquiry; inquiry learning; narrative inquiry; progressive inquiry; technology enhanced learning

Introduction

One of the key features of geography as a school subject is that it provides content that can mediate attainment of the higher-order thinking skills such as analyzing, making synthesis, and problem solving (Leat, 1997; Nagel, 2008; Pauw, 2015), which have been considered to be among the skills that are mostly needed in a world of rapid technological changes and increased globalization of economies. For example, creativity, innovativeness, critical thinking, problem-solving, decision-making, and metacognition have been found to be the most essential 21st century skills of thinking, and communication and collaboration skills have been identified as the most necessary

working skills (Binkley et al., 2012; Pauw, 2015; Soulé & Warrick, 2015). Further, information literacy and information and communication technology (ICT) literacy have been found to be the most crucial skills relating to work.

Progressive inquiry is an inquiry learning approach to teaching and learning which is aimed at enhancing the subject-related skills and knowledge as well as the aforementioned 21st century skills (Hakkarainen, 2004; Muukkonen, Hakkarainen, & Lakkala, 1999). The aim of progressive inquiry is to introduce a new way of creating knowledge to learners that resembles the scientific inquiry process, hence it suggests that inquiry is a question-driven process of understanding that can lead to knowledge creation (Paavola & Hakkarainen, 2005). Progressive inquiry is based on the *knowledge-building theory* of intentional learning and expertise (Bereiter, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 1994). It underlines the central role of the active learner and collaboration when directing one's behaviour in the inquiry process. Furthermore, the *theory of expansive learning* (Engeström, 1999), lies beneath the progressive inquiry model. The theory of expansive learning highlights the meanings of mediating artefacts, or tools, in learning, and learning is seen as an expansive process of activities that produce new activities.

Progressive inquiry is a nine-step process (Muukkonen et al., 1999), and in this study it was applied to a geographic inquiry. These steps include creating a context for learning, determining the research questions, constructing working theories, seeking and deepening knowledge, conducting a critical assessment of knowledge advancement, and sharing expertise. The manner in which these steps were applied in this study is described in detail in the section regarding the rationale behind the investigated geography course.

The aim of the present study was to extend the understanding of the strengths and weaknesses of the progressive inquiry teaching and learning model in a geographic inquiry. The conclusions regarding the feasibility of narrative inquiry for gathering information from adolescents are also presented. The research questions are as follows: (1) What kind of narratives of the progressive inquiry teaching and learning model are given by the students? (2) What characteristics and tools of progressive inquiry are beneficial for learning the geographical subject matter and skills, and the required 21st century skills?

Relevance of the Study

This study investigates adolescents' learning in the Finnish comprehensive school system, renowned for its success in Programme for International Student Assessment (PISA) investigations and belonging to the schooling tradition of the Nordic Countries. The concepts of inquiry learning and inquiry-based learning encompass progressive inquiry, and this approach to learning has been at the centre of recent educational reforms in Finland and many other countries since the 1990s (Finnish National Board of Education, 2015; Furtak, Seidel, Iverson, & Briggs, 2012; Kidman, 2012; Minner, Levy, & Century, 2010).

This study is the first part of a research project on students' motivation and cognition in classroom education when studying geography using progressive inquiry. In total, 314 students and 9 teachers participated in this research project. A practical objective was to propose a pedagogically meaningful teaching and learning model based on progressive inquiry that would introduce certain tools for learning Geography. The suggested model is based on the results of this and another related study.

The aim of this study was to describe and interpret the learners' experiences of the progressive inquiry and the specific tools used in geographic inquiry. This

complements the discourse provided by qualitative research about the meanings pupils have constructed in actual teaching situations thus contributing to evidence-based practice in the field of geography education (Roberts, 2010). Additionally, one objective was to test the narrative inquiry approach among middle school students. The narrative inquiry approach has not been applied much to study middle school education from adolescents' point of view, even though story-telling has been identified as a distinct feature of most human beings right from early childhood, when the first sentences are uttered (e.g., Abbott, 2008). The feasibility of the method was investigated by examining the level of narrativity (Fludernik, 2000, p. 282), and the adolescents' reliability to stick to their own experiences in the interviews (Abbott, pp. 70–77).

Motivation to Learn

To understand the differences between the narratives of progressive inquiry and develop the teaching and learning model further, the students' motivational aspects were investigated. The motivation to learn is a complex concept whose meaning has many different angles. One of the most recent syntheses of the research in this area suggests that there are three controversial key concepts to ponder when studying the motivation to learn: extrinsic motivation, intrinsic motivation, and freedom or autonomy (Ellett & Erickson, 2010, p. 347). Therefore, the narratives were scrutinized for depictions of the *value components* of motivation which involve learner goal orientation and the task value of learning (Pintrich & McKeachie, 2000). When learners are mostly internally goal-oriented, they experience curiosity, joy, and increased self-worth through learning. Those who are more externally goal-oriented are mainly motivated by good grades and rewards. The task value of learning describes the learners' perceptions of the importance of a task.

There are two kinds of *expectancy components* of motivation: control beliefs and self-efficacy beliefs (Pintrich & McKeachie, 2000). Learners who experience having control over their behaviour and the ability to influence their environment tend to achieve better learning outcomes than learners who do not believe that they have such control. The learners' self-efficacy beliefs consist of beliefs about performance capabilities when undertaking a certain learning task and beliefs about achieving grades. Both of these expectancy components positively affect the learners' performance via cognition, self-regulation, and metacognition. Both control beliefs and self-efficacy beliefs are linked to the skills of planning, monitoring, and regulating cognition.

Self-Regulated Learning Skills

Wolters, Pintrich, and Karabenick (2003) present a synthesis of the complex phases and areas of the self-regulated learning process. This constituted the theoretical background of the present study to scrutinize the adolescents' use of self-regulated learning skills when undertaking tasks of progressive inquiry during the geography course. The four phases that can occur in the areas of regulation are (1) forethought, planning, and activation; (2) monitoring; (3) control; and (4) reaction and reflection. This paper focuses on the third phase of regulation, control phase, and its three scales. The applied scales are as follows:

a. Cognition: Rehearsal, Elaboration, Organization, and Metacognitive Regulation
b. Motivation/Affect: Relevance Enhancement, and Situational Interest Enhancement
c. Behaviour: Effort Regulation, Time/Study Environment, and Help-Seeking

Cognitive strategies involve the memorization and retrieval of information, whereas metacognitive strategies are for planning, regulating, and modifying cognitive processes (Pintrich & McKeachie, 2000). Managing one's use of time is linked to the value

components of motivation, such as intrinsic orientation and task value, which affect the choice of behaviour, and thus the choice of activity. Another resource management strategy involves managing the physical studying environment. The third resource management strategy is effort regulation; this is considered one of the most important learning strategies, as it involves the learner's general self-management of effort and persistence. Learning how to seek and obtain help from peers or teachers is also an important resource management strategy. It is beneficial for the learners to recognize when they need help and must identify someone else as a provider of assistance.

Description of the Investigated Geography Course

Participants

This was a case study conducted in one comprehensive school in Central Finland. Three teachers of geography and their students took part in the study with the progressive inquiry teaching and learning model; the researcher/interviewer was one of these teachers. The average age of the 13 adolescents who participated in the interviews was 14.1 years, and the class sizes varied from 17 to 23 students. Typically, each interview lasted about half an hour. The teachers were interviewed after the course to gather additional information about the events that had taken place.

The aim was to recruit adolescents based on their freewill. The ethical dilemmas of participation were considered, including the fact that the researcher was a teacher of some of the informants, and the informants' young age, and the rationale for the investigation was sent to the Ethics Committee of the Tampere Region for revision. The committee gave consent for carrying out the investigation as planned. No differences were found between the narratives of researcher's students compared to the student narratives of other teachers.

The Rationale for the Geography Course

The researcher and teachers jointly planned the events of the geography course, and the objective was to perceive the following key elements of geographic inquiry in European context: (1) the human and physical phenomena and their associated relations, (2) the geospatial reference systems such as events, places and regions, (3) the spatial perspective, and (4) geographic vocabulary (Favier, 2011, p. 100). Progressive inquiry was applied to a geographic inquiry approach in order to investigate the geographical phenomena by collecting, processing and understanding the data (Chang et al., 2012). Data comprised of texts, animations, maps, and diagrams.

The events were designed to take place as follows. The teacher would present the outline of the course including its main contents, objectives, and assessment. Then each student would be asked to choose one European country for his or her project work, and the students with the same country would form a pair. Next, each pair would write down what they already knew about the country and why they had chosen it, and develop a study plan with questions. The digital learning platform Moodle would be used for writing the study plans, commenting on them, asking questions, and disseminating the best information sources to other peers. The project work would proceed progressively by searching for information by seeking answers to the questions in the study plan and inventing new questions. The project work on European countries would involve a task to draw maps of certain geographical topics, such as topography and livelihoods, and write down how the map relates to other maps and phenomena.

In addition to their progressive investigation, the adolescents would have to design simple digital games for their peers about two different topics. Their peers would then play each game by solving the geographical dilemmas. The teacher would use an interactive whiteboard during the geography course, and the students would use it when playing the interactive game.

At the end of the course, a tourism fair would take place in the classroom. Half of the student pairs would first play the role of experts advertising their country to the visitors, and then they would switch roles. Maps and diagrams would be presented at the fair with drawings, pictures, or souvenirs that the students would choose to display. The students would be guided to compare their original study plans to their project work outcomes in order to make the learning visible.

Narrative Inquiry as a Research Approach

A narrative inquiry approach was chosen for this study because it underlines the process of gaining an in-depth understanding of the events (Abbott, 2008) that take place in the classroom from the students' point of view. Moreover, according to constructivism, knowledge is created subjectively as an interplay between one's prior experiences and conceptions and new ideas; hence, one's conceptions of oneself and of the surrounding world are always changing (Bakhtin, 1986; Guba & Lincoln, 2005), thereby constructing a constantly transforming narrative. Knowledge can be seen as a network of these narratives. The orientation of the study was cross-sectional, as the aim was to investigate how the interviewees, which are referred to as informants, would narrate their experiences in the interviews.

The autobiographical approach was chosen because the focus lies in the events of the story—in other words, what happened and why—rather than investigating the structures and forms of these narratives using a more linguistic approach (Abbott, 2008). Therefore, the scientific classical realistic paradigm and constructivist interpretative paradigm are intertwined.

Not all talk is narrative, and oral and written language can be categorized into narrative, argumentative, instructive, conversational, and reflective macrogenres (Fludernik, 2000, p. 282). A narrative is not merely stating facts; it always encompasses

personal experiences and involvement (Abbott, 2008). Experiences are reconstructed into new narratives every time they are narrated; moreover, a narrative is first reconstructed according to the interpretation of the researcher, and then according to the interpretation of the reader.

Narrative Interviewing as a Means for Investigation

All qualitative interviews are based on conversation (Kvale & Brinkmann, 2009), where the epistemology of the qualitative interview is more constructionist than positivist (Holstein & Gubrium, 1995), and the participants are seen more as active meaning-makers than as passive transmitters of knowledge. Interviewing an under-aged person is an interactive process just as interviews with adults are (Eder & Fingerson, 2001).

In order to diminish the teacher–student question–answer setting, a *one question narrative interview* (Rosenthal, 2003; 2004; Wengraf, 2001) was chosen as the interviewing method. This method accords more freedom of expression in one's own words. An open-ended question was first asked to guide the informants toward story-telling in their interviews. Next, informants were asked particularised questions. The last phase of the interview was devoted to asking questions which were of significance to the study, if these topics had not surfaced in the previous answers.

In this study, the interviewer started the interview by telling a story about certain events in her life. The purpose of this story was to guide the informants into a narrative way of thinking and thus entice them to produce narratives. Furthermore, to express the interviewer's wish to receive narratives, instead of short answers, she stated the following:

> I would like you to tell me your own story about this specific geography course. Tell me in your own words the events and experiences that you regard as the most important ones. You can start wherever you like and take all the time you need. I will first listen to

you without interrupting, and take some notes in order to ask you questions later.

Analysing Techniques

This study used narrative inquiry as an analysis technique in two different ways: (1) as an analysis of narratives and (2) as a narrative analysis (Bruner, 1986; Polkinghorne, 1995). In other words, the narratives were both the target and outcome of the investigation, as the aim was to identify different narratives (both dominant and counter-narratives) from the data, and analyse the themes within them.

The analysis followed an inductive–deductive procedure, where the basic logic of each interview was first defined to construct each informant's narrative. During this phase, the narratives of the positively and negatively experienced events during the geography course emerged. Next, the narratives were categorized according to what seemed to be the most influential characteristics of the stories; thus, a thematic analysis was conducted according to both direct and indirect story-telling. One dominant narrative was depicted among most of the informants (8/13) and was named the "negotiating master of self-regulation", and two counter-narratives which differed from the dominant narrative were identified. The first of the two counter-narratives was identified among minority of the informants (4/13) and was named the "solo learner in need of support", whereas the second one was identified in only one narrative and was named the "solo master of self-regulation". Subsequently, composite stories were constructed from authentic interview extracts in order to ensure analytic transparency.

In the interpretation process, the researcher engaged in a dialogue with the informants, the data, the theoretical framework, and her own thoughts (Riessman, 2001). Hence, the interpretation was occurring already during the interview and continued through every subsequent phase, from writing the narratives of each interview, coding the themes of the transcripts and narratives, categorizing the

narratives, and creating composite narratives.

In order to enhance the reliability of the thematic categorization, the transcripts were given to a senior researcher for thematic analysis. The two researchers discussed the discrepancies, and the number of themes for further investigation was reduced.

The Dominant Narrative: The Negotiating Master of Self-Regulation

The dominant narrative was named the negotiating master of self-regulation, as all informants depicted the atmosphere during the geography course as talkative, relaxed, and supportive. All of these informants (8/8) considered the talkative atmosphere, where they were able to ask questions and negotiate with their peers, as beneficial for their learning. They all managed to complete their project work in time and sensed ease in proceeding at their own pace. Most of them (7/8) enjoyed the freedom to make their own choices about when to work on which task. In other words, they composed a joint narrative of an ideal student with respect to the goals of 21st century working, communication, and collaboration skills. Furthermore, they were all able to plan, monitor, and control their learning process and react to any obstacles. The narrative is presented as a composite constructed from the interviews with these eight adolescents:

> I find the atmosphere more pleasant when people are talking to each other and it's not totally silent. --- I like it when you are given the responsibility for your own work; you get to search for information and learn according to your own activity. And, even though you are studying things independently, you get to check if you got things right, and if you don't know something, ask someone who knows better. --- When you have someone to talk to, you negotiate things and perceive multiple views on the matters in question. --- We shared the workload quite equally. It has been nice to work both at home and at school, and to decide for yourself how much you do at home. --- And we worked on the text together, shared ideas, and modified each other's texts into our own words, too.

They all indicate a high task value and a high general motivation level. They mentioned variation in studying methods (7/8), freedom of choice and getting to make your own decisions (7/8), digital games (6/8), working in teams (5/8), drawing maps (4/8), using an interactive whiteboard (4/8), the supportive and relaxed atmosphere in the classroom (3/8), writing notes in one's notebook (2/8), and using Moodle (2/8) as motivating factors. All who mentioned the interactive whiteboard as a motivating factor expressed how much they had enjoyed using it together with the whole class to solve digital games, as everybody participated.

According to their stories, all of these adolescents had positive and realistic self-efficacy beliefs concerning their ability to learn. Altogether, this narrative depicts learners who realize when they need help and act on it; thus, they control their behaviour well during their learning process. Other self-regulated learning skills that they revealed are effort regulation, time management, and controlling their study environment.

Most of the adolescents (6/8) considered drawing and interpreting maps as beneficial for learning the subject matter. They had realized that explaining in their own words enhanced their understanding of the subject matter; hence, their metacognitive learning skills were improved. Drawing and interpreting maps was a task which motivated the adolescents, as they perceived the task as important and of intrinsic interest. Moreover, it enhanced their learning through elaboration.

Counter-Narrative 1: The Solo Learner in Need of Support

The first of the two counter-narratives identified in the data was named "solo learner in need of support". There are three things that characterize this narrative: the adolescents preferred doing the project work alone to negotiating with peers, they would have liked more teacher-led lessons, and they struggled with the timetable. Three of them had a lot

of extracurricular activities, such as intense sport training four times a week or meetings for the student union; two of them had missed some of the geography lessons and failed in trying to fit all their activities into their timetable, causing them to fall behind in the studying schedule and the project work schedule with their classmates. The narrative is presented as a composite constructed from the interviews with four adolescents:

> Well, it's pretty hard work, as it takes a lot of time, and you need to do it at home as well. It's hard because I have physical training exercises four times a week, and yet I have to find time to study. --- I felt that time flew by mysteriously quickly. Sometimes it was very difficult to find information. --- I felt that the teacher wasn't present that much, like he was more of a bystander or an observer. We had so much individual work, instead of learning from the teacher. This way, we had to study everything too quickly and I was struggling to manage with the pace. --- As everyone is working with his or her own work, there are no unpleasant disputes, either. I couldn't enjoy doing it, really, because I always felt the pressure of having too little time for it.

In this study, some students (2/4) said that they had not done this kind of long-term project work before, and thus they had not had opportunities to enhance their collaborative skills. Both the students and the teacher need to gain experience of using different collaborative studying methods involving the delegation of tasks and different roles before the learning results can improve (Viilo, Seitamaa-Hakkarainen, & Hakkarainen, 2011). To enhance these skills, students need to be told the benefits of the applied collaborative studying method (Viilo et al., 2011). In this case, the teacher has failed to support the students' self-regulatory process through the clarity and pace of instruction, and by influencing the students' feeling of control over their learning (Loyens, Magda, & Rikers, 2008).

Unlike the learners in the dominant narrative, these four adolescents did not perceive the progressive inquiry model as beneficial for them. They seemed to have an

impersonal orientation (Deci & Ryan, 1985), which means that they believe their outcomes to be beyond their control, thus leading to a sense of helplessness and amotivation. In other words, they either felt incapable of coping with the forces in the surrounding world or the forces of drive and emotion. The impersonal orientation is generally linked with a high level of anxiety, which is evident in two of these narratives.

Counter-Narrative 2: The Solo Master of Self-Regulation

There was one interview that differed from all the others by depicting a learner who prefers to work alone and has high self-regulation skills. This narrative reaffirms that the experience of choice is a key factor of the autonomy orientation (Deci & Ryan, 1985). Autonomy-oriented people make choices and regulate themselves when they aim for self-selected goals. The motivation can be either intrinsic or extrinsic, but the behaviour is nevertheless self-determined if it is based on choice. This narrative starts with an example of situational interest enhancement, which is one way she controls her motivation. Composite narrative is constructed from one authentic interview transcript as follows:

> I like to do chores which involve organizing things and putting small pieces together, so I enjoyed the kind of work where I got to take care of the tiny details on each page, draw maps, and all. --- It isn't nice when the class is too loud, with everybody talking aloud, as I can concentrate better when it's absolutely quiet. --- It kind of bothers me in general to have someone else sitting next to me with all his or her stuff scattered around. --- I am able to concentrate better when working alone, just by myself. --- When you interpreted the maps that you had drawn, you both better perceived what the map was about and you learnt what those things really mean.

Drawing maps with different themes was a task which clearly stimulated the informant to use elaboration as a metacognitive skill, and it induced creative reasoning when she was understanding and explaining the geographical phenomena. She also used a certain

city as a reference point to determine how far north or south the phenomena were situated; thus, she used organizing subject matter as a metacognitive skill to learn.

This informant displayed creative and flexible self-determined behaviour, which is more creative than control-determined behaviour, and its perceived locus of causality is usually internal, while perceived competence is high (Deci & Ryan, 1985). She managed to control her cognition, motivation, and behaviour well, even under challenging conditions.

Narrated Experiences of Educational Technology

In most of the narratives (12/13), the learners experienced creating and solving digital games as beneficial for learning the subject matter. The idea of learning the subject matter and collaborative working skills while creating something together (Paavola & Hakkarainen, 2005) was fortified by these informants. This learning task was valued the most in the dominant narrative and the second counter-narrative, and viewed as less beneficial in the first counter narrative. This is congruent with the fact that the narrators in counter-narrative 1 did not consider negotiating as beneficial to their learning.

The learners did not use Moodle's digital learning environment as planned. They wrote down questions in the field of geography and commented briefly on what they already knew about the country that they were about to investigate. However, they did not comment on each other's plans, and they did not compare the final outcomes of the project work with their original ideas and study plans; hence, they did not realize how much they had learnt. Some explanations emerged from the data, such as a lack of time, lack of familiarity with using Moodle, or experiencing its use as difficult, clumsy, or time-consuming. The students preferred to use their mobile phones to send each other information, such as pictures of maps.

Further, they did not use the interactive whiteboard for interactive activities other than playing the digital games together with the whole class. Both the students and teachers seemed to need more guidance and time to learn different ways of using Moodle and the interactive whiteboard, and information on why it was being used.

Feasibility of Narrative Inquiry Approach When Investigating Adolescents

Narrativity was found in every interview, and only a few (2/13) wanted mostly to be asked specific questions. The same adolescents also changed their perspective on whose experiences were being shared, thus distancing themselves from the events. All in all, the majority (9/13) used narrativity as the dominant macrogenre or as much as the argumentative or conversational macrogenre, and gave narratives from their own point of view. Although the involvement varied from medium to high, none of the stories was told entirely from an outsider's perspective. To summarize, the narrative inquiry approach undertaken with one question narrative interview proved suitable for investigating these 14–15 year-old adolescents.

Conclusions and Discussion

The results of this study are well in line with positive findings regarding the use of inquiry learning in geography education (e.g., Chang et al., 2012; Kidman, 2012). Most of the study participants (8/13) depicted the events of the geography course, which was run using a progressive inquiry teaching and learning model, as beneficial for their learning both the subject matter and subject-related skills, as well as some of the so-called 21st century skills (Table 1). Their stories were identified as the dominant narrative, named "negotiating master of self-regulation". It seems that learners with positive and realistic self-efficacy beliefs and good self-regulated learning skills benefit from the progressive inquiry learning model, where matters are negotiated with a peer

and the learners are given high autonomy and freedom of choice. Nevertheless, these students, like every student, also need support from their teacher to steer their learning process to some extent (Winne, 1995).

[Table 1 near here]

A few adolescents (4/13) were identified according to their narratives as "solo learners in need of support", and they were learners who did not benefit from the progressive inquiry learning model. On the contrary, they were struggling to complete their project work on time, as they lacked skills of effort regulation and time management. Moreover, they did not sense any benefits of working with a peer. These results indicate a need to rehearse self-regulated learning skills, as they are not fixed characteristics in a person and thus need to be strengthened repeatedly (Winne, 1995). In addition, more practice with collaboration is required to gain the necessary skills for working in the 21st century. These learners were not intrinsically motivated; therefore, they would have benefited from extrinsic support (Deci & Ryan, 1985), and they highlighted their need for the teacher's guidance and support. Especially the students who have poor time and effort management skills need practice to strengthen their self-regulatory skills. For example, teacher's enthusiasm and fairness, along with showing positive expectations of the students' capacities, can improve the self-regulated learning process (Boekaerts & Cascallar, 2006).

There was one narrative identified as the "solo master of self-regulation" depicting a learner who is highly skilled in all four levels of self-regulated learning and has good metacognitive learning skills, but lacks social skills. Yet progressive inquiry suited her well, as she benefited from learner autonomy and freedom of choice.

Inquiry learning, such as progressive inquiry, can be embedded in the classroom practices with or without ICT. Although, when ICT is used to provide tools for inquiry learning, it should strengthen the learners' abilities for scientific research and their collaboration skills (Banchi & Bell, 2008; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). In this case study, drawing and interpreting maps and creating digital games served as tools for learning, as the progressive learning model and knowledge creation metaphor suggest (Engeström, 1999; Paavola & Hakkarainen, 2005), but Moodle and the interactive whiteboard were under-used as such learning tools. This result indicates the challenges posed by the unpredictable evolution of ICT for both teachers and students, and the hardships that they struggle with (Cerratto-Pargman, Järvelä, & Milrad, 2012; Chang et al., 2012). Teachers tend to share the misunderstanding that because many learners are familiar with new technologies, they can learn different ways of utilizing them by themselves (Cerratto-Pargman et al., 2012). Instead, the teacher's role is even more important for scaffolding the students' thinking and supporting them in acquiring information and ICT literacy. On the other hand, it was interesting to notice that the lack of using the suggested ICT tools did not inhibit the students from carrying on with their geographic inquiry. It seems that the middle school students are able to come up with alternative solutions for achieving their learning goals, and especially the way they use mobile devices for sharing information and help-seeking when studying with geographic inquiry would be an interesting topic for further investigation.

This study provides evidence that can be used in geography education by suggesting that given adequate support, progressive inquiry can enhance motivation and the acquisition of both geographical skills and knowledge, and 21st century skills. Special attention is needed to guiding the students' learning process (1) at the beginning of the course, for writing down the study plan, (2) during the course, to remind about

giving feedback via Moodle, (3) at the end of the course, to compare the outcome with the original perceptions of the subject in order to make learning visible.

Progressive inquiry requires tremendous effort from both the teacher and the students, and what this study adds to the model is the notion that there are different kinds of learners, who can be identified by their self-efficacy beliefs and skills in self-regulated learning, and their need for support from the teacher differs greatly. Teachers and teacher educators should take this finding into account and focus on supporting the students with poor effort regulation skills and poor time management skills, when teaching with progressive inquiry. With these notions in mind, the cyclical learning process of progressive inquiry can be applied in geographical inquiry to transform a schooling culture into resembling a scientific inquiry culture, thus enhancing the skills that are required in a knowledge society.

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Tables with captions

Table 1. Juxtaposition between the dominant and counter-narratives for self-regulated learning skills, negotiation skills, self-efficacy beliefs, and motivation.

	Self-regulated learning skills	**Negotiation skills**	**Self-efficacy beliefs**	**Motivational factors**
The Dominant Narrative: ***The Negotiating Master of Self-Regulation*** Learner with high self-regulation skills and high negotiation skills	Planning, monitoring, controlling, and reacting phases took place, and cognition, motivation, and behaviour were controlled; maps enhanced metacognitive skills (elaboration) and the learning of the subject matter	Experienced the talkative atmosphere as a positive factor, negotiated matters actively	Positive and realistic	General motivation level high, task value got higher due to sensed freedom of choice, team work, and variation in studying methods
Counter-Narrative 1: ***The Solo Learner in Need of Support*** Learner with poor time management skills and poor effort regulation skills	Planned, but did not stick to the plan or did not plan; instead, drifted along and, hence, did not get the work done	Experienced talkative and noisy atmosphere as highly disturbing, did not consider negotiating matters as beneficial	Overly positive and unrealistic: half of the maps needed to be finished in one weekend's time, or poor beliefs	This course was hard work, with a lot of struggling; contextual motivation was low, progressive inquiry was not beneficial
Counter-Narrative 2: ***The Solo Master of Self-Regulation*** Learner with high self-regulation skills, poor negotiation skills, and poor social skills	Planning, monitoring, controlling, and reacting phases took place, and cognition, motivation, and behaviour were controlled; maps enhanced metacognitive skills (organizing and elaboration) and the learning of the subject matter	Experienced the talkative atmosphere as a negative factor, did not negotiate matters	Positive and realistic, overly positive about social skills	General motivation level high, task value got higher due to the ability to make one's own choices

PUBLICATION 3

Students' narratives and conceptual changes in a cross-curricular inquiry-based study unit in a Finnish upper secondary school

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Students' narratives and conceptual changes in a cross-curricular inquiry-based study unit in a Finnish upper secondary school

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ABSTRACT

Cross-curricularity is being implemented in the upper secondary school curriculum reform in Finland. This study investigates changes in conceptual constructs when studying humans and humanity from the points of view of six school subjects (biology, physics, physical education, philosophy, psychology and arts) in a pilot study unit. We found evidence of changes in conceptual constructs with vast individual differences. Learners with a mastery goal orientation manifested conceptual change, belief revision and threshold concepts the most. "Learning deepened by autonomy" was the dominant narrative in the students' narrative interviews. Two counternarratives, "struggling with motivation and schedule" and "active communicator with poor effort regulation", in which learners' self-regulated learning skills were poorer, were also identified.

1. Introduction

Upper secondary schools in Finland started to implement the new national curriculum in August 2021 (Finnish National Agency for Education, 2021). One of its aim is to establish a balance between subject knowledge delivery and cross-curricular learning opportunities with transversal competence areas: (1) well-being competence, (2) interaction skills, (3) multidisciplinary and creative competence, (4) civic skills, (5) ethical and environmental competence and (6) global and cultural competence. These competences are implemented at the national level within each school subject and within locally developed cross-curricular study units.

This study will find out how this new cross-curricular approach can be implemented at an upper secondary school. For this study, a local pilot study unit named "Human being – What am I" was developed in the Teacher Training School of Tampere as part of a project funded by the Ministry of Education and Culture. The project aims to formulate scalable teaching and learning models for all upper secondary schools in Finland to implement in curriculum reform. The concept pilot study unit was applied as the aim was to test study units' implementation locally before disseminating them for all upper secondary schools in Finland. The study unit in question embraces competence areas 1–3, as one aim is to enable students to be not only content specialists but also coherent communicators of interdisciplinary themes (Dannels & Housley Gaffney, 2009). Inquiry learning was chosen as a teaching and learning model to enhance deeper learning (e.g., Duran & Dökme, 2016; Paavola & Hakkarainen, 2005). Learning proceeds cyclically as the learners formulate questions according to their previous knowledge. This model fits this context well as learners study a common theme, humans, from the different perspectives presented by six school subjects.

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This is the third independent study of the three case studies together composing an action research study dealing with theory based pedagogical models of inquiry learning. This study aims to investigate how learners with different personal achievement goal orientations manifest changes in conceptual constructs and combine views of different school subjects in a cross-curricular study unit when they are given great autonomy over their tasks. We chose this approach because goal orientation has been linked to cognitive, affective and behavioural processes which affect academic learning outcomes (Dweck, 1986; Pintrich, 2003; Skaalvik, 1997). Moreover, we investigated conceptual change (Chi, 1997; Vosniadou, 1994) and threshold concepts (e.g., Land et al., 2010) because there were six school subjects from different scientific disciplines: biology, physics, physical education, philosophy, psychology, and arts; hence, the domain and its theoretical framework changed during the study unit. Several studies have investigated changes in conceptual constructs in different disciplines, especially in the field of science, but studies in an upper secondary cross-curricular context are nonexistent (Flanagan, 2020). Thus, this study seeks to contribute to filling this research gap.

2. Theoretical framework and research questions

2.1. Cross-curricular approach

The terms concerning curriculum integration when combining different school subjects around a common theme vary from "cross-curricular" to "interdisciplinary". Their definitions and implementation procedures share common features: Cross-curricular, multidisciplinary and interdisciplinary curricula should all involve not only increased motivation but also promoting understanding in relation to another subject (Beane, 1997; Fogarty, 1995; Heywood & Solomon, 2012; Jacobs, 1989; Savage, 2011). They are implemented in teaching and learning in various ways, yet their implications and theoretical background are understudied. We justify the course design and pedagogical practices of our study unit by referring to the pedagogical research tradition of exploiting the similarities between subjects in terms of content, pedagogies, and enhanced engagement and creativity via the application of multiple subjects to a common focus. We apply the following definition by (Savage (2011), pp. 7-8))

A cross-curricular approach to teaching is characterized by sensitivity towards, and a synthesis of, knowledge, skills and understanding from various subject areas. These inform an enriched pedagogy that promotes an approach to learning which embraces and explores this wider sensitivity through various methods.

Through our findings on changes in the conceptual constructs of learners with different goal orientations and self-regulated learning (SRL) skills, we aim to add to the discourse on curriculum integration.

2.2. Self-regulated learning

In this study, SRL is defined as an "active, constructive process whereby learners set goals for their learning and attempt to monitor, regulate and control their cognition, motivation, and behaviour, guided and constrained by their goals and contextual features in the environment" (Pintrich, 2000, p. 453). No research has been conducted on SRL implementation in cross-curricular learning in upper secondary schools. Therefore, we investigated SRL as a task-related event rather than an individual's long-term characteristic (Perry, 2002) by analysing the students' self-reported stories from cross-curricular courses that are narrated as portfolio texts or narratives formulated in an interview. Metacognitive knowledge and metacognitive regulation are widely regarded as constructs of SRL (e.g., Alexander, 1995; Boekaerts, 1995; Corno, 1995; Winne, 1995; Zimmerman, 1995), and knowledge of cognition and regulation of cognition are seen as components of metacognition (e.g., Brown, 1978). Students' learning diaries and portfolios both reveal and support their metacognition – that is, knowledge of their own cognition for supporting SRL.

Inquiry learning requires great autonomy from learners; thus, they need to use SRL skills and they need support from the teacher (Kuisma, 2018; Winne, 1995). To facilitate SRL, learners' behaviour should be intrinsic and not regulated by the teacher, parents or peers (Zimmerman, 1998); hence, careful planning of guidance is essential. Self-regulatory skills are not permanent characteristics of individuals but are affected by contextual, developmental and individual factors (Kuisma & Nokelainen, 2018; Loyens et al., 2008; Wolters, Pintrich, & Karabenick, 2003). We chose an inquiry-based teaching and learning model because we wanted to strengthen learners' SRL skills. These skills are strengthened as adolescents gain experience in controlling their behaviour (especially effort regulation, management of the study schedule and physical learning environment) as well as cognition and motivation (Kuisma, 2018; Winne, 1995; Wolters, Pintrich, & Karabenick, 2003).

2.3. Inquiry learning

Learners' competence at the cognitive and metacognitive levels as well as subject-related competences, such as conceptual competence, are needed for the knowledge-building processes of inquiry learning (Kuisma & Nokelainen, 2018; Le Deist & Winterton, 2005). Thus, the study unit in question was targeted at senior students. Instruction should focus on all three dimensions (metacognitive, motivational and behavioural) of SRL to succeed in promoting long-term effects on SRL skills (Zimmerman, 1990). This was taken into account when designing the learning diary and portfolio instructions (Appendix B) as tools for inquiry learning for the study unit. According to Bell and colleagues (Bell et al., (2010 p. 349)), collaborative inquiry learning is "a promising culture of teaching and learning … where students in groups engage in self-regulated learning activities supported by the teacher". The nine inquiry processes are (1) orientation and question making, (2) hypothesis generation, (3) planning, (4) investigation, (5) analysis and interpretation, (6) model exploration and creation, (7) conclusion and evaluation, (8) communication and (9) prediction. The degree of openness of the instruction can vary from giving the learner the opportunity to form research questions freely and collect data independently to

providing the learner with the questions and data (Bell et al., 2005). An activity can be viewed as inquiry based as long as learners conduct the analysis themselves and draw their own conclusions. The most demanding level with the most learner autonomy requires substantial knowledge scaffolding and was not applied in the lesson tasks, but the continuing learning diary and portfolio task with the requirement of formulating research questions is regarded as the most demanding level of inquiry learning.

In this study, we applied the model for a cross-disciplinary course which combines the views of natural science (biology and physics) with the views of psychology, philosophy, physical education and arts. The students were given lower-level inquiry activities as lesson tasks because they only had three lessons of 75 minutes per subject. Moreover, because of the complexity of the learning and SRL processes, we cannot assume that student-centred inquiry learning always promotes SRL skills (English & Kitsantas, 2013). Hence, we investigated SRL skills based on the students' narratives and learning outcomes (learning diaries, portfolios, and concept maps).

2.4. Conceptual change, enrichment, belief revision and threshold concepts

We aimed to investigate the changes in students' conceptual constructs during the learning processes of a cross-curricular study unit. This is especially interesting because the domain with its theoretical framework grounded in different epistemological and ontological views changes during the study unit. We studied whether the conceptual construct changes could be detected as enrichment, which entails adding new information to existing conceptual structures, or whether there would be belief revision, which is regarded as a change in the learner's beliefs or in the perception of a theory (Vosniadou, 1994). In belief revision, beliefs are tied to and constrained by certain ontological and epistemological presuppositions. Therefore, beliefs instead of smaller fragmented structures create a uniform structure.

People store concepts and situations on ontologically distinct associative trees (Chi, 1997). These "trees" can form barriers restricting our understanding and creativity; thus, we should be able to cross these barriers in a flexible way. When a person re-represents an entity in a new way, they switch from one ontological multi-branched tree of concepts and categories to another. A category means a set of objects that are believed to belong together. When people encounter new objects, they consider them members of a certain category and label them accordingly. Thus, people have a cognitive advantage when they use these familiar categories because they reduce the demand for processes such as storing and reasoning. A conceptual shift can occur among the branches of the same ontological tree; we regard this as either enrichment of the concept or belief revision (Vosniadou, 1994) if the change is related to the whole belief construct. If a person changed the entire ontological tree to which the concepts belong, it would require changes in a vast number of attributes linked to the concepts in question. Consistent with Chi (1997), we define conceptual change as shifting a concept from one ontological tree to another.

The most difficult and most creative shifts are the ones where concepts and their attributes shift across entire ontological trees. The sudden "aha moment" is regarded as a phenomenon of creativity, where every piece suddenly falls into place (Chi, 1997). This phenomenon can be viewed as an ontological shift because a concept that moves from one ontological tree to another inherits all the attributes of the first tree. Moreover, what may seem like trivial conceptual shifts from one person's perspective may be ontologically significant from another person's perspective (Chi & Brem, 2009). When a person detects a paradox concerning a new concept and its categorisation, it can trigger conceptual change (Bereiter, 1985; Chi, 1997; Chi & Brem, 2009). There can be anomalies in learners' concept categories, which can be left unchanged, especially if the learner is extremely committed to their current theories. In that case, conceptual changes do not happen. One can explain and accept these anomalies, thus expanding the current theory, as suggested by Ohlsson (2009), or one can make a belief revision or a conceptual change to avoid the problematic contrast.

We also aimed to identify possible threshold concepts. A threshold concept is always transformative, which means that it changes one's understanding or interpretation of something (Meyer & Land, 2003). Threshold concepts must be understood to progress in learning as they are gateways to understanding the critical content of a discipline. Threshold concepts transform learners by allowing them to view matters as biologists, philosophers, artists and so on; perceiving a threshold concept involves both an ontological and a conceptual shift. A threshold concept can be detected as a kind of gateway to the challenging content of a certain discipline, such as "genetic variation" in biology, "gravity" in physics or "personhood" in philosophy (Batzli et al., 2016; Land et al., 2010). Many learners tend to get stuck with threshold concepts and need support from the teacher to overcome this obstacle and learn the subject matter. Schwartzman (2010) suggested that crucial elements behind the difficult experience are unrelated to the disciplinary context. Instead, experiences of difficulty are based on reflective and defensive responses to rupture, which results from encountering existentially unfamiliar constructs. In other words, the foundation of a threshold concept is discipline independent by nature. The time frame following the encounter with the threshold concept can be viewed as Heidegger's "dynamic of rupture", as the learner's response is constructed in an explicit form by either reflectiveness or defensiveness. This results in a time frame of confusion and uncertainty by the learner. We investigated whether enrichment, belief revision, conceptual change or threshold concepts emerged by analysing learners' diaries, portfolios and concept maps and by conducting narrative interviews.

2.5. Objectives of the study and research questions

As subject teachers and teacher trainers, we are interested in knowing what kinds of narratives learners of different SRL skills and personal achievement goal orientations formulate about the cross-curricular study unit, thus this is referred to as our main research question (MRQ). This includes investigating how students perceive inquiry learning with a learning diary and portfolio as a method of learning. We address this main question also by following sub-research questions (SRQ): (1) How students of different personal achievement goal orientations perceive the points of view of different disciplines and their possible synergy and (2) can changes be detected in students' conceptual structures when they ponder different topics and perspectives of the cross-curricular study unit. The

research questions (RQs) are as follows:

MRQ What kinds of narratives from the points of view of SRL and inquiry learning do students formulate when they are interviewed?

SRQ1 How do personal achievement goal orientation profiles relate to the level of complexity and depth narrated in the portfolios and narrative interviews?

SRQ2 How does cross-curricular inquiry-based teaching and learning affect conceptual constructs (enrichment, belief revision, conceptual change, and threshold concepts)?

3. Methods

3.1. Participants

The study took place in the Pirkanmaa region of Central Finland. It investigated a pilot study unit in the Teacher Training School of Tampere as part of a project called "Cross-curricular learning in the general upper secondary school", funded by the Ministry of Education and Culture. The project is coordinated by Aalto University and Tampere University, and it aims to formulate scalable teaching and learning models for all upper secondary schools in Finland to implement in curriculum reform. There were 10 students in the class, and their ages ranged from 17 to 18 years. All the students were given pseudonyms. Only one male student was involved, so he was given a female pseudonym to protect his identity. Six subject teachers were involved, and one of the researchers had a double role as she was also the biology teacher. The study was an independent part of a wider dissertation study authorised by the Ethics Committee of the Tampere region and the participating school's headmaster. Participation in the study was voluntary, and learners provided written informed consent. They were also given a detailed privacy notice via email.

3.2. Data collection

We investigated changes in students' conceptual constructs by monitoring the process from the outside through their subject teachers and the researcher. The teachers and researcher kept diaries of their observations. The lessons were videotaped to keep a record of any signs of changes in conceptual constructs during the lessons. Parallel multimodal data were collected and analysed by triangulation, as multimodal data has been shown to provide different perspectives to learners' learning process and to better predict their learning outcomes (Cukurova et al., 2019; Giannakos et al., 2019).

3.2.1. Learning diaries and portfolios

Students kept learning diaries to help with their portfolios about how well they felt they had learned the subject matter, what concepts they had learned and which questions they wanted to find answers to (Appendix B). In this way, we gathered data about students' individual learning goals and achievement of these objectives. Students were instructed to ponder the meanings of the concepts, other ideas and observations of their learning process in their portfolios. The portfolios were graded by the six teachers on a scale of 1 to 3. When the assessment of portfolios by the teachers and the researcher were compared, no significant differences were detected.

3.2.2. Questionnaire on personal achievement goal orientations

At the beginning of the study unit, the students answered a questionnaire about their personal achievement goal orientations. The questionnaire was used to assess the relationships between students' learning outcomes (learning diaries, portfolios and concept maps) and the conceptual changes expressed in the narrative interviews. The questionnaire belongs to the Patterns of Adaptive Learning Scales (PALS) developed by Midgley and colleagues (2000). Their questionnaire was derived from goal orientation theory, which tackles the relationship between the learning environment and students' motivation, affect and behaviour. We chose the questionnaire to assess students' learning outcomes according to their mastery (six items), performance-approach (five items), and performance-avoidance (six items) goal orientation profile. The questionnaire uses a 5-point Likert scale (1 = not at all true, 3 = somewhat true, 5 = very true).

Personal achievement goal orientation investigates why learners engage in academic behaviour Midgley and colleagues (2000). Three different goals reveal different patterns, including cognitive, affective and behavioural components, which have been characterised as more or less adaptive. The first purpose of academic learning is labelled mastery goal orientation, where learners' goal is to develop their competence. Learners aim to deepen and broaden their understanding; as such, learning is perceived as interesting, and learners' focus is fixated on the task. The second purpose of academic learning is labelled performance-approach goal orientation. Learners aim to demonstrate their competence to the teacher and to other students, and their focus is fixated on the self. The mastery goal orientation approach has been associated with adaptive patterns of learning, whereas the performance-approach goal orientation has been associated with both adaptive and maladaptive patterns of learning (Pintrich, 2003). The third purpose of academic learning is labelled performance-avoidance goal orientation, where learners' purpose is to avoid the demonstration of incompetence (Midgley et al., 2000). Learners' attention is focused on the self, and their orientation is associated with maladaptive patterns of learning. In addition to demonstrating high ability, learners with a performance-approach goal orientation are focused on achieving at higher levels than others. By contrast, learners with a performance-avoidance goal orientation are concerned with avoiding the demonstration of low ability or appearing stupid (Pintrich, 2003). Adaptive processes refer to, for example, learners' abilities to calibrate their behaviour and cognition and not to constantly over- or underestimate their capabilities and then lose motivation as a result of negative

feedback.

One of the background views is Dwecks (1986) suggestion of motivational processes affecting children's knowledge acquisition, knowledge transfer and use of skills. When children aim for certain learning or performance goals, it shapes their reactions to success or failure and the quality of their cognitive learning outcomes. In other words, Dweck's model depicts adaptive and maladaptive learning patterns which affect learners' cognitive learning outcomes. Moreover, the scales for personal achievement goal orientations differ between the performance-approach and performance-avoidance dimensions (Middleton & Midgley, 1997). Therefore, there are items measuring (1) the goal of developing ability, (2) the goal of demonstrating ability and (3) the goal of avoiding the demonstration of a lack of ability.

In our study, we applied the items to measure studying in school in general. The items can also be refined to suit each school subject in a domain-specific way, but we used the scales to depict a general goal approach profile for each learner. Because the study unit that was investigated is voluntary for the students, we expected higher scores in mastery goal orientation than in performance-approach or performance-avoidance goal orientation. Based on previous studies about goal orientation profiles (see Pulkka & Niemivirta, 2013, 2015; Tuominen-Soini, Salmela-Aro, & Niemivirta, 2012), we expected to find (a) most learners focusing on learning new things and gaining competence, (b) some learners focusing on demonstrating their competence, (c) some learners with an emphasis on the avoidance of failure, (d) learners with a combined emphasis on mastery and performance goal orientations and (e) learners with no clear goal preferences.

3.2.3. Concept maps and qualitative narrative interviews

To explore what the learners perceived as key concepts and their connections, they were asked to draw a concept map of the most meaningful concepts they had encountered in the study unit. In this way, learners' conceptual structuring was made visible (Novak, 2010; Novak & Cañas, 2008). Concept maps were analysed through content analysis and in a quantitative way by counting the concepts and links (propositions) for each concept. The more links to a concept, the more meaningful it is for the learner. As the concept map was made hierarchically, the higher the concept is situated, the more meaningful it is for the learner.

A qualitative narrative inquiry approach was chosen because it focuses on an in-depth understanding of the events (Abbott, 2008; Kuisma, 2018) that took place during the study unit from the students' point of view. According to constructivism, people construct both knowledge and their identities by placing new constructs upon previous ones (Heikkinen, 2015); thus, knowledge is created subjectively as an interplay between one's prior experiences, conceptions, and new ideas. As individuals' conceptions of themselves and the surrounding world are always changing, an ever-changing narrative emerges (Bakhtin, 1986; Guba & Lincoln, 2005), and knowledge can be regarded as a network of these narratives. In our research, the narratives have two-dimensional characteristics because they are both the target of research (analysis of narratives) and its outcome (narrative analysis). The orientation of our study was cross-sectional as we focused on investigating what kinds of narratives interviewees would produce at the end of the study unit. An autobiographical approach was chosen because we focused on the events of the story – more precisely, what happened and why — rather than investigating the structures and forms of these narratives with a more linguistic approach (Abbott, 2008). Therefore, both the scientific classical realistic paradigm and constructivist interpretative paradigm are equally present.

We used the one-question narrative interview introduced by Fritz Schütze (Hyvärinen & Löyttyniemi, 2005; Rosenthal, 2004; Rosenthal, 2003; Wengraf, 2001). Students were asked one question to guide them into storytelling. After a narrative or short answer, the second phase of the interview followed, with questions derived from the previous answer. The last phase of the interview involved asking questions that were in the interest of the researcher for the current study (Appendix C) if these topics had not been addressed already. Therefore, the interviewer cannot be regarded as an objective bystander but as an active participant in the interview process. Furthermore, the students were regarded as experts of learning; to avoid alienating adolescents from their experiences through a formal question-answer setting and formal language, we decided not to use a structured or semi-structured interview but instead gave them more freedom to express themselves in their own words in a narrative interview.

The objectives of the narrative interview were to understand the past events of a cross-curricular study unit and to induce the adolescents into reshaping their experiences into an understandable narrative format. It was regarded as an extra benefit if the interview process led to the learners' self-reflection and they came to acknowledge their strengths in the learning process. All 10 students volunteered to participate in the interviews. Two students (Jannika and Katriina) wanted to be interviewed together, which was allowed to minimise their anxiety. The narrative interviews took an average of 45 minutes (ranging from 31 to 68 minutes).

3.3. Analysis techniques and reliability of the narrative analysis

A narrative analysis of the narrative interviews was done by composing composite narratives (Kuisma, 2018; Willis, 2019(Willis, 2019)). First, thematic analysis was used to categorise individual narratives according to the themes of the research questions (see section 4.1). Two researchers read the transcribed interviews and compared the results of their thematic analysis (Armstrong et al., 1997). The discrepancies were discussed, and some modifications were made to the individual narratives. Second, the most frequently detected narrative was identified and labelled the dominant narrative, and the others were labelled counternarratives.

The interviews were conducted and transcribed in the students' mother tongue, Finnish. After the transcripts were read through for the third time, a summary was made of each interview by extracting the key quotations. These individual narratives were translated into English, aiming for the most valid interpretation of the narrative rather than an accurate word-to-word translation with the finest semantic and linguistic details (Nikander, 2008), as the analysis of this study is more content oriented than interaction oriented. Next, composite narratives were made by combining the individual summaries sharing the same theme. Translation and combining were done to secure the precision and accuracy of the narratives and to ensure the readers of analytic transparency. The composite

Table 1
Programme of the study unit.

Discipline(s)	Topics and tasks
All six teachers (BI, PE, PHY, PHI, PSY, Arts)	Instructions; introductory lecture about the different approaches to humans according to existentialism, essentialism and naturalism, and culturalism (PHI); students start making their individual learning diaries
BI	Lecture about sensory systems of humans compared to other animals to give the students a biological point of view on humans compared to other animals and to create a context for the next lessons
BI	Students investigated the human senses in pairs.
e.g. Olfaction and taste: "Dry your tongue with kitchen paper and then place a piece of sugar in your mouth. Let the saliva moisten your mouth and then put a piece of sugar in your mouth. What differences do you notice in these situations? What is the significance of saliva for the taste buds?"	
Hearing: "One of the peers closes his or her eyes. The pair walks around inside the school and the seeing one gives only oral instructions to walk (i.e. no physical contact). Consider what it is like to perceive a familiar environment on the basis of the mere sense of hearing (and memory). Where are the auditory receptors situated and how do they function?"	
BI	Student pairs present their reports and conduct one exploration for their classmates.
PE+PHY	Physical education was taught jointly with physics in six lessons. Students were given instructions on how to perform specific exercises and why. Before the exercises, they were told that they would model these exercises later and analyse them using digital programs and tools that are commonly used in physics, such as Logger Pro and GeoGebra. The student pairs took photographs and video clips to record their performances and to enable the analysis process.
e.g. Standing long jump: The PE teacher shows how the jump is performed and explains the phases and their significance for performance. The jump is videotaped, and in the next lesson, the PHY teacher advises the students on how to use the computer program to make the trajectory visible and to measure and determine the different phases of the jump.	
PE+PHY	
PE+PHY	
PE+PHY	
PE+PHY	
PHI	Lecture about the goodness and evilness of humans according to Mengzi, Paul the Apostle, Socrates, Plato, Aurelius Augustinus, Thomas Hobbes, Rousseau, Immanuel Kant, Nietzsche and Hannah Arendt
PHI	Lecture challenging the ideas of poststructuralism and deconstruction by Jacques Derrida (e.g. impact of language on thinking and valuing, how naming things has affected the ways humans value animals and nature, how humans perceive themselves and whether humans are perceived as animals)
PHI	Lecture about language, how it depicts the world and how powerful words can be. Key question: "Are we all prisoners of language, and are we unable to step outside it to achieve reality cleansed of the effects of language?"
PSY	All three lessons of psychology dealt with humans' higher cognitive processes. The first lesson was a lecture with educational dialogue concerning language processing: speech production and speech comprehension. The topic was combined with the views of philosophy by bringing forth the multimodality and meanings of language. The teacher included the views of biology by going through the structure of the human brain and the different areas of the cortex for different senses. She also narrated the psychological experiments for teaching human language symbols to certain primate individuals. Variations between different languages in different human cultures were discussed.
PSY	Student pairs were tasked to plan and execute a mini-sized psychological study. The teacher provided the student pairs with language-related case descriptions and suggestions on whom to interview. The task was to formulate a research question and hypothesis, to collect and analyse the data, and to discuss the reliability, validity and generalisation of the results. The study reports were published in the Teams Files section.
e.g. Emotional Stroop test: "Use your phone's stopwatch. The emotional Stroop test measures the exact time that elapses between displaying a word in a slide and saying a colour out loud. Write the time on the paper next to each word. Show the slide set to the subject and ask him or her to name aloud the colour that is associated with the word as soon as it appears."	
PSY	Students were introduced to psychological studies dealing with human facial expressions conducted at Tampere University. This was executed as a Teams meeting between the class and the researchers because of the restricted visiting possibilities due to the coronavirus disease 2019 pandemic.
Arts	

(*continued on next page*)

Table 1 (*continued*)

	A synthesis of all the views presented by five school subjects was made in arts. During the first arts lesson, the teacher introduced learners to different possible angles of how to approach a joint artwork on the theme "Human being – What am I" and asked learners to formulate questions that resonated with them most.
e.g. Ideas of realisation of the joint artwork: What are humans like? What kind of person am I? Why do we create art? What kind of art do people want to see? Learners discussed their ideas in small groups and were then introduced to different methods of realisation. The researcher asked them to draw concept maps of the concepts they considered the most important in the study unit. After this, learners developed their ideas further. At the end of the lesson, one of the students acted as a secretary and wrote down each small group's ideas on a whiteboard and illustrated the main ideas. Thus, a joint plan was completed.	
Arts	Every student participated in the realisation of the artwork (see Appendix D).
Arts	

Note. BI denotes biology, PE physical education, PHY physics, PHI philosophy and PSY psychology.

narratives are presented in Appendix A and analyzed in section 4.1.

3.4. Course design

Six teachers planned the cross-curricular study unit's timetable, objectives and content with shared themes. They decided not to give a numerical grade for the course but a mark of "approved" or "rejected" to reduce performance pressure.

The upper secondary students in this study applied the inquiry learning model, where they proceeded cyclically by formulating research questions and finding answers. They were introduced to views on humans in the context of biology (senses, taxonomy and evolution, and humans as animals), psychology (higher-order thinking skills), physical education and physics (measuring and modelling exercises), philosophy (naturalism-culturalism and essentialism-existentialism) and arts (joint artwork expressing and exhibiting different views about humans). They were guided to monitor their own learning by setting research questions for themselves, assessing the level of attainment of their learning objectives and writing down the lessons' key concepts in their learning diaries, and pondering key concepts and learning experiences in their portfolios (Appendix B). In this way, the learning process was made more visible, and learners' SRL skills were strengthened.

Inquiry learning took place at two levels: At the first level, students' ongoing task was to write down research questions according to their points of interest in their learning diaries using Microsoft Office OneNote. The teachers responded to these questions by either talking with the student in question or writing to them. Thus, there was an ongoing scientific dialogue over the course of the study unit. At the second level of inquiry learning, each teacher planned the lesson tasks constituting inquiry learning if it was considered possible and useful for learning (Tables 1 and 2).

Three lessons were held in each subject. Physical education and physics lessons were combined and led by two teachers for all six lessons. During the first lesson, the students were given instructions regarding the whole study unit, the researcher informed them about the study, and the procedure of the two-level inquiry learning model with instructions for the learning diary and portfolio was explained to them.

Physical education and physics teachers provided students with questions, methods and solutions before they did the task, thus providing inquiry learning of openness level 1: "confirmation" inquiry learning (Tables 1 and 2; Bell et al., 2005; Herron, 1971; Schwab, 1962). Biology, psychology and arts teachers gave the students questions and methods but let them find solutions themselves (inquiry level 2: "structured inquiry"; see examples of given tasks in Table 1). All tasks involved the students' gathering of data, observations and conclusions. Students constructed explanations of phenomena, tested those explanations and communicated their ideas to others. In philosophy lessons, students were challenged with philosophical questions by engaging them in a teacher-led educational dialogue.

4. Results

4.1. Composite narratives

For MRQ, we first composed narratives of each individual interview by extracting quotations. The second step was to identify the similar themes of these narratives. After analysing each narrative from five viewpoints, namely (1) reaching one's learning objectives, (2) experiences with the learning diary and portfolio, (3) expressing one's SRL skills, (4) the support of different disciplines for each

Table 2
Lessons constituting inquiry learning

Introductory Lesson	Biology	Physical Education + Physics	Philosophy	Psychology	Arts
–	– 2 2	1 1 1 1 1 1	– – –	– 2 2	2 2 2

Note. The numbers denote the level of inquiry learning. – refers to no inquiry learning. (Bell et al., 2005, p. 31)

other and 5) experiences of transitions from one section to another, three narratives were detected and formulated as composite narratives (Appendix A). Most students (six out of 10) felt that they achieved their learning goals well and enjoyed the autonomy of the course assignments (learning diary and portfolio). Thus, this narrative was labelled learning deepened by autonomy. The first of the two counternarratives (expressed by three out of 10 students) identified in the data was labelled struggling with motivation and schedule, and the second (expressed by one out of 10 students) was labelled active communicator with poor effort regulation.

Dominant narrative depicts students who enjoyed making the learning diary and using it as a tool for portfolio writing (Appendix A). The students stayed on schedule the whole study unit, thus expressing good SLR skills of cognition (elaboration, organisation and metacognitive regulation), motivation/affect (relevance enhancement and situational interest enhancement) and behaviour (effort regulation, time and study environment management, and help seeking; Wolters, Pintrich, & Karabenick, 2003).

Some students found the learning diary quite easy but considered portfolio work challenging, thus expressing the first counternarrative (Appendix A). Forming research questions relevant to oneself was perceived as especially difficult. Students fell behind schedule. This demonstrates poor SLR skills at all three levels (cognition, motivation and behaviour) and the need for more support to strengthen those skills.

The second counternarrative depicts a learner who was an active communicator in the lessons but was unable to document their thoughts in the portfolio (Appendix A). The student failed the class because of the lack of a portfolio. When the student tried to report their thoughts in the portfolio, a kind of blockage emerged. The student fell behind schedule. This narrative demonstrates poor self-regulation behaviour skills, especially effort regulation, and the need for more support to strengthen those skills.

Even in such a small group, the differences between students' metacognitive awareness and regulation are vast. Marja, as an example of the dominant narrative, created four main categories at the beginning of the course and narrated that categorising concepts from the course allowed her to understand the concepts of the different subjects better. This was a new learning strategy for her, and she found it highly beneficial. She had already found out that categorising topics by colour supported her learning. Opposite abilities were evident in the cases of Jannika, Katariina (counternarrative 1) and Johanna (counternarrative 2) as they expressed poor SRL skills. Learners' abilities to monitor, reflect and modify their behaviour, metacognition and cognition are SRL skills; they are also referred to as adaptive learning patterns. In other words, students who expressed the dominant narrative showcased both adaptive learning patterns and high SRL skills.

In all narratives, the six school subjects were considered beneficial for the whole study unit. Two students stated that the physical education and physics section was detached from the other sections, and there were too many exercises and too much data collection for the time allotted for going through the results. Thus, it was perceived as messy and confusing. The transitions from one discipline's section to another were regarded as smooth and natural, except for the transition from physical education and physics to philosophy. This transition was described as abrupt by four students. The joint artwork (Appendix D) in the arts section had a significant role for all students because (1) it offered them a means to express themselves and communicate with others and (2) it helped make learning visible and allowed them to compose a synthesis of the different disciplines' viewpoints.

Some students within each composite narrative type regarded the thinking process in itself as the most important thing and recording these thoughts as secondary. Nevertheless, nine of the 10 students found the learning diary and portfolio beneficial in that it made their learning outcomes visible and helped them understand concepts and their relations. Thus, these kinds of self-assessment tools are a good way to carry out inquiry learning.

4.2. Relationship of goal orientation profiles with portfolios and narrative interviews

For SRQ1, we investigated how personal achievement goal orientation profiles related to the level of complexity and depth narrated in the portfolios and qualitative interviews. As expected, on the whole, students had higher scores in the mastery approach than in the performance-approach or performance-avoidance goal orientation (Table 3) because it was a voluntary study unit. The scores varied less between the items of mastery goal orientation than in the two other patterns.

Most students (seven out of 10) expressed a profile of mastery goal orientation (Table 3); they aimed to deepen and broaden their understanding, perceived learning as interesting and expressed an adaptive learning pattern. One student (Mari) expressed a

Table 3
Individual learners' mean scores for personal achievement goal orientation (5-point Likert scale), teachers' assessment of the portfolios (scale of 1–3) and composite narratives (N = 10; names are pseudonyms).

	Mastery approach M (SD)	Performance approach M (SD)	Performance avoidance M (SD)	Portfolio M (SD)	Narrative type
Susanna	4.3 (1.21)	4.4 (0.89)	2.8 (1.33)	2.6 (0.5)	Counter 1
Tiina	3.8 (0.98)	3.4 (1.52)	2.5 (0.55)	1.6 (0.8)	Dominant
Marja	3.5 (1.05)	3.6 (1.14)	1.8 (0.98)	1.5 (0.7)	Dominant
Johanna	4.2 (1.17)	2.2 (0.84)	2.5 (0.84)	-	Counter 2
Leena	4.3 (0.82)	3.8 (1.64)	2.5 (1.05)	2.4 (0.5)	Dominant
Mari	4.0 (1.10)	4.4 (0.89)	1.8 (1.33)	2.8 (0.4)	Dominant
Sofia	4.8 (0.41)	1.8 (1.10)	1.8 (0.75)	1.8 (0.6)	Dominant
Pilvi	4.7 (0.52)	3.8 (0.84)	1.7 (1.63)	1.9 (0.6)	Dominant
Jannika	3.5 (0.55)	2.6 (1.82)	1.5 (0.84)	1.4 (0.5)	Counter 1
Katriina	3.2 (0.75)	2.2 (1.79)	1.5 (0.84)	1.0 (0.0)	Counter 1
Total	4.0 (0.97)	3.2 (1.49)	2.1 (1.08)	1.9 (0.8)	

Note. BI denotes biology, PE physical education, PHY physics, PHI philosophy and PSY psychology.

performance-approach profile; thus, her focus was more on the self and demonstrating her competence to others. This is clearly related to her academic performance as she scored the highest points in portfolio assessment. Two students (Susanna and Marja) expressed a combined emphasis on mastery and performance-approach, but only one of them (Susanna) excelled in portfolio work. No students had a performance-avoidance profile (e.g., focusing on avoiding showing one's incompetence). These results, together with data from the narrative interviews, indicate that all 10 students were likely to possess adaptive learning patterns in an academic learning context.

Table 4
Concepts in the learning diaries, concept maps, portfolios and interviews.

	Concepts in the learning diary	Concepts in the concept map	Portfolio assessment score (1–3)	Links (propositions) to the three most meaningful concepts (excluding the link to the main concept) in the concept map	The most challenging concepts The most interesting concepts Threshold concepts, conceptual change, enrichment or belief revision narrated in the interview
Susanna	52	23	2.6	psychology: 5 senses, physical education, philosophy: 4 each	a. mechanoreceptors (BI), PHY concepts b. mind (PSY), good and evil (PHI), BI and PSY concepts c. belief revision: the whole field of philosophy was "confusing"
Tiina	30	26	1.6	biology: 9 physical education + physics: 7 psychology: 4	a. EEG, EMG (PSY), PHY concepts b. BI and PHI concepts c. belief revision: the whole field of philosophy was "strange"
Marja	20	26	1.5	biological side: 9 physical side: 5 mental and spiritual side: 4	a. PHY and PE concepts b. PHI and PSY concepts c. belief revision: the whole field of philosophy was "confusing"; conceptual change: also aha moments in philosophy, felt transition from PE & PHY to PHI as abrupt (suddenly studying questions which have no answers)
Johanna	6	23	-	psychology: 4 philosophy: 3 what is human: 3	a. cognitive processes (PSY), PHY and PE concepts b. existentialism, essentialism, dualism (PHI), cognitive processes and other PSY concepts, BI concepts c. does not narrate any
Leena	52	47	2.4	thinking: 7 senses: 5 needs: 5	a. PHY concepts b. PHI concepts c. enrichment of conceptual constructs in all sections of the study unit; found it annoying that there were many PHI questions left unanswered
Mari	64	103	2.8	mind: 8 ECG: 8 sensory areas of the cortex: 6 scientific research: 6	a. does not narrate any b. PHI, PHY and PE concepts c. does not narrate any; articulates that concepts only help her formulate thoughts in verbal form and that she learned a lot of new concepts
Sofia	51	21	1.8	senses: 6 brain and thoughts: 4 knowledge: 2	a. brawn (muscle strength), energy (PHY), good and evil (PHI) b. PHI concepts c. conceptual change + belief revision: most advanced species (BI, PHI); threshold concepts + conceptual change: fully human – incomplete human (BI, PHI, PSY); cumulative knowledge (BI, PHI)
Pilvi	30	16	1.9	philosophy:4 biology: 3 psychological entity: 3	a. PHY concepts (e.g. mass, weight and acceleration) b. existentialism, essentialism, dualism (PHI); good and evil (PHI) c. threshold concepts + conceptual change: fully human – incomplete human: Can you become human if you are brought up outside the society? (BI, PHI, PSY)
Jannika	36	19	1.4	cognitive processes: 4 concept of human being: 4 consciousness: 2	a. BI and PHY concepts b. existentialism, essentialism (PHI), good and evil (PHI), PSY concepts c. belief revision: the whole field of philosophy was "confusing"
Katriina	11	23	1.0	senses: 5 cognitive processes: 4 concept of human being: 4	a. PHI concepts b. BI and PSY concepts, existentialism, essentialism (PHI), good and evil (PHI) c. belief revision: the whole field of philosophy was "confusing"

The student with a performance-approach profile may have either adaptive or maladaptive learning patterns, but her narrative interview revealed that she possessed excellent SRL skills; hence, her learning pattern can be described as adaptive.

When individual goal orientation patterns were investigated together with the types of composite narratives (Table 3), the findings were as follows: First, the learners with the highest scores in the mastery approach (Sofia, Pilvi, Susanna, Leena, and Mari) narrated either the dominant narrative or counternarrative 1 even though they all should have had adaptive learning patterns with high SRL skills. SRL skills are not a fixed feature in a person (Pintrich, 1999; Wolters, Pintrich, & Karabenick, 2003). For instance, a high number of courses in the same period can result in a decline in effort regulation and motivation and in lagging behind the schedule. Second, the two students with the highest scores in the mastery approach (Sofia and Pilvi) scored poorly in their portfolios. The narrative interviews gave an explanation for this result: These students were so immersed in pondering new ideas that instead of formulating them as text, they preferred discussing these topics with others and letting their own thoughts mature. Furthermore, they did not worry about excelling in the portfolio or other matters related to their studies.

These results are in line with those of previous studies. Both the mastery approach and the performance approach seem to facilitate good academic performance. The performance approach is related to excelling in the short run in written outcomes, and the mastery approach is related to the retention of key concepts and phenomena in the long run (Elliot & McGregor, 1999). Academic performance was strengthened by the absence of a performance-avoidance goal, which has been proven to weaken both types of performance (Elliot & McGregor, 1999).

4.3. Changes in conceptual constructs

We investigated changes in the conceptual constructs in SRQ2 through content analyses of learning diaries, portfolios and concept maps and an analysis of the narratives in the interviews. Mari narrated that all new concepts helped her verbalise her thoughts more accurately than before. Incongruity emerged in her narrative; she first narrated not having learned much but then described how abundantly she had learned new concepts. Her concept map (Appendix E) was the most complex and possessed the most concepts (Table 4). Many students expressed the same kind of inconsistency in their interviews, thus exemplifying how ambiguously upper secondary students are able to reflect on their own learning processes and outcomes. Some students, like Sofia, said that it was difficult for them to put their thoughts into words. Sofia used her cell phone to record good ideas for further modification, while Mari narrated using concepts effortlessly to express her thoughts. Differences in the ability to express one's thoughts were vast between the students.

The data gathered through narrative interviews show that some students did not consider the deepening of their concept perception or the examination of the same phenomenon using the concepts of different disciplines to be relevant (e.g., Susanna). Instead, they would have preferred to learn things that would help them excel in the matriculation exam (e.g., Leena) or enhance their competence in their future profession (e.g., Marja). However, some students (Sofia and Pilvi) identified deepening and broadening their own understanding of humans and humanity as their main objective.

The concept map helped some students (Leena and Mari) make their thinking and concept analyses visible (Appendix E). The only student with a performance-approach orientation (Mari) wrote down more concepts than others in her learning diary and concept map (Table 4) but did not consider learning new concepts or broadening their meanings as learning something new. This is an example of the inconsistency in students' narratives. Another inconsistency is that some students described philosophy as fascinating and interesting in the interview, but its concepts were almost nonexistent and were poorly analysed in the portfolios. Some (six out of 10) students found the whole epistemological and ontological view of the discipline of philosophy confusing or strange and different from all the others because it does not have explicit answers to questions (Table 4). Even though the researcher pointed out that disciplines have different epistemological and ontological views and gave the views of relativism and critical realism as examples, this state of confusion was still evident in the interviews. Nevertheless, the resistance to tackling philosophical dilemmas seemed to lessen after this dialogue took place at the end of the philosophy section. As most of these students found philosophy fascinating and interesting, we regard this confusion as a manifestation of belief revision. However, we were unable to distinguish whether there were some anomalies left in the learners' concept categories.

Physics concepts were identified as the most challenging by nine out of 10 students (Table 4). Some students mentioned having too many exercises and too little time to analyse the physical education and physics phenomena. These results point to a need to lessen the amount of subject matter and give students more time to gain an understanding of the phenomena and their concepts.

Data triangulation suggests that an enrichment of concepts took place in all sections of the study unit even though the narratives were inconsistent. In physics, there was significantly less enrichment; only one student narrated having learned to understand new phenomena or the phenomena in a new way.

Some students (Sofia and Pilvi) vividly narrated how their perception of the world changed when they encountered the concept "fully human", which we regard as a threshold concept (Table 4). Sofia started to ponder what is regarded as fully human and what is incomplete: If a person is blind and deaf or has a developmental disorder, is that person regarded as fully human? In this way, she manifested both a threshold concept and conceptual change when moving concepts across the ontological trees of biology, philosophy and psychology. At the same time, she realised how we use familiar concepts, such as human, without really being aware of their meanings. She also pondered whether "cumulative knowledge" changes the whole human species and what the future might look like, again manifesting a threshold concept as well as conceptual change.

Sofia's narrative is an example of how different learners individually experience meaningful moments in upper secondary education when given stimuli by highly educated teachers. Whole new ways of viewing the world were opened, and she will never see things the same way again. Sofia narrated that she found it extremely fascinating when there were teachers of different subjects present in the lesson and they offered differing views on topics. For example, the philosophy teacher took it for granted that homo sapiens is the

most advanced species, and the biology teacher challenged this by stating that different species are adapted to different environments; hence, some bacteria can be seen as more advanced than humans, as organisms living in hot springs. This made Sofia revise her belief of humans as a species, and there was a conceptual change as she moved the concept with its many attributes from the ontological tree of biology to the ontological tree of philosophy.

5. Discussion and conclusions

The objective of this study was to find out what kinds of narratives upper secondary school students formulate when piloting a cross-curricular study unit with six disciplines. As the school subjects included natural sciences, physical education, humanities, and art, we were especially interested in conceptual changes, whether transitions from one subject to another were perceived as smooth and whether different disciplines were perceived as supporting each other. We also wanted to know whether the learning diary and portfolio could be regarded as beneficial tools for inquiry learning and SRL.

We found that high-quality multimodal parallel data were vital to gathering and understanding the most accurate data possible from individual learners. Quantitative analysis of the PALS questionnaire and content analyses of the learning diaries, portfolios and concept maps provided data that would have been poorly understood without the interviews and their analysis. We found narrative interviews extremely well suited to gathering data from upper secondary school students. Data triangulation provided interesting results that can be applied to teacher training and in-service training for teachers and that support scaling the study unit in question.

According to students' narratives, the pilot study unit succeeded in the two essential requirements of curriculum integration (Jacobs, 1989): (a) there was a clear scope and sequencing with a cognitive taxonomy, thus encouraging thinking skills, and (b) students narrated both discipline-based and interdisciplinary experiences. We found one dominant narrative, which suggests that most students achieved their learning objectives well and applied SRL skills to benefit from the autonomy of the course assignments (learning diary and portfolio), to deepen their thinking and to stay on schedule. On the other hand, some students lacked these SRL skills, thus struggling to calibrate motivation, behaviour and cognition and being unable to stay on schedule.

Three personal achievement goal orientation profiles were found, the most common being the mastery approach. When personal goal orientation profiles were compared to the complexity shown in the concept maps and the depth of thinking shown in the portfolios, we made an interesting discovery: The mastery approach does not relate to the in-depth reasoning in portfolios and concept maps, but it seems to relate to the occurrence of threshold concepts and conceptual change shown in the narrative interviews. This is consistent with previous research (Elliot & Church, 1997; Elliot & McGregor, 1999), which found that the mastery approach does not predict performance outcomes but seems to predict reduction in worry cognitions. Therefore, educators should design cross-curricular study unit assessment in a multimodal way that allows students to showcase their thinking processes and ideas in forms other than writing. This is intertwined with another item included in the curriculum reform: the validity and reliability of assessment. For example, at the end of the study unit, students created a joint artwork, which helped to bring forth ideas that otherwise would have been left invisible and to synthesise different disciplines' views. This is in line with research on connection-building-strength of the visual arts (Scott & Twyman, 2018). As suggested by Hertzberg and Roe (2016), we need more research-based guidance for pedagogical practices to improve upper secondary school students' academic writing skills in various school subjects in the cross-curricular context. Writing or drawing one's ideas and thus elaborating on the subject matter in one's own manner helps students learn better; hence, it is a beneficial SRL skill.

It would be interesting to add a fourth construct, namely the mastery-avoidance goal (Baranik et al., 2010; Elliot & McGregor, 2001), to the trichotomous achievement goal framework applied in this study, especially if investigated with a quasi-experimental design. The mastery-avoidance construct entails the learning profile of a perfectionist who focuses on avoiding a negative possibility, like failing to produce a perfectly organised and illustrated portfolio. This could explain failure in getting the portfolio done.

All but one in the student group narrated that they perceived positive synergy from combining the six subjects with common themes. There was also a spontaneous discussion about the epistemological and ontological differences between the subjects. Some adolescents seemed to reach an in-depth understanding of the essential view in science that beliefs and presuppositions are not true facts but theoretical interpretations which are subject to falsification (Vosniadou, 1994), but many found this confusing and contrary to their ontological and epistemological beliefs. Discontinuities in the narratives may derive from years of studying school subjects within more traditional institutional structures (de Freitas & Bentley, 2012). We encourage teachers to enable students to encounter unfamiliar, educationally critical content of the disciplines ()(Schwartzman, 2010) by carefully selecting common themes for cross-curricular study units to strengthen learners' higher-order thinking skills. While carrying out cross-curricular studies, similarities, differences, and relationships between subjects need to be addressed (Kleve & Penne, 2012) to strengthen students' discipline awareness.

This study suggests that there are adolescents who earn high grades in the academic learning context but cannot see any benefits in learning more concepts or widening their meanings. These students seem to regard only the subject matter useful for excelling in the matriculation exam as relevant. Hence, the matriculation exams or credits required for higher education should take into greater account these cross-curricular study units to raise students' interest in participating in them. Our results indicate that the learning diary and portfolio could be effective in encouraging students to value and strive for deeper thinking skills, and they helped some students open up whole new worldviews. The learning diary helped all the students make their aims, learning outcomes, thinking and concept perception visible; the concept map did the same for some students.

Most students manifested an enrichment of concepts in their interviews, learning diaries or portfolios as they learned more concepts and widened their meanings. Some threshold concepts and conceptual changes were detected. The encounters of some learners with threshold concepts such as "fully human" ignited powerful changes in their mindsets and a whole new worldview. A lot of belief

revision was detected in the philosophy section, but most adolescents failed to describe the concepts in more detail, which can be a sign of defensive responses to unknown conceptual constructs. It would be interesting to investigate these possible anomalies in learners' concept categories further. This result also implies the need for more training in verbal reasoning.

This study shows that learning diaries and portfolios can be used to guide learners to pay more attention to concepts and their importance as tools for thinking. Students can enhance their SRL skills by formulating their personal points of interest as questions in their learning diaries and pondering them further in their portfolios. The findings suggest that it is beneficial for upper secondary students to have opportunities to break subject boundaries, thus strengthening deeper thinking skills and SRL skills and making their learning processes visible. Hence, we suggest a critical approach to cross-curricularity in terms of advocating not the potpourri-like approach of different subjects lacking a clear focus but a well-organised pedagogy, contributing to the tradition of cross-curricular curiosity and proactivity (Dannels & Housley Gaffney, 2009; Jacobs, 1989). It would be interesting to investigate teaching and learning models with cross-curricular approach similar to the one depicted in this study also in other educational levels, such as higher education.

Appendices

Appendix A. The composite narratives.
Appendix B. Guidelines for the learning diary and portfolio.
Appendix C. Narrative interview.
Appendix D. Making the joint artwork.
Appendix E. Concept maps.

Note. Colours are needed for both printable and online versions of the supplemental files "Guidelines for the learning diary and portfolio", "Making the joint artwork" and "Concept maps".

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Supplementary materials

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Appedices

Appendix A. The composite narratives.

Title of the composite narrative	Narrative composed of narrators' quotations
Dominant narrative: Learning deepened by autonomy	The intention was to deepen my knowledge of humans and get different perspectives, and I think I did just that. One might say that this was the nicest class of the whole period. The class was even better than I anticipated. I liked the learning diary and portfolio tasks as I could do them at my own pace and in my own way. The diary was a means to proceed with the portfolio. It was good as we all learn things in different ways and our points of interest differ, so the freedom of choice was a good thing. The learning diary was a very straightforward task. I wrote down the concepts right after the lesson. I listed the concepts in the portfolio and wrote down their meanings. That traffic light thinking was really good because I noticed that I really internalised the subject matter, and then it was also nice when there were those colours, so it wasn't just black and white. The colours summed it up. And then I was able to think more about those concepts and questions. It was quite laborious to pick up the concepts from the teachers' talks or slides, and I missed some of them as I was taking notes at the same time. But this way, I really had to focus and stay alert during each lesson, and I liked that the students were made to actively ponder things. You have more time to think about things and do the task. It's a well-organised way to proceed, and it's nice to design the look of the portfolio. I stayed well on schedule when making the portfolio. At first, it was difficult to compose the research questions, but I quickly got the hang of it. I took the time and effort to find the answers, especially in biology, but I didn't write everything down. It [formulating questions] was nice and challenged me to think and reflect on things. Right at the beginning of the course, I named different main categories for the concepts: biological, social, physical, and mental and spiritual, then I identified and combined different concepts under those categories, so I could better understand concepts and their meanings when I knew which area they belonged to. I also use colour-coding to memorise notes that I take. Yes, I feel that I now [after this class] have a clearer idea of how I think, how my world of thought might work, what my presuppositions are, so the emphasis is on how much I learn and remember after all. It's good to write things down right away because I know that otherwise I wouldn't remember it later. Psychology and philosophy [best supported each other]; they already had those connections anyway, and physics and physical education went hand in hand. Biology explained the foundation of the phenomena, especially in psychology and philosophy. Yes, all the subjects were nicely connected to each other. Arts tied everything we had thought together into a nice package. When making the work of art, it felt like living only in the moment, and it made it feel so free. When it was finished, it turned out fine just because it was not done with any stress but with such sheer joy and a bit like everyone's passions were on that paper; it was really fascinating. It really broke loose the good team spirit; there was a good feeling about the whole course, like, that there was a good boogie going on. Somehow, when processing the artwork, everyone was just talking about all the lessons we had had, so it was good, a bit like repeating and connecting them all. That work of art we made together became awesome. Transitions from one subject to another went quite smoothly, in a logical order, except when proceeding from physical education and physics to philosophy; that was rather abrupt. It was confusing to move on to a subject that doesn't have specific

	answers to questions. Other transitions felt like the story kind of continued from where it had ended in the previous section. We kind of started with practical exercises and proceeded to sort of deeper thinking. We proceeded a bit like from toes to head, the complete human body.
Counternarrative 1: Struggling with motivation and schedule	Well, I didn't really have any specific goals for this study unit. As long as I get a course mark from this, that's enough. Well, I got that overall picture; normally, when I have a lesson in one discipline, such as psychology, then I don't think of the same topic from other disciplines' point of view, but here it was easy to combine all the views of different disciplines. That [the learning diary] was in itself relatively easy. It was fast. You just wrote in it. Putting those concepts into it was perhaps the most difficult thing to do, to know what was wanted or how many of them should have been put into it. It kind of gathered the thoughts of that lesson. It [making research questions] was pretty challenging. When you asked those questions, you really had to start thinking about things. So yes, it was useful [for learning]. Yes, for all questions, I have an answer [in the portfolio], but the quality of the answers may not be terribly good. Especially on those physical education issues. Especially making that portfolio was maybe a bigger job than I had thought. On the other hand, because I did it in three days at the end of the course, it could have made it feel a lot heavier than if I had done it one topic at a time after each lesson. I'm actually the kind of person who really does not do those things just when they should be done, but I will make them a week behind, which is really bad. … It was good that it [the portfolio] replaced the course exam, but then it was forgotten after the lessons when I went home, to work, or somewhere right away, and I no longer remembered when I had left the school that it should be done. I haven't even started the portfolio yet. Yes, we will somehow always find answers ourselves, but we will not be such active help seekers for some reason. Raising your hand actively, it's not like me. Well, maybe I'd rather ask Katriina first or some other student rather than the teacher for some reason. It's not because the teacher is scary to me, but I'm not really that kind of socially active person … Yes, all those subjects supported each other. From philosophy and psychology, for example, came the same concepts and the same examples. Biology basically put it all together. Yes, physics and exercise supported each other well. I found it nice to make the joint artwork. It became better than I expected. I think it worked well as a summary of the whole course. It brought out everything we had said about humans, like, for example, goodness and evil. [Transitions] felt a bit like going from one topic area to another in a history lesson, for example. It wasn't confusing in any way. It was quite relaxed and just smooth.
Counternarrative 2: Active communicator with poor effort regulation	The goal was to find new perspectives and get answers. There were a lot of perspectives and questions, but a lot of questions arose that have not yet been answered. I have a personal problem with tasks like the portfolio and learning diary, as they are easily left undone; I didn't fill them up much. They are really difficult for me for some reason. I can write an essay in a week if it's an assignment, and it goes quite easily, but when I have to write something like a progressive portfolio, I can't. For me, such a free-form portfolio is somehow really difficult. I'm like, "What am I now actually writing here?" and although I have the lesson topic, I'm still like, "Yeah, you should write something about this, but what?" In my opinion, I'm a pretty good conversationalist; I know how to carry on conversations with other people, interesting discussions, and bring a new point of view. It all goes easily. But then when that conversation should, like, take place with myself, then my mind somehow goes blank and I can't challenge myself in the same way. And because of that, it was

really hard for me to come up with research questions. Which shows in the diary as there aren't many of them. And then all those concepts and so on, basically I deal with them pretty much in my head. But then I forget to write them down. And that feels like, "So damn, I failed again."

I didn't have enough motivation to write them down also because those questions were largely asked during the lesson and already answered in class; thus, they were left unrecorded because of it.

Here you can see how strongly all these disciplines intertwine because, like I just said, psychology, biology and philosophy were also involved. Because they belong together in a certain way, it is good that they have been combined into such a course. Well, philosophy and psychology did support each other really strongly, and then there was physics and physical education combined. And then I think biology, in turn, supports a bit like all of these in the background. All the other transitions went really smoothly, but the transition from physical education to philosophy felt abrupt.

Appendix B. Guidelines for the learning diary and portfolio.

Instructions in OneNote for the learning diary

A. As the course progresses, paint the topic with a colour at the end of the lesson:
   - Green: I feel like I learned things perfectly, and I can tell others about them. (3)
   - Yellow: I feel like I'm learning things, but something was still a little unclear. (2)
   - Red: I feel like I didn't really learn anything. (1)
B. Write down new research questions at least after the introductory section of each subject.
C. Write down the key concepts after each lesson.
D. Reflect on what you have learned and write down your thoughts in your portfolio.

Instructions in OneNote for the portfolio

Make your own portfolio but discuss the research questions and assignments with your peer.

A. Write down the research questions that you want to find answers to, as well as the answers.
B. Ask more questions as the study unit progresses, at least whenever the teacher changes and after you have had the first lesson (the introduction).
C. Write down the key concepts you consider relevant for each subject as the study unit progresses. What do the concepts mean? Do all subjects have their own concepts? How do these concepts differ between the subjects?
D. How do the new concepts feel? Is the transition from one subject to another abrupt or smooth? Describe your feelings.
E. At the end of each subject section, briefly describe how you worked to achieve your learning goals.
F. Keep a portfolio as a diary and record your findings there. You are free to write, draw, take photos, take video clips, etc.
G. At the end, reflect on the study unit as a whole: What were the most interesting, thought-provoking things? What did you learn? What helped you learn and what bothered you? Finally, what is human?
H. At the end of the study unit, review the research questions you composed during the study unit. What do you think of them now?

By formulating questions and clarifying their answers and the meanings of new concepts, you will progress during the course according to the cyclical learning model of inquiry learning, and your knowledge and understanding will deepen. By engaging in formulating your own research questions carefully, you will get the most out of the course.

Extracts from students' learning diaries

Leena's learning diary

Oppimispäiväkirja

perjantai 2. lokakuuta 2020 13.30

Oppimispäiväkirja

Kurssin edetessä maalaa aiheen väri tuntemuksesi mukaan kyseisen oppitunnin päätyttyä:

Vihreä: Minusta tuntuu, että opin asiat erinomaisesti, ja pystyn kertomaan niistä muillekin. (5)

Keltainen: Minusta tuntuu, että opin asioita, mutta jotakin jäi vielä vähän epäselväksi. (3)

Punainen: Minusta tuntuu, että en oikein oppinut juuri mitään. (1)

- Kirjaa muistiin uusia tutkimuskysymyksiä ainakin seuraavan oppiaineen johdanto-osuuden jälkeen (Uudet:)
- Pohdi oppimaasi ja kirjaa ajatuksesi muistiin portfolioosi

	Aihe	Tutkimuskysymykseni	Käsitteet
ti 6.10.	Kurssin esittely	Ihminen ei voi olla olemassa ilman soluja, mutta solut voivat olla olemassa ilman ihmistä? Kyllä. Onko solut siis meitä vai onko ne vain väline, jotta me voidaan olla me? Sekä että. - Merja Minkälaisia ihmisyyksiä on olemassa? Minkälaisia eri tapoja katsoa mitä ihminen on on olemassa? Voidaanko ajatella esimerkiksi, että ihminen on sen fyysinen keho ja sen mieli. Entä kun ihminen kuolee niin onko sitä enää vaikka sen fyysinen keho vielä muuttuisi? (Parta kasvaa kun ihminen kuolee) Jos tekee elinsiirron niin onko sitten osa sinua toisessa ihmisessä? Onko syöpä osa minua? Hyviä, vaikeita kysymyksiä. Itse koen viimeisen kysymyksen niin, että syöpäsolut ovat omia solujani, joita kehoni ei pysty hallitsemaan. Ne ovat osa minua, solujen kapina sisälläni. Kapina, johon ei välttämättä ole mitään syytä, edes perimissäni geeneissä. Merja	Eksistentialismi, Essentialismi, Kulturalismi, naturalismi
to 8.10.	Ihminen eläimenä	Uudet: Mikä on sellainen lista asioista mitkä ovat negatiivisia, jotka erottavat ihmiset eläimistä? (aina esitetään vaan positiivista) Vain ihminen on lisääntyessään muokannut elinympäristöään niin voimallisesti, että on aiheuttanut sukupuuttoaallon. - Merja	magnetiittikide=>solunsisäinen kompassi, tappisolut; havaitsee näön, hajukäämi; otsalohkossa, kumulatiivinen kulttuuri: käytössämme on edellisten sukupolvien aikaansaannokset. Limbinen järjestelmä >> nisäkkäiden ja matelijoiden aivoissa tunteet muodostuu. "Poimuttunut" neokorteksi/myöhäisiavokuori>> rationaalinen ajattelu ja tunteiden hillitseminen (Eläimillä ei ole)
pe 9.10.	Palautepäivä: ei oppituntia		
ti 20.10	- Tehtävät oli helppoja, mutta oli vaikeaa perustella mitä ihmisessä Biologisesti tapahtuu testien aikana.	Onko silmän "käyttäytymistapoja" olemassa, joita ei voi vain selittää? Miksi optisia illuusioita on vain nämä oudot kuvat emmekä törmää niihin reaalielämässä? Ihmisen silmän toimintakykyäkin voi siis kuormittaa liikaa? Voimme törmätä arkielämässäkin niihin, mutta emme yleensä kiinnitä niihin huomiota. Esimerkiksi jälkikuvia muodostuu, kun katsomme pitkään yhteen esimerkiksi vihreään kohteeseen. Todellakin, ihmisen silmän toimintakyky kuormittuu melko nopeastikin. Esimerkiksi silmän sisällä olevat pienet lihakset väsyvät, jos luet pitkään. Tästä johtuen et pysty tarkentamaan enää katsettasi.- Merja	Opetusta oli niukasti joten käsitteet eivät olleet uusia: syvyysnäkö, hämäränäkö, näkötarkkuus. (Olisi ollut kiva saada jotakin artikkeleja, joissa selitettäisiin miksi testimme antoivat sellaisia tuloksia kun antoivat. Nyt jouduimme itse etsimään internetistä, kun niin asiasta innostuimme. Ei ongelma sinänsä.)
to 22.10.	Aistitehtävien purku	Onko ihmisen ainut keino kommunikoida ja kokea ympäristönsä ja elämän vain aistien varassa? Ilman aisteja ihminen ei voi kokea elämää ollenkaan eikä sitä täten olisi? Aistit antavat meille viestiä kehomme sisältä	Kerrattiin aiempia käsitteitä vaikka niitäkin oli niukemmin, sillä keskityttiin testienpurkuun.

Tiina’s learning diary

pe 9.10.	Pääsiäispäivä: ei opiskelua		
ti 20.10	Aistitehtävät	Millaista olisi elää jos joku aisti yhtäkkiä puuttuisi? Onko mahdollista saada ihmisen näöstä yhtä hyvä, kuin haukalla? Millaiset silmät kaloilla tai muilla veden alla eläimillä on?	Kuulo, aistit, aistinsolut, aksoni
to 22.10.	Aistitehtävien purku	Mitä jos silmät eivät tuota ollenkaan/tarpeeksi rodopsiinia ja mistä se johtuisi? Auttavatko isommat korvat kuulemaan paremmin?	näkökenttä, rodopsiini, tappi /sauvasolut, aisti reseptorit, iho
pe 23.10.	Liikuntasuorituksia mittauksineen	Uudet: (Painojen kanssa hypätessä) Millä painolla pystyisi hyppäämään kalkista pisimmälle ja voiko sen määritellä omasta painosta?	Refleksi, painovoima, staattinen lihastyö
ti 27.10.	Liikuntasuorituksia mittauksineen		
to 29.10.	Liikuntasuorituksia mittauksineen		Aktiini, myosiini, lihassäie, sarkomeeri
pe 30.10.	Liikuntasuoritusten mittausten työstäminen/mallintaminen/fysiikan suureet	Uudet:	Ekg, lämpökamera, syke
ti 3.11.	Liikuntasuoritusten mittausten työstäminen/mallintaminen/fysiikan suureet		
to 5.11.	Liikuntasuoritusten mittausten työstäminen/mallintaminen/fysiikan suureet		
pe 6.11.	Filosofia + elämänkatsomustieto (En ollut paikalla)	Uudet:	
ti 10.11.	Filosofia + elämänkatsomustieto		Itsetietoisuus, psykoanalyyttinen filosofia,
to 12.11.	Filosofia + elämänkatsomustieto	Kuvaavatko ajatukset paremmin todellisuutta?	
pe 13.11.	Korkeammat kognitiiviset toiminnot (En ollut paikalla)	Uudet:	
ti 17.11.	Korkeammat kognitiiviset toiminnot		
to 19.11.	Virtuaallinen vierailu HIP-labraan (PinniB)		EEG, herätevaste (ERP), EMG,SCR

Appendix C. Narrative interview with students.

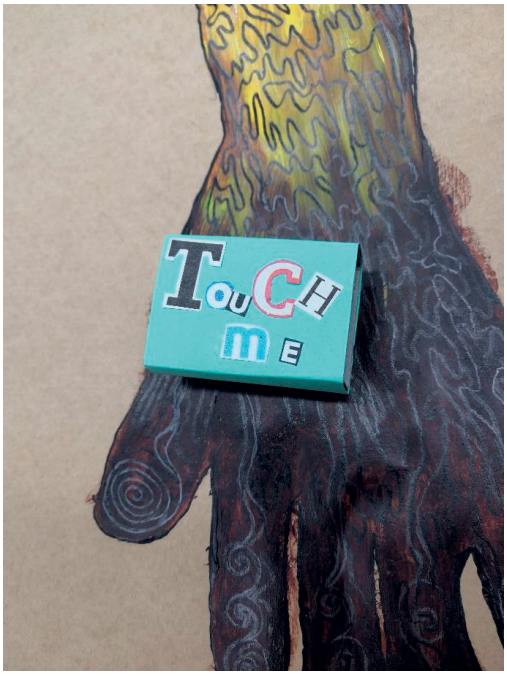
1. What made you choose this course?
2. I would like you to tell me your own story about this specific study unit. Tell me in your own words the events and experiences that you regard as the most important ones. You can start wherever you like and take all the time you need. I will listen to you without interrupting and take some notes to ask you some things about them later.

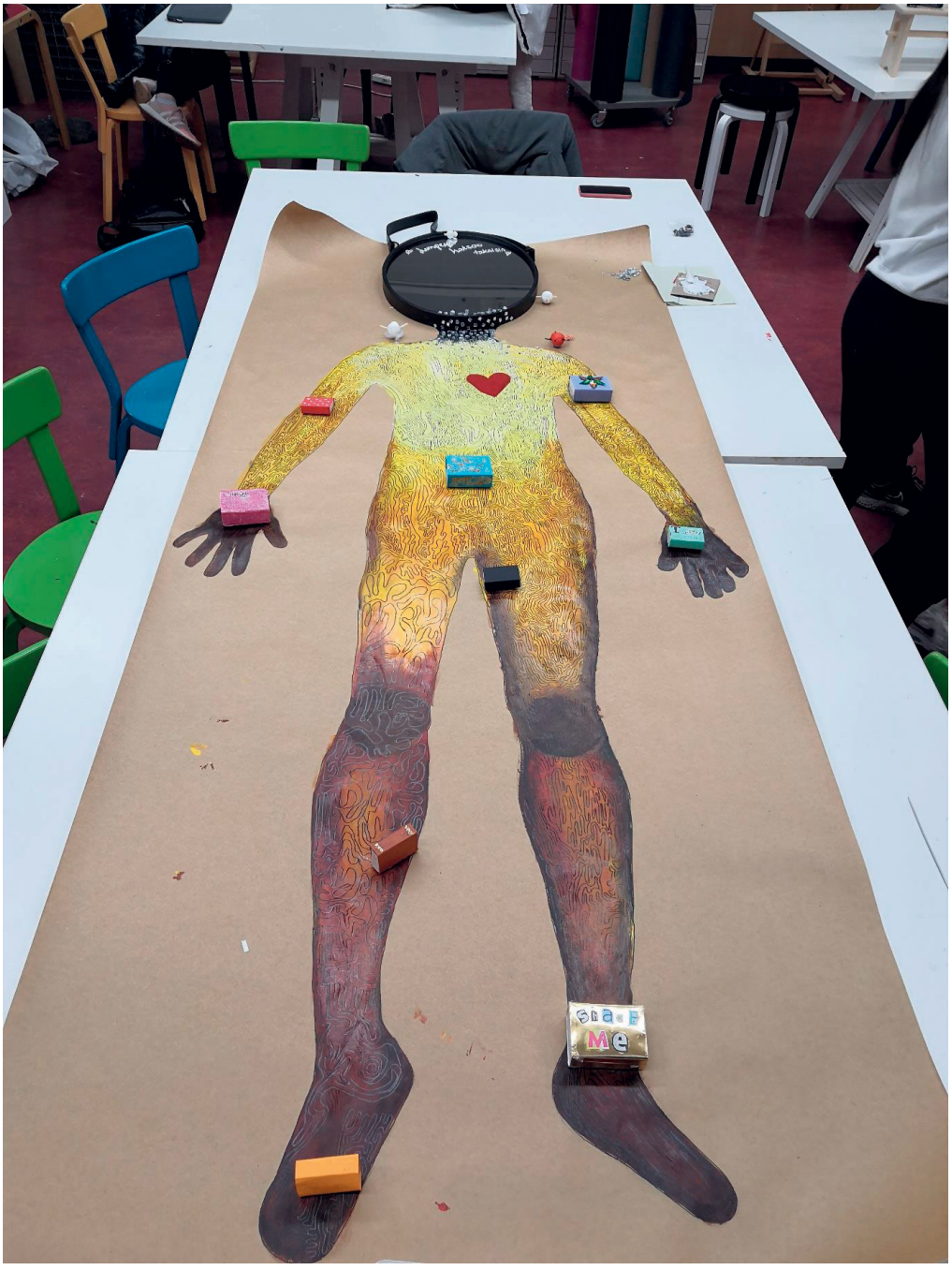
A. Concept perception, changes in conceptual constructs, cross-curricularity
   1. Which subjects did you find the most interesting? Can you explain why?
   2. Which subjects did you find the least interesting? Can you explain why?
   3. Which concepts were the most interesting? Why? (We have the concept map the learner has drawn.)
   4. Which concepts were the most difficult? How did they make you feel? (We have the concept map the learner has drawn.)
   5. How did you find combining six very different school subjects?
   6. Did you perceive benefits from combining different subjects?
   7. In your opinion, which of the six subjects supported or complemented each other?
   8. How did it feel to change from one subject to another? (see timetable)

B. Digital learning platform
   1. Describe in your own words the suitability of Microsoft Office Teams as a learning platform.
   2. Did Teams make an impact in any way when you set learning goals and sought to achieve them?
   3. Were the learning materials easy to find?
   4. Were the tasks easy to find?
   5. Describe how it was to fill in the learning diary.
   6. Describe how you found the portfolio tasks.
   7. Describe the assignments of biology/physical education + physics/philosophy/psychology/ arts. How did you find them?

C. Inquiry learning as a method of learning
   1. What are your thoughts on formulating your own research questions?
   2. How much did you invest in drafting the questions?
   3. What about finding answers to them?
   4. How did you find the task of writing down and explaining the key concepts?
   5. Would you have needed more help from teachers to learn things?
   6. What do you think of arts as a synthesis?
   7. Do you think you succeeded in achieving your learning goals?

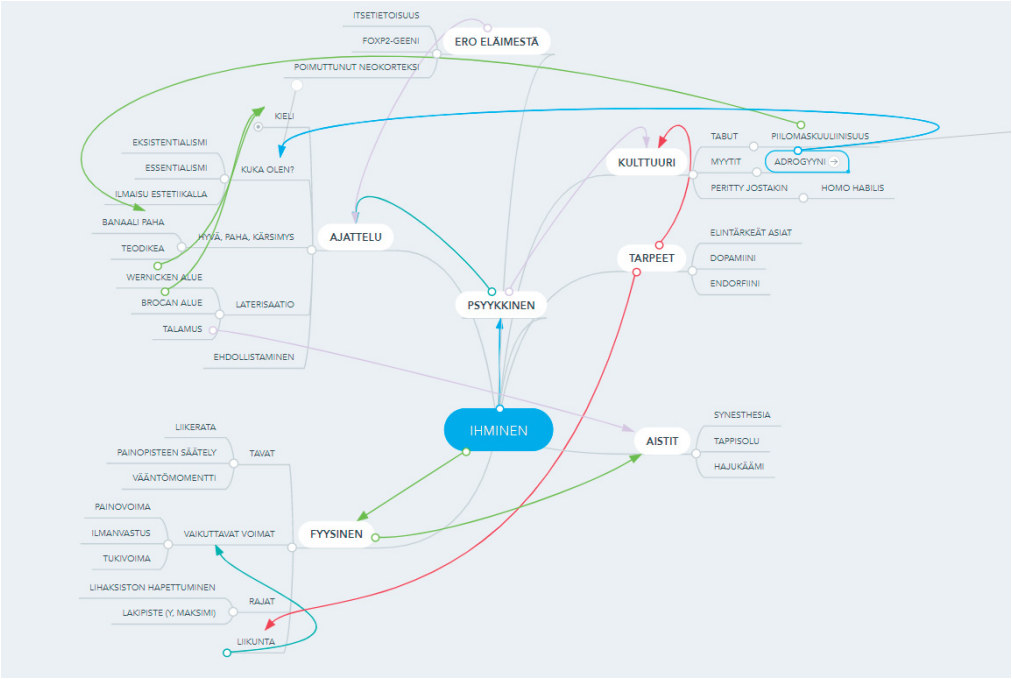
Appendix D. Making the joint artwork.


TOUCH
ME


Me

Appendix E. Concepts maps.

Concept map made by Leena:



Concept map made by Mari: