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UNIVERSITY STUDENTS' REGULATION OF LEARNING AND TEXT PROCESSING – Examples from medical and teacher education

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SUMMARY

The general aim of the thesis was to study university students' learning from the perspective of regulation of learning and text processing. The data were collected from the two academic disciplines of medical and teacher education, which share the features of highly scheduled study, a multidisciplinary character, a complex relationship between theory and practice and a professional nature. Contemporary information society poses new challenges for learning, as it is not possible to learn all the information needed in a profession during a study programme. Therefore, it is increasingly important to learn how to think and learn independently, how to recognise gaps in and update one's knowledge and how to deal with the huge amount of constantly changing information. In other words, it is critical to regulate one's learning and to process text effectively. The thesis comprises five sub-studies that employed cross-sectional, longitudinal and experimental designs and multiple methods, from surveys to eye tracking.

Study I examined the connections between students' study orientations and the ways they regulate their learning. In total, 410 second-, fourth- and sixth-year medical students from two Finnish medical schools participated in the study by completing a questionnaire measuring both general study orientations and regulation strategies. The students were generally deeply oriented towards their studies. However, they regulated their studying externally. Several interesting and theoretically reasonable connections between the variables were found. For instance, self-regulation was positively correlated with deep orientation and achievement orientation and was negatively correlated with non-commitment. However, external regulation was likewise positively correlated with deep orientation and achievement orientation but also with surface orientation and systematic orientation. It is argued that external regulation might function as an effective coping strategy in the cognitively loaded medical curriculum.

Study II focused on medical students' regulation of learning and their conceptions of the learning environment in an innovative medical course where traditional lectures were combined with problem-based learning (PBL) group work. First-year medical and dental students (N = 153) completed a questionnaire assessing their regulation strategies of learning and views about the PBL group work. The results indicated that external regulation and self-regulation of the learning content were the most typical regulation strategies among the participants. In line with previous studies, self-regulation was

connected with study success. Strictly organised PBL sessions were not considered as useful as lectures, although the students' views of the teacher/tutor and the group were mainly positive. Therefore, developers of teaching methods are challenged to think of new solutions that facilitate reflection of one's learning and that improve the development of self-regulation.

In Study III, a person-centred approach to studying regulation strategies was employed, in contrast to the traditional variable-centred approach used in Study I and Study II. The aim of Study III was to identify different regulation strategy profiles among medical students (N = 162) across time and to examine to what extent these profiles predict study success in preclinical studies. Four regulation strategy profiles were identified, and connections with study success were found. Students with the lowest self-regulation and with an increasing lack of regulation performed worse than the other groups. As the person-centred approach enables us to individualise students with diverse regulation patterns, it could be used in supporting student learning and in facilitating the early diagnosis of learning difficulties.

In Study IV, 91 student teachers participated in a pre-test/post-test design where they answered open-ended questions about a complex science concept both before and after reading either a traditional, expository science text or a refutational text that prompted the reader to change his/her beliefs according to scientific beliefs about the phenomenon. The student teachers completed a questionnaire concerning their regulation and processing strategies. The results showed that the students' understanding improved after text reading intervention and that refutational text promoted understanding better than the traditional text. Additionally, regulation and processing strategies were found to be connected with understanding the science phenomenon. A weak trend showed that weaker learners would benefit more from the refutational text. It seems that learners with effective learning strategies are able to pick out the relevant content regardless of the text type, whereas weaker learners might benefit from refutational parts that contrast the most typical misconceptions with scientific views.

The purpose of Study V was to use eye tracking to determine how third-year medical students (n = 39) and internal medicine residents (n = 13) read and solve patient case texts. The results revealed differences between medical students and residents in processing patient case texts; compared to the students, the residents were more accurate in their diagnoses and processed the texts significantly faster and with a lower number of fixations. Different reading patterns were also found. The observed differences between medical students and residents in processing patient case texts could be used in medical education to model expert reasoning and to teach how a good medical text should be constructed.

The main findings of the thesis indicate that even among very selected student populations, such as high-achieving medical students or student teachers, there seems to be a lot of variation in regulation strategies of learning and text processing. As these learning strategies are related to successful studying, students enter educational programmes with rather different chances of managing and achieving success. Further, the ways of engaging in learning seldom centre on a single strategy or approach; rather, students seem to combine several strategies to a certain degree. Sometimes, it can be a matter of perspective of which way of learning can be considered best; therefore, the

reality of studying in higher education is often more complicated than the simplistic view of self-regulation as a good quality and external regulation as a harmful quality. The beginning of university studies may be stressful for many, as the gap between high school and university studies is huge and those strategies that were adequate during high school might not work as well in higher education. Therefore, it is important to map students' learning strategies and to encourage them to engage in using high-quality learning strategies from the beginning. Instead of separate courses on learning skills, the integration of these skills into course contents should be considered. Furthermore, learning complex scientific phenomena could be facilitated by paying attention to high-quality learning materials and texts and other support from the learning environment also in the university. Eye tracking seems to have great potential in evaluating performance and growing diagnostic expertise in text processing, although more research using texts as stimulus is needed. Both medical and teacher education programmes and the professions themselves are challenging in terms of their multidisciplinary nature and increasing amounts of information and therefore require good lifelong learning skills during the study period and later in work life.

Keywords: *regulation of learning, self-regulation, text processing, medical education, teacher education, higher education, university students, person-centred approach, eye tracking, expertise*

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VILPPU, HENNA: Yliopisto-opiskelijoiden oppimisen säätely ja tekstin prosessointi - esimerkkeinä lääketieteen ja luokanopettajakoulutuksen opiskelijat

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TIIVISTELMÄ

Tässä väitöskirjassa tutkittiin yliopisto-opiskelijoiden oppimista oppimisen säätelyn ja tekstin prosessoinnin näkökulmasta. Tutkimukseen osallistuneet opiskelijat valittiin lääketieteen ja luokanopettajakoulutuksen koulutusohjelmista, joita yhdistää tarkasti aikataulutettu opiskelu, monitieteisyys, teorian ja käytännön monimutkainen suhde sekä lääkärin ja luokanopettajan ammattien professionaalinen luonne. Nykyinen tietoyhteiskunta, jossa tieto lisääntyy ja muuttuu nopeasti, asettaa uusia haasteita oppimiselle, kun kaikkea ammatinharjoittamisessa tarvittavaa tietoa ei voi oppia koulutuksen aikana. Yhä tärkeämpää onkin oppia ajattelemaan ja oppimaan itsenäisesti, huomaamaan aukkoja omissa tiedoissaan ja päivittämään tietojaan, sekä oppia käsittelemään alati lisääntyvää ja muuttuvaa informaatiota. Toisin sanoen tulee oppia säätelemään omaa oppimistaan ja prosessoimaan tehokkaasti tekstejä. Väitöskirja koostuu viidestä osatutkimuksesta, joissa hyödynnettiin pitkittäis-, poikittais- ja kokeellisia asetelmia sekä monimetodista lähestymistapaa.

Väitöskirjan ensimmäisessä osatutkimuksessa selvitettiin yleisten opiskeluorientaatioiden ja oppimisen säätelystrategioiden välisiä yhteyksiä. Yhteensä 410 toisen, neljännen ja kuudennen vuoden lääketieteen opiskelijaa kahdesta suomalaisesta yliopistosta vastasivat opiskeluorientaatioita ja oppimisen säätelystrategioita koskevaan kyselyyn. Tulokset osoittivat lääketieteen opiskelijoiden orientoituvan opiskeluunsa valtaosin syväsuuntautuneesti. Sitä vastoin tyypillisimpänä säätelystrategiana näyttäytyi oppimisen ulkoinen säätely. Lisäksi tutkimus paljasti useita teoreettisesti kiinnostavia ja ymmärrettäviä yhteyksiä yleisten opiskeluorientaatioiden ja oppimisen säätelystrategioiden välillä. Esimerkiksi itsesäätely oli positiivisesti yhteydessä syväorientaatioon ja suoritusorientaatioon, mutta negatiivisesti opiskeluun sitoutumattomuuteen. Ulkoinen säätely oli niin ikään positiivisesti yhteydessä syvä- ja suoritusorientaatioon, mutta lisäksi myös pinnallisempaan orientaatioon. Ulkoinen säätely saattaakin toimia tehokkaana selviytymisstrategiana kognitiivisesti raskaassa lääketieteen koulutusohjelmassa.

Toisessa osatutkimuksessa tarkasteltiin ensimmäisen vuoden lääketieteen ja hammaslääketieteen opiskelijoiden (*N* = 153) oppimisen säätelyä ja käsityksiä

oppimisympäristöstä, jossa perinteisen luento-opetuksen ohella järjestettiin ongelmalähtöisen oppimisen (PBL) periaatteiden mukaista pienryhmätyöskentelyä. Aineisto kerättiin kyselylomakkeen avulla. Tulokset osoittivat opiskelijoiden tyypillisimmiksi säätelystrategioiksi oppimisen ulkoisen säätelyn sekä opittavien sisältöjen itsesäätelyn, esimerkiksi aktiivisen tiedonhaun. Yhdenmukaisesti aiempien tutkimusten kanssa itsesäätelyn todettiin olevan yhteydessä opintomenestykseen. Opiskelijat pitivät luentoja hyödyllisempinä kuin PBL-istuntoja, vaikkakin heidän näkemyksensä pienryhmästä ja opettajatuutorista olivat pääosin positiivisia. Tulokset haastavat opetuksen kehittäjät pohtimaan uudenlaisia ratkaisuja oppimisympäristöiksi, jotka mahdollistavat oman oppimisen reflektoinnin ja lisäävät itsesäätelyn kehittymistä.

Kolmannessa osatutkimuksessa oppimisen säätelystrategioita tutkittiin yksilötasolla. Tutkimuksen tavoitteena oli tunnistaa erilaisia oppimisen säätelyn profiileja lääketieteen opiskelijoilla (N = 162) ajan suhteen, sekä selvittää missä määrin nämä profiilit ennustavat opintomenestystä lääketieteen opintojen prekliinisessä vaiheessa. Neljä erilaista oppimisen säätelyprofiilia löydettiin. Opiskelijat, joilla oppimisen itsesäätely oli heikointa ja jotka ilmensivät lisääntyviä vaikeuksia oppimisen säätelyssä, suoriutuivat opinnoista muita ryhmiä heikommin. Koska yksilökeskeinen lähestymistapa mahdollistaa oppimisen säätelyltään erilaisten opiskelijoiden tunnistamisen, sitä voitaisiin hyödyntää opiskelijoiden oppimisen tukemiseen ja oppimisvaikeuksien varhaiseen tunnistamiseen.

Neljännessä osatutkimuksessa 91 luokanopettajaopiskelijan ymmärrystä monimutkaisesta tieteellisestä ilmiöstä selvitettiin esi-jälki-mittausasetelmalla, jossa opiskelijat vastasivat avoimiin kysymyksiin ennen ja jälkeen tekstin lukemisen. Tekstinä käytettiin joko perinteistä selittävää tekstiä tai ns. törmäyttävää tekstiä, joka kannustaa opiskelijaa muuttamaan uskomuksensa tieteellisen käsityksen mukaisiksi. Lisäksi opiskelijoiden oppimisen säätelyä ja tekstinprosessointistrategioita selvitettiin kyselylomakkeen avulla. Tulokset osoittivat opiskelijoiden ymmärryksen kehittyvän tekstin lukemisen myötä ja törmäyttävän tekstin tukevan ymmärryksen rakentumista paremmin kuin selittävän tekstin. Oppimisen säätely- ja tekstinprosessointistrategiat olivat yhteydessä ilmiön ymmärtämiseen. Näyttää siltä, että tehokkaita opiskelustrategioita hyödyntävät opiskelijat kykenevät löytämään tekstistä ilmiön ymmärtämisen kannalta olennaiset asiat tekstityypistä riippumatta, kun taas heikommat opiskelijat saattavat hyötyä enemmän törmäyttävästä tekstistä, jossa tyypillisimpiä virhekäsityksiä on törmäytetty tieteellisen selityksen kanssa.

Viidennessä osatutkimuksessa selvitettiin silmänliikemenetelmän avulla, miten kolmannen vuoden lääketieteen opiskelijat (n = 39) lukevat ja ratkaisevat potilastapaustekstejä verrattuna sisätautien erikoistuviin lääkäreihin (n = 13). Tutkimus osoitti erikoistuvien lääkärien olevan tarkempia diagnoosien tekijöitä sekä prosessoivan tekstit huomattavasti nopeammin ja vähemmillä fiksaatioilla kuin opiskelijat. Lisäksi opiskelijoiden ja erikoistuvien lääkäreiden lukustrategiat poikkesivat toisistaan. Havaittuja eroja potilastapausten prosessoinnissa voitaisiin hyödyntää lääketieteen koulutuksessa asiantuntijan päättelyn mallintamiseen sekä sen opettamiseen, miten hyvä potilastapausteksti rakennetaan.

Väitöskirjan päälöydökset osoittavat, että oppimisen säätelyssä ja tekstin prosessointistrategioissa saattaa olla huomattavia eroja jopa hyvin valikoitujen opiskelijapopulaatioiden sisällä. Tämä asettaa haasteita niin opiskelijoille kuin opetuksen järjestäjille, sillä edellä kuvatut oppimisstrategiat ovat yhteydessä opinnoissa pärjäämiseen ja opintomenestykseen. Opiskelijoiden sitoutumista opiskeluun ei usein voi kuitenkaan tiivistää yhteen strategiaan tai lähestymistapaan, vaan ennemminkin opiskelijat tuntuvat yhdistelevän erilaisia strategioita opiskelussaan. Näin pelkistettyyn näkemykseen oppimisen itsesäätelystä hyvänä ja oppimisen ulkoisesta säätelystä huonona tapana tulee suhtautua kriittisesti. Yliopisto-opintojen alku saattaa olla monelle kuormittavaa, sillä lukio- ja korkeakouluopintojen erilaisuus voi olla merkittävä ja lukiossa toimivaksi osoittautuneet opiskelustrategiat eivät välttämättä enää toimi yhtä hyvin. Siksi olisikin tärkeää kartoittaa opiskelijoiden oppimisstrategioita ja kannustaa heitä korkeatasoisten strategioiden käyttöön jo opintojen alkuvaiheista lähtien. Irrallisten opiskelutaitokurssien sijaan tulisi pohtia opiskelutaitojen integrointia kurssisisältöjen opetukseen. Väitöskirjan tulokset antavat lisäksi viitteitä siitä, että monimutkaisten tieteellisten sisältöjen oppimista voitaisiin tukea kiinnittämällä huomiota korkealaatuisiin oppimateriaaleihin ja teksteihin, sekä muuhun oppimisympäristön antamaan tukeen myös yliopistossa. Silmänliiketutkimuksella on mahdollista kartoittaa asiantuntijuutta tekstin prosessoinnissa, vaikkakin lisätutkimusta tarvitaan. Monitieteisyys ja alati lisääntyvä tieto tekevät lääketieteen ja luokanopettajan koulutuksista haastavia, joten hyvät elinikäisen oppimisen taidot ovat tarpeen niin koulutuksen aikana kuin myöhemmin työelämässäkin.

Asiasanat: *oppimisen säätely, itsesäätely, tekstin prosessointi, lääketieteen koulutus, luokanopettajakoulutus, korkeakoulutus, yliopisto-opiskelijat, yksilökeskeinen lähestymistapa, silmänliiketutkimus, asiantuntijuus*

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LIST OF ORIGINAL PUBLICATIONS

Study I

Olkinuora, E., Virtanen, H., & Mikkilä-Erdmann, M. (2010). Regulation of learning and study orientations of medical students. *Procedia Social and Behavioral Sciences, 2*, 3850–3856.

EO contributed to data analysis and interpretation and was responsible for writing the manuscript. HV contributed to the study conception and design, data collection, analysis and interpretation. MM-E contributed to the study conception and design and interpretation of the data. All authors critically revised the manuscript and approved the final version for publication.

Study II

Virtanen, H., Mikkilä-Erdmann, M., Murtonen, M., & Kääpä, P. (2010). Lääketieteen ja hammaslääketieteen ensimmäisen vuoden opiskelijat oppimisensa säätelijöinä [Medical and dental first-year students as regulators of their learning]. *Peda-forum – yliopistopedagoginen aikakausjulkaisu,17*(1), 6–17.

HV contributed to the study conception, design and data collection and was responsible for data analysis and interpretation and writing the manuscript. MM-E and MM contributed to the study concept and design and interpretation of the data. PK participated as a content specialist, contributing to the study design and data collection. All authors critically revised the manuscript and approved the final version for publication.

Study III

Vilppu, H., Laakkonen, E., Mikkilä-Erdmann, M., & Kääpä, P. (submitted). Seeing beyond variables: Applying a person-centered approach to identifying regulation strategy profiles – a case of medicine.

HV contributed to the study conception and design; the data collection, analysis and interpretation and was responsible for writing the manuscript. EL contributed to data analysis and interpretation. MM-E contributed to the study concept and design and interpretation of the data. PK facilitated the data collection. All authors critically revised the manuscript and approved the final version for publication.

Study IV

Vilppu, H., Mikkilä-Erdmann, M., & Ahopelto, I. (2013). The role of regulation strategies in understanding science text among university students. *Scandinavian Journal of Educational Research, 57*(3), 246–262.

HV contributed to the study conception and design and data collection, analysis and interpretation and was responsible for writing the manuscript. MM-E contributed to the study concept and design and interpretation of the data. IA participated as a content specialist, contributing to the study conception and design; materials and data collection; analysis and interpretation. All authors critically revised the manuscript and approved the final version for publication.

Study V

Vilppu, H., Mikkilä-Erdmann, M., Södervik, I., & Österholm-Matikainen, E. (under review). Exploring eye movements of experienced and novice readers of medical texts concerning the central cardiovascular system for finding the right diagnosis.

HV contributed to the study conception and design and data collection, analysis and interpretation and was responsible for writing the manuscript. MM-E contributed to the study concept and design and interpretation of the data. IS contributed to the study conception and design and data collection and was responsible for developing the patient case texts. EÖ-M contributed to the data collection. All authors critically revised the manuscript and approved the final version for publication.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Current demands for learning in higher education

The goal of higher education is to equip graduates with the knowledge and core transferable competences they need to succeed in high-skill occupations (COM 2011; Tynjälä, Helle, & Murtonen, 2002). Currently, as society is rapidly evolving and knowledge is becoming obsolete ever faster, the societal demand on higher education is to pay more attention to teaching how to think and learn independently and how to deal with a huge amount of information that is exponentially increasing and changing (e.g. Vermunt, 1996; Välijärvi, 2006). Therefore, lifelong learning skills are emphasised as they seem to form the basis for all studying and working (e.g. COM 95, COM 2013; Vermunt & Verloop, 1999).

One of the most essential skills appreciated by both educational psychologists and policymakers is self-regulation because it plays an important role in learning and achievement in school and beyond and is therefore considered an essential element in lifelong learning (Boekarts, 1999; Boekarts & Cascallar, 2006). Multiple conceptualisations of the construct of self-regulation exist, but most researchers seem to share the view of self-regulation as comprising multi-component, iterative, self-steering processes that 'target one's own cognitions, feelings and actions, as well as features of the environment for modulation in the service of one's goals' (Boekarts, Maes, & Karoly, 2005). However, self-regulated learning and other proximal concepts, such as metacognition and self-directed learning often seem to overlap and have been inconsistently used in different studies (cf. Boekarts, 1999; Entwistle & McCune, 2004; Evensen, Salisbury-Glennon, & Glenn, 2001; Lonka, Olkinuora, & Mäkinen, 2004; Vermunt & van Rijswijk, 1988; Zimmerman, 1989, 2001). Metacognition traditionally refers to person's knowledge and cognition about cognitive phenomena (e.g. Brown, 1987; Flavell, 1979; Perry & Winne, 2006; Schraw & Moshman, 1995), while self-directed learning encompasses multiple factors connected to students' responsibility and independence in learning (Silén & Uhlin, 2008). As for self-regulated learning, it seems to be an umbrella term for a number of processes (Loyens, Magda, & Rikers, 2008), and it incorporates, for example, aspects of metacognition (Dinsmore, Alexander, & Loughlin, 2008). To sum up, various perspectives and different explanatory models seem to share the view of self-regulated learning as students' skill and activity in using a variety of learning functions and adapting this usage to the task at hand. In other words, self-regulated students seem to be metacognitively and motivationally skilled.

Self-regulation has also been recognised as a characteristic of expertise (e.g. Bereiter & Scardamalia, 1993; Patel, Glaser, & Arocha, 2000; Tynjälä, 2004; Tynjälä & Gijbels, 2012; Tynjälä, Häkkinen, & Hämäläinen, 2014). The traditional cognitive view of expertise sees expertise as comprising individual knowledge and problem-solving processes. According to this view, the elements of expertise are formal or theoretical knowledge; practical, experimental knowledge and self-regulatory knowledge (e.g. Bereiter, 2002; Bereiter & Scardamalia, 1993; Tynjälä, 2004).

If we take a closer look at expertise in the teaching profession from the cognitive point of view, three important elements can be discerned. First, formal, theoretical knowledge is divided into substance knowledge, that is, knowledge about the subject being taught, and educational knowledge, such as pedagogy and knowledge about communication and interaction (Tynjälä, 2004). According to Tynjälä (2004), it is essential in teacher education to integrate these two into pedagogical substance knowledge, which refers to knowledge about how certain topics can be taught, what kind of conceptions students have of topics and what kind of problems are related to learning them. Second, the practical knowledge in teacher education is associated with teaching skills and the ability to guide the learning process. The last element, self-regulatory knowledge – which includes metacognitive skills and reflectivity – is especially important in a profession where one should guide students to master these skills (Tynjälä, 2004). Further, it is essential that teachers learn to regulate their own learning during teacher education because they act as role models for their students (Endedijk, Vermunt, Verloop, & Brekelmans, 2012; Hagger, Burn, Mutton, & Brindley, 2008; Kramarski & Michalsky, 2009; Vermunt & Endedijk, 2011). As teacher education programmes are increasingly being organised on the basis of partnerships between universities and schools (Edwards & Mutton, 2007), a high degree of self-regulated learning is required from student teachers. For example, they need to integrate knowledge gained from teaching experiences and university courses, self-evaluate their competencies and identify their learning needs (Endedijk et al., 2012). The same can be said about medical students whose learning takes place in a variety of environments from lecture halls to university hospitals and health-care centres and requires integrating knowledge acquired from these environments.

Expertise in medicine can also be simplified into four essential elements. In medicine, two theoretical knowledge domains are typically discerned, namely biomedical, basic science knowledge that incorporates subjects such as biochemistry, anatomy and physiology and clinical knowledge that encompasses an understanding of disease entities and associated findings, investigative procedures and therapeutic management (Kaufman, Keselman, & Patel, 2008). Practical knowledge can be described as encompassing a range of performance skills, such as motor and interpersonal skills (see Norman, Eva, Brooks, & Hamstra, 2006; Patel et al., 2000). Last, through extensive experience, experts develop self-regulatory skills, which enable them to control their performance and allow them to adapt to changing situations (Patel et al., 2000). For example, experts are capable of monitoring their problem-solving processes by predicting the difficulty of the problems, allocating time effectively, noting their errors and checking questionable solutions (see Patel et al., 2000).

Working with different types of texts is an inescapable part of a teacher's or doctor's work. Although e-learning, online learning, blended learning and multimedia learning environments have been extensively researched and refined, text still remains the key element in various learning environments, and learning has a strong connection to reading and text processing (Pirnay-Dummer & Ifenthaler, 2011). Therefore, in addition to self-regulatory skills, effective text processing skills are required. For example, clinical practitioners are continuously under pressure to maintain or improve their standard of competency, which requires keeping up with the latest related scientific developments. This again requires finding, reading, evaluating and comprehending new information and incorporating it into one's patient care conventions (Kaufman et al., 2008). Furthermore, medical texts, such as epicrises, referrals, medical records and journal articles, are very complex documents with their own rules and structures (Charon, 2000). Teachers, for their part, need to keep current with the developments in the subjects they teach and be aware of the best didactic practices in teaching them.

The level of expertise has been proven to have an effect on attention allocation (e.g. Reingold & Sheridan, 2011; van Gog & Scheiter, 2010), and therefore more experienced practitioners are more capable of processing visual stimuli faster, more accurately and more selectively than novices (Haider & Frensch, 1999). Further, the level of expertise seems to affect the organisation of knowledge and problem solving, as suggested by encapsulation theory (see, e.g. Boshuizen & Schmidt, 1992; Boshuizen, Schmidt, Custers, & Van de Wiel, 1995; Schmidt & Boshuizen, 1993; Schmidt & Rikers, 2007). The idea of encapsulation is that through practical experience, theoretical biomedical knowledge merges with experiential knowledge, resulting in knowledge encapsulation and so-called illness scripts (Boshuizen & Schmidt, 1992, 2008; Schmidt & Boshuizen, 1993). Illness scripts are a typical feature of expert clinical reasoning, and they contain a lot of clinically relevant information about diseases (Schmidt & Rikers, 2007). Therefore, through encapsulation, the lines of reasoning gradually get shorter during the development of medical expertise.

In Finland, the teaching and medical professions share a high level of academic education; provide a necessary service for society and incorporate great responsibility, high professional ethics and serve the common good (Rinne & Jauhiainen, 1988; Välijärvi, 2006). Medical and teacher education programmes in Finland are both very popular and highly competed for; therefore, only about 10–15% of applicants are accepted in annual entrance exams. These programmes are characterised by the highly regulated and scheduled nature of studying, meaning that students are given ready-made timetables to guide their studies. Relating to the previous point, the programmes proceed quickly and require students to keep up with the fast pace if they want to graduate within the recommended time span (usually within five years). Additionally, both medical and teacher education are multidisciplinary in that they require students to master and work in multiple branches of science.

Therefore, both medical education and teacher education programmes can be described as highly demanding programmes that aim to produce knowledgeable and skilful experts, with the strong emphasis on professionalism. Therefore, it is suggested that successful studying and practicing of these disciplines requires self-regulation of learning and good text-processing skills. The aim of this thesis is to investigate how university students studying medicine and education regulate their learning and process the learning materials. The thesis integrates multiple methods; in addition to traditional self-test surveys, performance measures and eye tracking methodology are used. Further, both cross-sectional and longitudinal samples and experimental designs are used.

1.2. A brief overview of the students' approaches to learning tradition

The demand for lifelong learning in a rapidly changing environment requires developing new practices at universities. In order to support high-quality student learning in higher education, it is important to understand what kind of learning processes enable optimal learning outcomes (Lastusaari & Murtonen, 2013; Lonka et al., 2004). Psychological research on student learning in higher education has been underway for several decades, which is why the related terminology is multifaceted and varies from one study to another. Different meanings have been given to the same term, and there are various terms apparently covering the same aspects of studying (Entwistle & McCune, 2004). Student learning in higher education has been studied, for example, from the point of view of approaches to learning (e.g. Biggs, 1987; Entwistle & Ramsden, 1983; Lastusaari & Murtonen, 2013; Marton & Säljö, 1976), orientations (e.g. Gibbs, Morgan & Taylor, 1984; Entwistle, 1988; Lehtinen, Vauras, Salonen, Olkinuora, & Kinnunen, 1995; Murtonen, Olkinuora, Tynjälä, & Lehtinen, 2008; Mäkinen & Olkinuora, 1999) and learning styles or patterns (Vermunt, 1996, 1998). According to Vanthournout, Donche, Gijbels, and Van Petegem (2014), a common feature of these studies seems to be the aim to arrive at integrative models of learning by searching for relationships between various aspects of learning (Biggs, 1993; Entwistle & McCune, 2004; Vermunt & Vermetten, 2004). These models of learning are related to a European research tradition, students' approaches to learning (SAL), which in general focuses on different ways students engage in learning as reported by themselves and how these different ways are associated with qualitatively different learning outcomes (Vanthournout, Donche, Gijbels, & Van Petegem, 2014). The parallel research tradition is based on North American research and is known as information processing (IP) or later as self-regulated learning perspective (SRL). It focuses on study strategies and their relationships to learning processes and study outcomes (see Lonka et al., 2004; Pintrich, 2004).

The SAL tradition stems from the phenomenographic studies of Ference Marton and colleagues in the 1970s (Lonka et al., 2004). Marton and Säljö (1976) identified two qualitatively different approaches to learning that represent students' intentions concerning academic reading tasks. In the surface approach, the reader pays attention to the superficial elements of the text and tries to memorise the text as it is, whereas a student with a deep approach pays more attention to the whole and tries to incorporate new information into his/her previous knowledge and experience. In later models and questionnaires representing the SAL tradition, the original distinction between the surface and deep approaches as articulated by Marton and Säljö (1976) seems to remain a central characteristic (Lonka et al., 2004). Later models have also incorporated a third dimension, the strategic (Entwistle & Ramsden, 1983) or achieving approach (Biggs, 1987), which refers to the objective of getting high grades by using time and space effectively. However, these approaches have been criticised for their conceptual differences: whereas the deep and surface approaches refer to the ways in which students engage in learning, the strategic/achieving approach mainly describes how students organise their learning (see Biggs, 1985; Kember, Wong, & Leung, 1999; Lonka et al., 2004).

Although approaches to learning are highly responsive to the learning context, there is persuasive evidence of the consistency in approaches over time and tasks. The term orientation is one attempt to capture such relatively stable preferences for particular approaches (Ramsden, 1988). Sometimes, these preferences are referred to as styles (Pask, 1976; Vermunt & van Rijswijk, 1988). For example, a preference for the deep approach across various situations indicates a meaning orientation, whereas a preference for the surface approach is often interpreted as a reproducing orientation (Lonka et al, 2004).

Orientations have been studied from various perspectives or levels, for example, educational orientations (Gibbs et al., 1984), study orientations (Entwistle, 1988), general study orientations (Mäkinen & Olkinuora, 1999), situational orientations (Lehtinen et al., 1995) and domain-specific situational orientations (Murtonen et al., 2008). Pask (1976) uses the term ‘learning style’ to refer to a person’s general tendency to apply either a holist or serialist strategy. According to Lonka et al. (2004), the term ‘learning style’ used in this sense is somewhat problematic because it is close to the definition of orientation. Vermunt and van Rijswijk (1988) also use the term learning style[1] but in a broader sense than Pask (1976). In addition to the tendency to use certain learning strategies spontaneously, the broad definition includes students’ conceptions of learning and study orientations (e.g. Vermunt, 1996, 1998; Vermunt & van Rijswijk, 1988). The theory put forth by Vermunt and colleagues will be further elaborated in the next chapter.

[1] Vermunt (1996, 1998) uses the term ‘learning style’ as an encompassing concept in which four components of learning (cognitive processing of the subject matter, metacognitive regulation learning, conception of learning and learning orientation) are combined. As the term ‘learning style’ is often associated with invariant personality characteristics, he and his colleagues later changed the term to ‘learning pattern’ (Vermunt, 2005, 2007, Vermunt & Vermetten, 2004). Therefore, the term ‘learning pattern’ will be used throughout this thesis.

1.3. Learning pattern model – an attempt to capture qualitative differences in university students' learning

The historical heritage of the studies by Marton and Säljö (1976) and the approaches to learning models by Entwistle and Ramsden (1983) and Biggs (1987) also form the basis for the learning pattern model by Vermunt and colleagues, at least to a certain degree (Vanthournout et al., 2014). However, the learning pattern model also expands, refines and updates these models by integrating metacognitive regulation and learning conceptions that are not explicitly included in the original approaches to learning models (Entwistle & McCune, 2004; Vermunt & Vermetten, 2004; Vanthournout et al., 2014). The learning pattern model (originally the learning style model) was developed in the 1990s in order to formulate a comprehensive understanding of learning. The theory integrates four learning components, namely cognitive processing strategies, metacognitive regulation strategies, conceptions of learning and orientations to learning (e.g. Vermunt & van Rijswijk, 1988; Vermunt, 1996, 1998, 2007). Cognitive processing strategies refer to all the thinking activities students use to process learning contents and to attain their learning goals, whereas metacognitive regulation strategies are used to regulate and steer the learning processes. Conceptions of learning are defined as the beliefs and views people have about learning and related phenomena, such as good teaching. Last, learning orientations can be described as students' personal goals, motives, expectations, attitudes and worries about learning and studying. Each of the four learning components includes several learning dimensions. The learning components, related dimensions and their meanings are described in Table 1.

Table 1. Learning components, related dimensions and their meanings (Vanthournout et al., 2014; Vermunt, Bronkhorst & Martínez-Fernández, 2014)

Learning component	***Learning dimension***	***Meaning***
Processing strategies	Deep processing	
	- Relating and structuring	Relating elements of the subject matter to each other and to prior knowledge; structuring these elements into a whole.
	- Critical processing	Forming one's own view on the subjects that are dealt with, drawing one's conclusions, and being critical of the conclusions drawn by textbook authors and teachers.
	Stepwise processing	
	- Analyzing	Going through the subject matter in a stepwise fashion and studying the separate elements thoroughly, in detail and one by one.
	- Memorizing and rehearsing	Learning facts, definitions, lists of characteristics etc. by heart and by rehearsing them

Learning component	***Learning dimension***	***Meaning***
	Concrete processing	Concretizing and applying subject matter by connecting it to one's own experiences and by using what one learns in a course in practice.
Regulation strategies	Self-regulation	
	- Learning process and results	Regulating one's own learning processes through, for example, planning learning activities, monitoring progress, diagnosing problems, testing one's own results, adjusting and reflecting.
	- Learning content	Consulting literature and sources outside the syllabus.
	External regulation	
	- Learning process and results	Letting one's own learning processes be regulated by external sources, such as introductions, learning objectives, directions, questions or assignments of teachers or textbook authors.
	- Learning content	Testing one's learning results by external means, such as the tests, assignments and questions provided.
	Lack of regulation	Monitoring difficulties with the regulation of one's own learning processes.
Conceptions of learning	Construction of knowledge	Learning viewed as constructing one's own knowledge and insights. Most learning activities are seen as tasks of students.
	Intake of knowledge	Learning viewed as taking in knowledge provided by education through memorizing and reproducing; other learning activities are tasks of teachers.
	Use of knowledge	Learning viewed as acquiring knowledge that can be used by means of concretizing and applying. These activities are seen as tasks of both students and teachers.
	Cooperative learning	Attaching a lot of value to learning in cooperation with other students and sharing the tasks of learning with them.
	Stimulating education	Learning activities are viewed as tasks of students, but teachers and textbook authors should continuously stimulate students to use these activities.
Orientations to learning	Personally interested	Studying out of interest in the course subjects and to develop oneself as a person.
	Self-test oriented	Studying to test one's own capabilities and to prove to oneself and others that one is able to cope with the demands of higher education.

Learning component	Learning dimension	Meaning
	Certificate oriented	Striving for high study achievements; studying to pass examinations and to obtain certificates, credit points and a degree
	Vocation oriented	Studying to acquire professional skill and to obtain a(nother) job
	Ambivalent	A doubtful, uncertain attitude toward the studies, one's own capabilities, the chosen academic discipline, the type of education, etc.

The fundamental idea of learning on which the learning pattern model is based is that mental models of learning and learning orientations affect the regulation of learning, which in turn affects processing strategies (Vermunt, 1998). Thus, processing strategies lead directly to learning outcomes in terms of knowledge, understanding and skills, while regulation strategies have a more indirect effect (via processing strategies) (Vermunt, 2007). In order to test their model, Vermunt and van Rijswijk (1988) developed the Inventory of Learning Styles (ILS). The initial set of items was based on phenomenographic analyses of student interviews combined with an exploration of existing inventories and the literature on student learning which is typical of SAL models (Entwistle & McCune, 2004; Vermunt, 1996, 1998). Further, item groupings were refined through psychometric analyses. The combination of qualitative and quantitative analyses resulted in four main categories of description that represent qualitatively different learning patterns – undirected, reproduction-directed, meaning-directed and application-directed learning patterns (Vermunt, 1996, 1998). Each pattern is different from the others in four areas or components: cognitive processing, regulation of learning, mental model of learning and learning orientation (see Table 2).

Table 2. Learning patterns and their components (Vermunt, 2007; Vanthournout et al., 2014)

	Learning pattern			
Learning component	***Undirected***	***Reproduction directed***	***Meaning oriented***	***Application oriented***
Processing strategies	Hardly any processing	Stepwise processing	Deep processing	Concrete processing
Regulation strategies	Lack of regulation	External regulation	Self-regulation	Both self- and external regulation
Conceptions of learning	Cooperation and being stimulated	Intake of knowledge	Construction of knowledge	Use of knowledge
Learning orientations	Ambivalent	Certificate and self-test oriented	Personally interested	Vocation oriented

Thus, a learning pattern seems to be a coordinating concept that refers to a coherent whole of activities, study orientations and learning conceptions that is characteristic of a student in a certain period of time (Vermunt, 1996; Vermunt & van Rijswijk, 1988). However, as Vanthournout et al. (2014) point out, what constitutes that 'certain period of time' is somewhat unclear, and making hypotheses is complicated because the model incorporates more stable and more changeable components. The learning pattern model suggests that conceptions of learning and learning orientations are more stable elements in learning patterns, whereas processing and regulation strategies seem to be more dynamic in nature (e.g. Entwistle & Peterson, 2004; Vanthournout, Donche, Gijbels, & Van Petegem, 2010; Vanthournout et al., 2014; Vermetten, Lodewijks, & Vermunt, 1999; Vermetten, Vermunt, & Lodewijks, 1999). For example, Vermetten, Lodewijks, and Vermunt (1999) found variability in students' learning strategies among university courses, which indicated that the students were responding to changes in the learning environment. However, according to Vanthournout et al. (2010), some learning and regulation strategies, such as stepwise processing and especially external regulation, seem to be extremely resistant to change because they were probably developed in the early school years and have been used frequently since then (Vermetten, Vermunt, and Lodewijks, 1999). Thus, they might have become a relatively permanent part of students' learning patterns by the time they begin their higher education studies, whereas meaning-directed learning is further developed during higher education studies. To sum up, a learning pattern is not an unchangeable personality attribute but a result of the temporal interplay between personal and contextual influences (Vermunt, 1996), which is a view of learning shared by other SAL models as well (Vanthournout et al., 2014). According to Vanthournout et al. (2014), however, the learning pattern model's primary focus seems to be on more general, less context-specific preferences in learning, as opposed to approaches to learning models that are focused on the task level (Marton & Säljö, 1976) or the course level or the learning environment (Biggs, 2001; Entwistle, McCune, & Scheja, 2006).

Although the theory of learning patterns is based on the presumption that there are certain expected interrelations between mental models, learning orientations and learning strategies (Table 2), one student may manifest features in different patterns (Vermunt, 1996). When the expected interrelations do not emerge, one may speak of dissonance (see, e.g. Lindblom-Ylänne & Lonka, 2000; Meyer, 2000; Vermunt & Minnaert, 2003; Vermunt & Verloop, 2000; Vermunt & Vermetten, 2004). Previous research has shown that students with dissonant learning patterns may perform worse and be more dissatisfied with their studies than those with more coherent learning patterns (see, e.g. Beishuizen, Stoutjesdijk, & Van Putten, 1994; Lindblom-Ylänne & Lonka, 2000; Vermunt, 2007).

ILS has been used in higher education across various branches of science and around the world, such as in Europe (the Netherlands, Belgium, Finland, Norway, the United Kingdom, Cyprus and Spain), the United States, South America (Brazil, Argentina, Colombia, Mexico, Venezuela) and Asia (Indonesia, Sri Lanka, China and Thailand) (see Vermunt et al., 2014; Vermunt & Vermetten, 2004). However, longitudinal research concerning the development of learning patterns is scarce (Vanthournout et al., 2010). It seems that students' learning patterns may change and develop during higher education, mainly towards a more meaning- or application-oriented learning pattern and away from an undirected learning style (e.g. Vanthournout et al., 2010; Vermetten, Vermunt, & Lodewijks, 1999). Further, Vermunt (1996) has argued that development from external to internal regulation within a learning pattern seems to exist. Therefore, the more experienced and skilled students become in a certain learning pattern, the more they tend to execute it under internal control. Further, a certain pattern is adopted until students experience friction between the pattern and the demands of the learning environment, for example. An alternative pattern is then adopted, first under external control.

Many studies report the relationships between students' learning patterns and the learning outcomes they achieve. A shared general picture seems to emerge: meaning-directed learning mostly shows a positive relationship with exam achievements; an undirected learning pattern mostly has a negative; a reproduction-directed learning pattern has no or a negative correlation; and an application-directed learning pattern has no relationship at all (Busato, Prins, Elshout, & Hamaker, 2000; Heikkilä & Lonka, 2006; Lindblom-Ylänne & Lonka, 1999; Vermunt, 2005, 2007). A study by Lastusaari and Murtonen (2013) also shows that meaning-directed learning helps students to engage in their studies better than other learning patterns. In the next chapters, regulation and processing strategies of the learning pattern model are described in detail.

1.3.1. Regulation strategies of learning

Recently, researchers of higher education learning have recognised the importance of regulatory strategies both in higher education and working life (Gijbels, Raemdonck & Vervecken, 2010; Lonka et al., 2004). Vermunt and Verloop (1999) give two conceptualisations of different levels of specificity for the term 'regulation': it can be understood either as one type of learning activity (the others being cognitive and affective) or in the more general sense of student regulation of learning processes, which incorporates the three types of learning activities. In this thesis, regulation is understood according to the first definition, as in Vermunt's studies, to reduce the often shown overlap between categories of cognitive, affective and regulatory learning activities (see Vermunt & Verloop, 1999).

According to Vermunt and colleagues, there are three types of regulation strategies that students employ – self-regulation, external regulation and lack of regulation (e.g. Vermunt, 1996, 1998, 2007; Vermunt & van Rijswijk, 1988). According to their view, learning is self-regulated when the student him/herself guides the learning process by, for example, planning, monitoring, controlling and evaluating. The learning pattern model distinguishes between self-regulation of learning processes and results and self-regulation of the learning content. The first refers to planning processing activities, diagnosing the cause of problems in learning and directing oneself to learning objectives that one poses for him/herself, while the latter means consulting literature and sources outside the syllabus (Vermunt, 1998; Vermunt et al., 2014). In higher education settings where external support is very limited, self-regulation of learning seems to be the most appropriate strategy (Vermunt & Verloop, 1999). However, according to Vermunt and van Rijswijk (1988), fully self-regulated learning is not as common as the combination of self-regulated and teacher-regulated learning. Therefore, a certain distribution of work seems to exist between the teacher and the student regarding, for example, who monitors and evaluates the learning process. Problems arise when the teacher's and the student's expectations of these responsibilities are divergent (Vermunt & van Rijswijk, 1988; Vermunt & Verloop, 1999).

The opposite of the self-regulation of learning seems to be external regulation, which refers to the regulation of learning by teachers, study materials or other aspects of the learning environment (e.g. Vermunt & van Rijswijk, 1988; Vermunt, 1996, 1998, 2007). In external regulation, the responsibility for learning is therefore given to the teacher, who plans, sets goals, evaluates, etc. External regulation can also be divided into two separate dimensions: external regulation of the learning process, which means that students let themselves be directed by the regulation sources supplied by instruction, such as learning objectives, directions and assignments, and the external regulation of learning results, which refers to testing and evaluating one's learning results by doing the questions, tasks and tests offered by instruction (Vermunt, 1996; Vermunt et al., 2014).

A third dimension of regulation strategies is called lack of regulation, which means that neither the student nor the teacher or the students together regulate the learning process (e.g. Vermunt, 1996, 1998, 2007; Vermunt & van Rijswijk, 1988). Students who experience lack of regulation notice that they have problems learning but do not know how to do it differently and better, and they have difficulty in evaluating whether they have mastered certain content. Typical of this regulation strategy is that students strongly direct themselves toward the regulation as supplied by the instruction, but they find it is not enough to support the regulation of their learning (Vermunt, 1996).

1.3.2. Processing strategies of learning

Vermunt and colleagues (e.g. Vermunt, 1996, 1998; Vermunt & van Rijswijk, 1988; Vermunt & Verloop, 1999) also distinguish different types of cognitive processing activities, by which they mean those thinking activities that students use to process the subject matter. These activities lead directly to learning results in terms of changes in student's knowledge base, understanding, skill, etc. Examples of different processing activities are relating, that is, looking for relationships among parts of the subject matter or between new information and prior knowledge; memorising, that is, imprinting separate information by rehearsing it numerous times and selecting, which refers to distinguishing between main and minor points of the subject matter and reducing large amounts of information to the most essential parts (e.g. Vermunt, 1996; Vermunt & van Rijswijk, 1988; Vermunt & Verloop, 1999). These separate activities usually tend to emerge in certain combinations, which form the processing strategies (Vermunt, 1996; Vermunt & Verloop, 1999).

According to Vermunt and colleagues (e.g. Vermunt, 1996; 2007; Vermunt & Verloop, 1999), the main categories of processing strategies are deep, stepwise and concrete processing. Deep processing is further characterised by separate dimensions of relating and structuring, that is, relating parts of the subject matter to each other and to prior knowledge and structuring separate elements into coherent wholes and critical processing, which refers to forming one's own views and conclusions about the subjects that are dealt with and being critical of the conclusions presented by teachers or textbook authors (Vermunt et al., 2014). Stepwise processing, in turn, can be described as going through the material in detail, analytically and by heart. Therefore, it is characterised by memorising, rehearsing and analysing. The third strategy, concrete processing, refers to dealing with the subject matter in a very concrete way, such as forming concrete images with abstract material and thinking about how the subject matter could be applied in practice (Vermunt, 2007).

1.4. Other models of self-regulated learning

As the ability to self-regulate learning has intrigued researchers for decades, several models dealing with the phenomenon have been proposed in addition to that of Vermunt. In this chapter, two of these models (Pintrich, 2000, 2004; Zimmerman, 1989, 2000) and their differences are briefly compared to Vermunt's model.

Zimmerman (e.g. 1989, 2000) proposes a social cognitive perspective (Bandura, 1986) of self-regulated academic learning in which self-regulation is seen as an interaction of personal, behavioural and environmental triadic processes. This view differs radically from theoretical traditions that attempt to define self-regulation as a singular internal state, trait or phase that is either genetically endowed or personally discovered. Instead, self-regulation is seen as comprising context-specific processes that are used cyclically to reach personal goals. Besides metacognitive knowledge and skill, these processes require affective and behavioural processes and a sense of self-efficacy to control them. Therefore, the emphasis on personal agency differs from purely metacognitive views of self-regulation in which only knowledge states and deductive reasoning are highlighted in choosing cognitive strategies, for instance. Within the social cognitive model, self-regulatory processes and beliefs are described using three cyclical sequential phases – forethought, performance or volitional control and self-reflection (Zimmerman, 2000).

Another fairly well-known model of self-regulated learning is that put forth by Pintrich (e.g. 2000, 2004; see also Schunk, 2005), which can also be thought of as a social-cognitive framework. His model suggests four phases of self-regulation –

forethought, planning, and activation; monitoring, control and reaction and reflection. Each of these phases includes four possible areas of self-regulation – cognition, motivation, behaviour and context. The phases are not linearly ordered but may occur at any time during task engagement. Further, they are interactive in that individuals may simultaneously engage in more than one. In the model, a possible range of activities is described, but these are not required. The idea behind Pintrich's model is that self-regulatory activities mediate the relationship between learners and their environments and influence their achievements (Pintrich, 2000). The essential element in Pintrich's model is the emphasis of motivation as a key factor in self-regulation, meaning that besides it is a separate area of self-regulation, it is intertwined in all the phases. This characteristic distinguishes the model from many other self-regulation models that emphasise cognitive or behavioural factors.

In contrast to Vermunt's model, the above models represent the North American tradition referred to as the IP or SRL perspective (Pintrich, 2004). They seem to highlight the environmental and motivational aspects in self-regulated learning more than the learning pattern model. Vermunt views the regulation of learning solely as a metacognitive learning activity, as opposed to more general views that incorporate cognitive, affective and regulatory learning activities (Vermunt & Verloop, 1999). However, the focus of the presented models is exclusively on self-regulated learning, whereas Vermunt's model concentrates more on general preferences of learning, in which the regulation of learning is only one dimension. Further, Vermunt brings in his model other aspects of regulation besides self-regulation, namely the dimensions of external regulation and lack of regulation. Thus, as the focus of the thesis was on regulation of learning and not solely on self-regulated learning, Vermunt's model was considered the most appropriate. Furthermore, the European context of the model was considered as an asset.

1.5. Text processing and science understanding

Learning complex science concepts requires self-regulation of learning and high-level text processing skills. It is a widely shared view that learners even in higher education often hold deeply rooted conceptions that are inconsistent with accepted scientific notions. In particular, many concepts of biology and the natural world are constructed early on, based on everyday experiences and spontaneous knowledge acquisition (Vosniadou, 1994). These concepts form naïve theories that are often narrow and rather superficial but offer a relatively coherent explanatory structure that may have been adequate or even productive at an earlier point in students' learning (Vosniadou, 1994; Kaufman et al., 2008). However, when new information does not fit into existing knowledge, that is, when the learner has misconceptions, learning can be very complex (Broughton, Sinatra, & Reynolds, 2010; Chinn & Brewer, 1993; Chinn & Malhotra, 2002; Sinatra & Mason, 2008; Murtonen, 2015; Murtonen & Nokkala; Nokkala & Murtonen, 2013). Therefore, learning complex scientific phenomena often seems to require conceptual change, a process in which learners reorganise their cognitive structures according to scientific notions and abandon their misconceptions derived from everyday life (Duit & Treagust, 2003; Vosniadou, 1994; Vosniadou, Ioannides, Dimitrakopoulou, & Papadimetriou, 2001). Conceptual change is achieved through either enrichment or revision. Enrichment involves adding information to existing conceptual structures, while revision usually involves changing individual beliefs or the relational structure of a theory (Vosniadou, 1994). However, the problem with misconceptions is that they seem to be very resistant to change (Chi, 2005; Chinn & Brewer, 1993). Further, even though a learner might undergo a process of conceptual change, the result may not always be permanent but temporary or even too tenuous to detect (e.g. Broughton et al., 2010; Duit & Treagust, 2003).

1.5.1. The possibilities of text in promoting science understanding

Different text designs have been successfully used to support the construction of a coherent understanding from text and thus conceptual change (e.g. Brouhgton et al., 2010; Hynd, 2001; Mikkilä-Erdmann, 2001, 2002; Södervik, Virtanen, & Mikkilä-Erdmann, 2015). Traditionally, expository texts have been the primary method of instruction across curriculum contexts. Despite their wide usage and popularity, researchers have criticised the organisation and lack of explanatory coherence of expository texts (see, e.g. Beck, McKeown, Sinatra, & Loxterman, 1991; Mikkilä-Erdmann, 2002).

According to Hynd (2001), a refutational text might be superior when conceptual change is the aim because the objective of the text is to persuade the reader to change his or her existing beliefs according to the new information by showing that it is useful and believable. A typical characteristic of a refutational text is that it introduces a common theory or belief, refutes it and then offers an alternative theory, a scientific view that is shown to be more satisfactory (Hynd, 2001; Limón, 2003). Thus, a refutational text aims to bring about a condition of meaningful cognitive dissonance, whereby the person recognises that the new information is in conflict with what one currently believes (Posner, Strike, Hewson, & Gertzog, 1982). However, the new information should exist in many forms and be credible and unambiguous in order to be better accepted and thus allow conceptual change to occur (Chinn & Brewer, 1993). Getting students to give up their intuitive notions in favour of current scientific views takes a lot of persuasion, which refutational text can offer. Hynd (2001) suggests that the persuasive power of a written argument compared to an oral one may be rooted in two factors: first, students may believe that what is written is true, and second, they may review the written arguments. Broughton et al. (2010) further hypothesise that the refutation effect may result from a reader's co-activation (simultaneous activation of prior and new conceptions) and integration of prior conceptions with the new information or from increasing the learner's engagement with the text (Dole & Sinatra, 1998).

1.5.2. Eye tracking method in text processing

Reading is a complex process that requires visual, attentional, language-related and oculomotor processing (Kliegl, Nuthmann, & Engbert, 2006). The tradition of using the eye tracking method in research on reading is long, and reading different texts has been studied from various perspectives, such as a reading strategy perspective (e.g. Goldman & Saul, 1990; Hyönä, Lorch, & Kaakinen, 2002; Hyönä & Nurminen, 2006) and text structure and characteristics effects on reading (e.g. Hyönä & Niemi, 1990; Klusewitz & Lorch, 2000; Vauras, Hyönä, & Niemi, 1992; Wiley & Rayner, 2000). Recording readers' eye movements is very appropriate in studying spontaneous reading strategies, as eye movements are a necessary and integral part of normal reading. This technique allows readers to freely inspect the text the way they want (e.g. Hyönä & Nurminen, 2006; Rayner, 1998). During reading, the eyes move constantly in a sequence of rapid saccades and fixations, during which the eyes remain relatively still (e.g. Holmqvist et al., 2011; Kliegl et al., 2006; Rayner, 1998). The intake of information is believed to happen largely during fixations, whereas saccades bring the centre of the eyes to new locations (Hyönä, 2010; Rayner, 1998).

Currently, human eye movements are used to index ongoing mental processes while people interact with visual environments, such as texts, illustrations or animations. Researchers have accepted the so-called eye–mind hypothesis (Just & Carpenter, 1980), according to which there is a close connection between the direction of human gaze and the focus of attention. They share the assumption that people attend to and process the visual information they are currently looking at if it is relevant to the task at hand (Hyönä, 2010). However, alternative views have been suggested. For example, a study by Kliegl et al. (2006) demonstrated that the mind might process several words parallel at different perceptual and cognitive levels. Therefore, the mind can be ahead of the eyes at the fixation location and lag behind cognitively (cf. Rayner, 1977, 1978).

Further, the effects of expertise have been one of the focuses of eye tracking research but mostly with visual material as stimulus. Previous research has demonstrated that attention allocation is often influenced by expertise: the more experienced the participants are with the material at hand, the more and the faster they seem to fixate on task-relevant information (Reingold & Sheridan, 2011; van Gog & Scheiter, 2010). Differences have been observed between experts and novices (Charness, Reingold, Pomplum, & Stampe, 2001), between individuals with smaller differences in expertise (van Gog, Paas, & Merriënboer, 2005) and even within individuals over time as an outcome of practice (Haider & Frensch, 1999). With the help of eye movements it is possible to not only study learning processes but to help improve the design of learning materials and processes (van Gog & Scheiter, 2010).

2. AIMS

The purpose of the thesis was to study the regulation of learning and text processing in the two programmes of medical and teacher education, which share the features of highly scheduled study and a complex relationship between theory and practice. The five studies that comprise the empirical part of this dissertation explore studying in higher education with respect to regulation and processing strategies. Studies I–III focus on the regulation of learning, Study IV focuses on both the regulation and processing strategies of learning and Study V focuses on text processing at a behavioural level utilising the process measures in eye tracking methodology. The specific aims of the five studies were as follows:

1) The aim of Study I was to investigate the relationships between students' general study orientations and their ways of regulating learning.
2) Study II examined first year medical and dental students' regulation of learning and their conceptions of the learning environment, which includes traditional lectures and small group study sessions based on problem-based learning (PBL).
3) The purpose of Study III was to discover what kind of regulation strategy profiles can be discerned among medical students across time and to what extent these profiles predict study success in preclinical studies. In addition, the function of the regulation scales was examined in a medical education context.
4) Study IV aimed at investigating the role of regulation and processing strategies in understanding science text. Additionally, the role of different text types in constructing understanding of a complex science phenomenon was examined.
5) The aim of Study V was to use eye tracking methodology to investigate how medical students and residents read and solve a patient case text.

Thus, the regulation of learning and text processing were studied in various learning environments and at different levels using both self-test surveys and process and performance measures. The study design is shown in Figure 1.

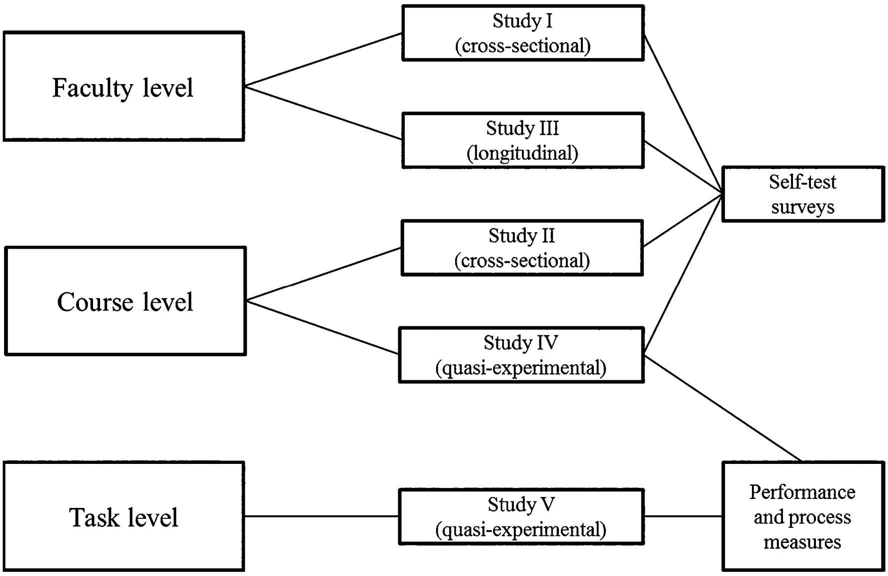

Figure 1. Framework of the study

3. METHODS

3.1. Participants

The participants in the studies were Finnish university students. Participation was voluntary and informed consent was obtained. The data were collected between 2009 and 2012.

The participants in Study I consisted of 410 second-, fourth- and sixth-year medical students at two Finnish universities. The participants in Study II consisted of 153 medical and dental first-year students, and the participants in Study III consisted of 162 medical and dental students who were followed during their first three years in medical school. A total of 91 second-year student teachers took part in study IV. The participants in Study V consisted of 39 third-year medical students and 13 internal medicine residents.

3.2. Materials, data collection procedures and analyses

The empirical studies in this dissertation are based on five different data sets. Table 3 summarises the methods used in each study. Study I and Study II used traditional self-test surveys with cross-sectional student samples. The data from these two studies were analysed using basic statistical methods, such as principal component analyses and correlation tests. The data in Study III was also collected via a questionnaire, but a longitudinal design was used by following up the same students throughout the first three years of medical school. Additionally, latent profile analysis was used to explore a person-centred approach to study regulation strategies, in contrast to Study I and Study II that focused on a more traditional, variable-centred approach. In Study IV, a self-test survey was enriched by a quasi-experimental pre-test/post-test design using two different science texts. The materials in Study V consisted of two texts, but the measurements were completed using the eye tracking methodology and analyses were carried out using non-parametric statistical tests appropriate for non-normally distributed data. The methods used in the empirical studies are described in more detail in Chapter 4.

Table 3. Summary of methods

Study	Participants	Materials and data collection methods	Analyses
Study I	Second-, fourth- and sixth-year medical students, *n* = 410	Inventory of Learning Styles (ILS, 28 items concerning the regulation of learning) Inventory of General Study Orientations (IGSO)	Principal component analysis (PCA), correlation analysis, independent samples t-tests, one-way ANOVAs
Study II	First-year medical and dental students, *n* = 153	ILS (28 items concerning the regulation of learning) Questions concerning learning environment and PBL study sessions	PCA, correlation analysis
Study III	The same cohort of medical and dental students, *n* = 162 (followed up in 2009, 2010 and 2011)	ILS (28 items concerning the regulation of learning)	Confirmatory factor analysis (CFA), latent profile analysis (LPA), one-way ANOVA
Study IV	Second-year student teachers, *n* = 91	Pre-test/post-test (open-ended questions concerning photosynthesis) An exploratory vs. refutational text about photosynthesis ILS (28 items concerning the regulation of learning, 20 items concerning processing strategies)	PCA, K means cluster analysis, independent samples t-tests, repeated measures ANOVA
Study V	Third-year medical students, *n* = 39; internal medicine residents, *n* = 13	Patient case texts Eye tracking measures	Mann–Whitney U tests, Friedman tests, Wilcoxon signed rank tests

4. OVERVIEW OF THE EMPIRICAL STUDIES

4.1. Study I

Olkinuora, E., Virtanen, H., & Mikkilä-Erdmann, M. (2010). Regulation of learning and study orientations of medical students. *Procedia Social and Behavioral Sciences, 2*, 3850–3856.

University students are often seen as a homogenous population with the same goals and converging motivations, but actually their motivational patterns may vary, even among students within the same faculty or study programme. Study orientations refer to values, interests and feelings that determine the significance of one's studies. It has been shown that study orientations or other constructs measuring similar aspects of motivation are related to the ways students approach specific learning tasks and studying during longer periods. Because of the rich research tradition on student learning, there has been confusion about what has actually been measured and at which level. It is argued that differentiated measuring of general study orientations directed at studies as a whole would be useful background information when monitoring the progress of degree studies.

The aim of this study was to examine the connections between medical students' general study orientations and the ways they regulate their learning. A total of 410 second- (n = 169), fourth- (n = 181) and sixth- (n = 60) year medical students at two Finnish medical schools participated in the study. They answered a questionnaire consisting of background information questions, 28 regulation strategy items (ILS; Vermunt, 1998) and 39 items measuring general study orientations (IGSO; Mäkinen, 2003; Mäkinen & Olkinuora, 2004). PCAs with Varimax rotation were used separately to regulation items and general study orientation items. Based on PCAs, sum scales of regulation strategies and study orientations were formed. Data was further analysed with t-tests, analyses of variances and correlation tests.

According to the results, medical students are strongly deep-oriented, that is, they strive to understand the subject matter holistically and study for personal development. Further, they expressed work–life orientation and reported interest in courses related to work life. However, the most common regulation strategy was external regulation, which means that medical students let the teachers and learning materials guide their learning. We argue that they might use external regulation as a coping strategy in the cognitively loaded medical curriculum. Several reasonable correlations between general study orientations and regulation strategies were found. Lack of regulation was positively correlated with social and non-commitment orientation and was negatively correlated with deep and work–life orientation. Further, both types of self-regulation were correlated positively with deep orientation and negatively correlated with non-commitment. Interestingly, external regulation was also positively correlated with deep and achievement orientation, as well as with surface-systematic orientation. Older students reported more self-regulation of the learning contents and work–life orientation, which might indicate that students' anticipation of work life directs their studying.

4.2. Study II

Virtanen, H., Mikkilä-Erdmann, M., Murtonen, M., & Kääpä, P. (2010). Lääketieteen ja hammas-lääketieteen ensimmäisen vuoden opiskelijat oppimisensa säätelijöinä [Medical and dental first-year students as regulators of their learning]. *Peda-forum – yliopistopedagoginen aikakausjulkaisu, 17*(1), 6–17.

Becoming a medical expert requires the ability to work with increasing amounts of information that is constantly changing. One of the skills determining expertise is the ability of self-regulation, which helps in guiding one's own performance and adjusting to variable situations. Self-regulation of learning can also be seen as a prerequisite of high-quality learning. Therefore, developing self-regulation skills and growing into professional learners from the beginning of medical school is considered important. One of the solutions to support learning of complex medical contents has been curricular changes from traditional, lecture-based curriculums – which are clearly divided into preclinical, theoretic and clinical phases – to more innovative, PBL curriculums in which scientific concepts and practice are directly integrated. The aim of the study was to investigate medical students' regulation of learning and conceptions of the learning environment in a course, which, in addition to lectures, included PBL group work sessions, exercises and self-directed studying.

The study data were collected from first-year medical and dental students ($N = 153$) at a Finnish university. The participants answered a questionnaire consisting of background information questions, regulation strategy items (28, ILS; Vermunt, 1998), and items concerning the learning environment during their last PBL group session (33). Students' study success in the course was measured by the exam score. The data were analysed with PCAs that were conducted separately for regulation items and PBL items. Connections between regulation strategies, conceptions of PBL group work and exam scores were examined using correlation analyses.

The results show that first-year medical and dental students mostly relied on external support, such as the teacher and the learning materials, in their regulation of learning. However, they also showed almost as much self-regulation of learning contents. Manifestation of external regulation might be explained by students' earlier studies; perhaps they were used to regulating their learning externally in secondary education, which tends to be more teacher-centred than higher education. Or, as in Study I, external regulation might work as an effective coping strategy in the cognitively loaded curriculum. However, sub-types of self-regulation (i.e. self-regulation of learning processes and outcomes and self-regulation of learning contents) were correlated with study success, which is in accordance with previous studies. Therefore, it is argued that integrating learning skills into course contents early on, when the students are confronted with the cognitive challenges of medical school, would be reasonable.

When the students evaluated the learning environment, they considered traditional lectures and demonstrations more useful than PBL, and they were not very pleased with PBL. However, they felt quite positive about the group and the teacher/tutor. Working in small groups is more demanding than listening to a lecture, and it often requires preparation. As strictly organised PBL seems to divide the students, developers of teaching curriculum are challenged to think of new solutions. To overcome the cognitive overload of medical curriculum, it is important to develop modes of learning that enable reflection of one's own learning and thus increase the development of self-regulation.

4.3. Study III

Vilppu, H., Laakkonen, E., Mikkilä-Erdmann, M., & Kääpä, P. (submitted). Seeing beyond variables: Applying a person-centered approach to identifying regulation strategy profiles – a case of medicine.

The increasing amount of medical knowledge, the fast pace of studies and the accompanying stress make studying medicine demanding for many students. To cope with these and other challenges the medical curriculum poses, students must be able to regulate their learning effectively by planning, monitoring, evaluating and taking responsibility for their learning. Most studies about learning strategies focus on variables; therefore, in this study latent profile analyses (LPAs) were used to explore a person-centred approach to the regulation strategies of learning. The aim of the study was to investigate how medical and dental students regulated their learning during the first three years of medical school and how this was connected with study success.

Medical and dental students (N = 162) at a Finnish university completed the regulation strategy scale consisting of 28 items (ILS; Vermunt, 1998) during each of their three first years in medical school. As slight changes had been made to the original scale, the items were first validated with CFA in the Finnish medical school context. Based on the analysis, sum scales were formed and test-retest reliabilities were determined. In order to identify different subgroups of students with different regulation strategy profiles, LPA was used. Students' study success was measured with a general performance assessment (GPA) score in preclinical studies. Last, the connections between regulation strategies and study success were examined using a one-way ANOVA with post hoc comparisons.

The analyses yielded a three-factor model that included two subscales of self-regulation and one subscale of lack of regulation, and the reliability of the scales was verified across time. Four profiles of regulation scales were found. The group of students with low self-regulation and average to a high lack of regulation performed worse in their studies than the other student groups. To conclude, the study lends support to the validity of the regulation scale in medical education. Further, it reveals that even in such a homogenous sample, there are different regulation strategy profiles among high-achieving medical students. The person-centred approach used in the study could be used as a tool for student counselling to support learning, as it enables the identification of individual students with different regulation patterns that reflect study success.

4.4. Study IV

Vilppu, H., Mikkilä-Erdmann, M., & Ahopelto, I. (2013). The role of regulation strategies in understanding science text among university students. *Scandinavian Journal of Educational Research, 57*(3), 246–262.

Learning can be very complicated if new information does not fit into existing knowledge, that is, if the student has misconceptions about a certain topic. Many concepts of biology and the natural world, such as photosynthesis, are constructed early on based on everyday experiences and thus might be in conflict with the information presented through instruction. Therefore, learning complex scientific phenomena often requires conceptual change, a process whereby learners reorganise their cognitive structures according to the scientific explanations and abandon their misconceptions. Textbooks seem to play a crucial role in science teaching, and therefore the quality of text might support students' conceptual change. In particular, refutational text that encourages the reader to change his/her existing beliefs according to the scientific ones has shown to be effective. Further, self-regulation and other individual characteristics might play an important role in high-level learning, such as conceptual change. The aim of the study was to examine the role of processing and regulation strategies on the one hand and the role of refutational vs. expository science text on the other in understanding science text.

A total of 91 second-year student teachers at a Finnish university participated in the study. The study was based on a quasi-experimental pre- and post-test design and was carried out during two seminars. In the first seminar, the students answered open-ended questions about photosynthesis (pre-test), read either a refutational or an expository science text about photosynthesis (intervention) and answered the same open-ended questions again (post-test). In the next seminar, the students answered 20 items concerning their processing and 28 items concerning their regulation strategies (ILS; Vermunt, 1998) and were also given feedback about their answers about photosynthesis in the previous seminar. The answers to the open-ended questions were scored with the help of a mind map-like analysis tool in which several links highlighted the central concepts of photosynthesis. PCAs were separately applied to regulation and processing strategy items, and sum scales were formed. *K*-means clustering was used to sum scales, producing a two-cluster model that divided the students into reproductive and support-dependent learners and deep and independent learners.

The results showed that the understanding of photosynthesis was relatively poor in the pre-test but improved after the text reading intervention. Deep and independent learners had a better understanding of photosynthesis both before and after the text reading than the reproductive and support-dependent learners. However, the latter group improved their scores more. Additionally, refutational text promoted understanding of the phenomenon better than the traditional expository text. A weak trend showing that reproductive and support-dependent learners would benefit more from the refutational than the traditional text was found. A worrying group of students was formed by those reproductive and support-dependent students who read the expository text because they got lower scores than the other groups. It is argued that learners with effective learning strategies might be able to pick out the relevant content from any kind of text, whereas weaker learners could benefit from refutational parts that help them to focus on the important content.

4.5. Study V

Vilppu, H., Södervik, I., Österholm-Matikainen, E., & Mikkilä-Erdmann, M. (under review). Exploring eye movements of experienced and novice readers of medical texts concerning the central cardiovascular system for finding the right diagnosis.

Working with different kinds of texts, such as medical records and referrals, is an essential element in a doctor's practice. Therefore, text processing and learning from texts can be seen as valuable skills in present-day medical practice. Although several studies on medical text reading have been conducted, those that integrate eye tracking seem to be scarce. Eye tracking has been used in medical education for years but mostly in studies concerning medical image perception. Eye tracking research has demonstrated expertise effects, according to which attention allocation is often influenced by the level of expertise. Experts seem to be capable of global processing; they fixate on relevant parts of the image faster and spend more time looking at them than novices. Experts seem to outperform novices cognitively as well, which is evidenced by various studies on medical problem solving. One explanation for novice vs. expert differences in problem-solving is offered by encapsulation theory, according to which biomedical knowledge encapsulates into illness scripts that are used in expert problem solving. Thus the lines of reasoning are gradually getting shorter, and solving routine cases will become faster. The aim of the study was to use the eye tracking method to examine how medical students and residents read and solve a patient case text.

The study participants were 39 third-year medical students and 13 internal medicine residents who read two patient case texts concerning cardiovascular medicine from a computer screen into which the eye tracker was integrated. The texts were divided into three slides (medical history, status and laboratory results) to simulate the phases of a patient encounter. The participants were supposed to read each slide and give a diagnosis after reading. The texts contained both task-relevant and task-redundant information. The given diagnosis, processing time per slide and the number of fixations and average fixation duration in task-relevant vs. task-redundant areas of the text were analysed.

Almost all the participants solved the first patient case, and the second case was diagnosed correctly by all the residents but only 17 of the students. The residents processed the texts remarkably faster than the students and with a lower number of fixations on both task-relevant and task-redundant areas of the texts. Therefore, compared to students, they need less time to produce accurate diagnoses. Interestingly, students and residents demonstrated different reading patterns. For the residents, reaching a decision about the diagnosis seemed to reduce the reading time of the forthcoming slides, whereas the students increased their reading time in both cases towards the end of the case. The results of residents' efficiency in problem solving are supported by both visual and cognitive expertise literature. For example, shorter overall viewing times and time on task have been reported in earlier studies. Further, residents' knowledge structures might be encapsulated, enabling faster reasoning and problem solving. The observed differences between medical students and residents could be used in medical education to model expert reasoning and to teach how a good medical text is constructed. Eye tracking seems to have great potential in evaluating performance and growing diagnostic expertise in medical text processing, although more research using texts as stimulus is needed.

5. DISCUSSION

5.1. High-achieving university students represent diverse regulation and processing strategies

The aim of the present work has been to explore the regulation of learning and text processing among university students studying medicine and education by using multiple methods and by integrating both cross-sectional and longitudinal data. The results show that even among relatively homogenous student groups, such as high-achieving university students, there are differences in both the regulation and processing of learning. Both medical school and teacher education students are admitted based on very selective entrance exams[2], but there still seems to be variability in terms of the regulation strategies of learning and text processing. Therefore, students enter these educational programmes with different chances of managing and achieving success. Both programmes and professions are challenging in terms of their multidisciplinary nature and constantly changing information; therefore, good lifelong learning skills are required during the study period and in work life.

In Study I and Study II, the most common regulatory strategy among medical students was external regulation. This was somewhat surprising considering that the participants were high-achieving university students. It is argued that external regulation might function as an effective coping strategy in the cognitively loaded curriculum; for example, one uses the ‘hints’ given by the teachers, learning materials or other students to conclude what is important. According to Lonka et al. (2004), only the deep approach can be seen as ‘natural’, as the others (the surface and achieving approaches) are likely to be created by the learning environment, such as assessment practices (see Ramsden, 1988). Therefore, external regulation, which is often associated with the surface approach, could rather be created by the study environment – either the current one or a previous one. At the beginning of university studies, the previous and usually more teacher-centred upper secondary school environment might still have a strong influence on students’ study strategies (Vermunt, 1996). This might explain the fact that external regulation was common among the first-year medical and dental students.

The term external regulation and the definition given by Vermunt seem to come somewhat close to ‘other-regulation’, a kind of asymmetric interaction between partners (Whitebread, Bingham, Grau, Pino Pasternack, & Sangster, 2007; Whitebread et al., 2009). Other-regulation refers to the idea that an individual’s learning is fostered by the activity of the supportive other (see Brown, Bransford, Ferrara, & Campione, 1983), which may be a more capable adult, a peer or some other source, such as technology (see Iiskala, 2015). Strategic help seeking might also be seen as an element of self-regulated

[2] In Finland, the teaching profession is a very popular goal among young people. Therefore, to become a class teacher one must pass an extremely selective entrance exam. As a result, fewer than 10% of the applicants are admitted. Later, they will graduate as Masters of Education. Medical students are also accepted only after passing a demanding entrance exam. Approximately 15% of applicants are admitted to medical school.

learning. According to Schunk (2005), good self-regulators seek help selectively from an appropriate source they believe will be helpful in order to understand a particular point. Further, Zimmerman (2008) sees self-regulated learning as an important aspect in social forms of learning, such as help seeking from others. What makes help seeking a part of self-regulated behaviour is that the learner displays proactive qualities, such as personal initiative, perseverance and adaptive skill.

In Study I, interestingly, older students showed more self-regulation of learning contents, whereas younger students scored higher in self-regulation of the learning processes and results. Although the cross-sectional sample does not allow making conclusions about the development of these strategies, it could be suggested that medical students learn to regulate the materials effectively during medical school: they learn to know where to get relevant information and actively use other sources in addition to course books. It is common for students at Finnish medical schools to use resources available on the Internet, such as Terveysportti[3] and PubMed[4].

Several theoretically consistent connections were also found between regulation strategies and general study orientations in Study I. Both self-regulation dimensions were positively correlated with deep orientation and negatively correlated with non-commitment. External regulation was positively correlated with deep orientation, achievement orientation and surface-systematic orientation. Regarding lack of regulation, it was positively linked with social and non-commitment orientation and negatively associated with deep and achievement orientation. In the longitudinal study (Study III), four distinct student profiles of regulation were found: high self-regulation – average lack of regulation; average self-regulation – low lack of regulation; low self-regulation – average lack of regulation and low self-regulation – high lack of regulation.

Although external regulation was highly represented in Study I and Study II, it had to be left out in the longitudinal study with medical students (Study III). Problems with the scale have also emerged in other studies; for example, a comparative study using ILS in different cultures indicated less internal consistency in external regulation subscales compared to other scales (Vermunt et al., 2014), and a longitudinal study with medical students using ILS had to omit the external regulation scale because of low reliability or variability (Van der Veken, Valcke, De Maeseneer, & Derese, 2009). One of the reasons for omitting the external regulation scale in Study III might be that a modified and shortened version of the ILS regulation scale was used because many of the items did not really fit the context of Finnish medical education, especially the preclinical phase (e.g. teachers do not give any assignments or exercises, there are seldom any self-tests in text books, etc.) (see Vermunt, 1998). However, a separate dimension of external regulation was not found in Study IV with student teachers, even though the original 28-

[3] A web-based service that integrates several databases for students and professionals in health-care. The service is administered by Duodecim Medical Publications Ltd. which carries out the Finnish Medical Society Duodecim's mission to publish medical information. (Suomalainen Lääkäriseura Duodecim, 2014) http://www.duodecim.fi/web/english/home
[4] A database that incorporates citations and abstracts for biomedical literature from MEDLINE and additional life science journals administered by National Center for Biotechnology Information (NCBI). http://www.ncbi.nlm.nih.gov/pubmed

item regulation scale was used. This might be because the items determining external regulation did not fit Finnish teacher education well. Therefore, it is suggested that we need more domain-specific measurement of learning, which would truly serve the needs of students and of student counselling for instance.

Nevertheless, other regulatory strategies in addition to external regulation were found in all the samples. In both Study I and Study II, the students scored high in self-regulation of the learning contents, which indicates that they used other material in addition to that in the curriculum to get more information about the subject. In Study IV, however, the students scored higher on self-regulation of learning processes and results than on the learning content. The student teachers seemed to plan and evaluate their studying but were not as used to regulating the learning materials. It is not that common to use Internet databases in teacher education compared to medical school.

5.2. Learning strategies are related to study success

Previous studies about students' learning strategies have shown that learning strategies are related to academic achievement (Donche, Coertjens, van Daal, De Maeyer, & Van Petegem, 2014; Dinsmore & Alexander, 2012; Vermunt, 2005; Vermunt & Vermetten, 2004). Therefore, in Study II, Study III and Study IV, learning strategies were examined in relation to study success, which was measured either with success in a specific task (Study IV), course (Study II) or with a more general performance score (Study III). In Study II, students also gave self-evaluations about how well they had learned the course content.

It is a common theoretical assumption that deep and surface learning strategies lead to higher and lower achievement, respectively (Marton & Säljö, 1976). However, according to results from empirical studies, often only positive and weak to moderate correlations between deep processing and academic achievement are shown (e.g. Richardson, Abraham, & Bond, 2012; Vermunt, 2005). Several studies demonstrate only a very weak or no negative relationship between surface processing and academic achievement (Vermunt, 2005). Additionally, both self-regulation and external regulation have been associated with higher achievement (Vermunt, 2005). One aspect that affects the relationship between learning strategies and academic achievement is the way in which learning is assessed. When learning is measured based on course grades, surface learning strategies might lead to good grades, if reproducing acquired knowledge is weighted in the assessment. For example, in traditional, reproduction-oriented instruction, students are encouraged merely to memorise information and reproduce it in examinations (Tynjälä & Gijbels, 2012). Therefore, other measures of study success besides course grades, such as portfolio or process evaluation tools, are needed. However, in teaching practices these might be difficult to realise in mass courses with cohorts of over 100 students.

In Study II with first-year medical and dental students, self-regulation of learning processes and results was weakly positively correlated with students' self-evaluations of having learned the course content and the exam scores. Self-regulation of learning content had the same correlations, but the correlation with students' experiences of learning was stronger. Additionally, lack of regulation was positively correlated with students' insecurity about whether they had learned the contents of the course. Previous research has indicated that university students may experience difficulty in regulating learning, particularly at the beginning of their studies when they first encounter the new learning environment (Heikkilä, Lonka, Nieminen, & Niemivirta, 2012). Further, the findings of De Clercq, Galand, and Frenay (2014) suggest that self-regulation might play an important role in explaining study success, especially at the beginning of studies when students have to adapt to a new learning context and new learning tasks.

The ways in which students engage in learning can seldom be characterised by a single approach or strategy (Donche & Van Petegem, 2009). Therefore, they do not learn in purely a deep or surface manner but often combine several learning strategies taken from various approaches but to different degrees. This is shown in Studies I–IV but most clearly in Study III and Study IV, where the students were grouped according to their regulation strategies (and processing strategies in Study IV). In Study III, the student group with low self-regulation and average to high lack of regulation had a poorer general performance score than the other groups. Thus, it seemed to be the combination of low self-regulation and average to high lack of regulation that differentiated this group from the others. An unregulated learning strategy or non-academic orientation has been constantly associated with lower academic achievement (e.g. Busato et al., 2000; Entwistle & Ramsden, 1983; Vermunt, 2005). In Study IV, students with high self-regulation and deep processing achieved the highest scores on the test about understanding photosynthesis. The finding is in line with other studies that show a positive correlation between meaning-oriented learning, a combination of self-regulation and deep information processing, and study success (e.g. Lindblom-Ylänne & Lonka, 1999). Further, a weak trend was found showing that students with high lack of regulation and a tendency toward stepwise processing would benefit more from a scientific text that persuades the reader to change his or her ideas by showing how plausible the new information is compared to traditional, expository text. Those with high self-regulation and a deep processing strategy seem to succeed regardless of the text type. However, more research is needed concerning the interaction effects between learning strategies and text types. To sum up, it seems that self-regulation is important for study success as defined by high grades, but when looking at dropping out or acquiring credits, lack of regulation might have more predictive power. Therefore, both meaning-directed and unregulated learning can predict academic achievement (Donche et al., 2014).

As seen in Study III, each student represents a rather unique learning profile that can be identified by applying a person-centred approach (as opposed to a variable-oriented approach) (e.g. Heikkilä et al., 2012; Räisänen, Postareff & Lindblom-Ylänne, in press;

Vanthournout et al., 2014). Consequently, the same students might express both self-regulation and external regulation, for instance, and still have a meaning-directed learning pattern (Vermunt et al., 2014, p. 50). This might indicate that for many students both self-regulation and external regulation of learning are important as drivers for meaning-oriented learning and co-exist together or that external regulation is a relevant step to acquire self-regulation strategies later on. A typical developmental pathway is from external regulation to self-regulation within a certain learning pattern; the more experienced and skilled students become, the more they tend to execute the learning pattern under internal control (Vermunt, 1996). Therefore, the reality of studying in higher education is more complex than a simplistic view of self-regulation as a good quality and external regulation as a bad quality.

Sometimes it is also a matter of perspective whether one or the other way of learning is regarded as ‘better’ (Vermun et al., 2014). In general, meaning-directed learning and application-directed learning are viewed as superior to undirected learning in higher education. However, a distinction is sometimes made between university and higher vocational studies in the sense that meaning-directed learning would be most appropriate in the former and application-directed learning would be most appropriate in the latter (Vermunt et al., 2014). The role of reproduction-directed learning seems to be somewhat controversial because some regard it as an important route to basic factual knowledge, while others argue that even this factual knowledge would be better learned through meaning- or application-directed learning (Vermunt, 2003; Vermunt, 2007).

De Clercq et al. (2014) point out that it is not straightforward to compare students from different faculties, although one would use a global measure of performance. The grade point average does not necessarily contain the same underlying components but can reflect different kinds of learning. Therefore, the link between students’ learning patterns and achievement is not the same from one discipline to another (Vermunt, 2005), which is also a reason why there might be inconsistencies in the results between various disciplines. According to Entwistle (2005), it is important to recognise not only the effect of the contrasting content matter but also the effect of the distinct academic and professional cultures on the differences in the nature of learning outcomes across various disciplines.

5.3. How to support learning in higher education

Powerful learning environments are the ones that encourage students to adopt high-quality learning approaches and discourage them from adopting lower-quality approaches (Vermunt, 2003, 2007). Thus, they prepare students for lifelong, self-regulated, cooperative and work-based learning. Further, it is essential for the development of self-regulation that the teaching method changes in response to students’ increasing metacognitive, self-regulatory skills. However, this is often not the case in classical PBL, for instance, but the ‘seven steps’ pattern stays about the same throughout the study years (Vermunt, 2003). Usually, after long-term exposure to a certain teaching method, a sort of ceiling effect seems to occur. This means that students’ self-regulatory skills will no longer develop once they have mastered the regulatory skills needed to be effective in a particular teaching method, if the method stays the same. It is therefore important to progressively expose the students to more comprehensive and complex tasks and assignments. In addition, the amount of external regulation in the tasks and learning environments should gradually decrease so that students will have a greater role in deciding the tasks and problems, the learning objectives, the choice of learning activities etc. (Vermunt, 2003). The aim is to gradually shift the task division of the learning process from educational agents, such as teachers, tutors or textbooks, to students and to withdraw the support stepwise (Vermunt, 2007). At the same time, students are taught how to take control of their learning processes. A large body of evidence shows that when learners deal with new information, they should be explicitly shown what to do and how to do it (see Kirschner, Schweller, & Clark, 2006). Without instruction or feedback, they might easily get lost or frustrated (Brown & Campione, 1994; Hardiman, Pollatsek, & Weil, 1986) or even acquire misconceptions or incomplete or disorganised knowledge. This might explain the negative attitudes of students towards the PBL method in Study II; in the first year of medical school, they perhaps needed more instructional support to get the confidence that they really had learned the course contents (see also Mikkilä-Erdmann, Södervik, Vilppu, Kääpä, & Olkinuora, 2012). It seems that particularly in the beginning of their studies, when learners have little prior knowledge about the content being learned, they would benefit from stronger teacher guidance (cf. Kirschner et al., 2006).

Vermunt and Verloop (1999) theorise about the interplay between teacher-regulation and student-regulation of learning. According to them, students' self-regulation and teachers' external regulation of learning processes are constantly interrelated. When they are compatible, one might speak of congruence, and when they are not, friction occurs. However, friction might be positive or constructive in that it challenges students to increase their learning strategy skills. On the other hand, destructive friction may cause a decrease in learning skills (Vermunt & Verloop, 1999).

In some learning situations, more teacher-regulation is needed (Vermunt & Verloop, 1999). For example, when students are unable to employ certain learning activities that are essential for the material to be learnt, strong teacher-regulation might be appropriate. However, when students are skilled in the use of particular learning activities, less teacher-regulation might be sufficient. Therefore, when the goal of teaching is for students to gain an understanding of the subject matter and to support self-regulated knowledge construction, the key issue is the development from teacher-regulated to student-regulated learning (Vermunt & Verloop, 1999). However, in current degree programmes, teaching/learning methods tend to be rather stable over time (Vermunt, 2007). Further, as students seem to employ rather diverse regulation strategies within a course or student cohort, establishing a balance between teacher- and student-regulation might be challenging.

Guidance through text also seems to have positive effects on learning. According to Hynd (2001), in order to change one's ideas one must be persuaded to change them, which can happen through text. At least the learning of complex science phenomena seems to require this kind of overcoming of significant conceptual and affective obstacles (Sinatra & Mason, 2008). In Study IV, the role of text in guiding science learning was addressed. Only a weak trend was found, indicating that weaker learners would benefit more from the refutational text, whereas deep and independent learners seemed to get good learning results regardless of the text type. However, there is evidence that science texts aiming at bringing about cognitive dissonance have positive learning effects compared to traditional texts (see, e.g. Broughton et al., 2010; Södervik et al., 2015). As texts seem to play a significant role in learning at the university level where independent and self-regulated learning is emphasised (e.g. Biggs & Tang, 2007), instructors should pay attention to the quality of textbooks.

Refutational texts have been criticised for being authoritative, manipulative and anti-constructivist in the sense that they neither let students discover for themselves the preferred stance nor encourage critical thinking, as they directly tell the reader what to believe and why (Hynd, 2001). Hynd's (2001) answer to the ethical dilemma is to use refutation as a curricular tool to help students learn and to help them understand what they experience when they are persuaded. The goal of refutation should not only be to encourage change but should also be to promote open mindedness, critical reflection and the assessment of the message's credibility.

Working with different kinds of texts seems to remain essential in many occupations, such as teaching and medicine, regardless of whether the texts are traditional paper documents or electronic files. Constant updating of one's knowledge seems to be a prerequisite today, when information is rapidly renewing itself. Therefore, text processing and learning from texts are important skills that are needed on a daily basis. Integrating the eye tracking method into text study seems to open new insights into text processing and it also has potential in producing behavioural evidence of expertise, as shown in Study V. Using the eye tracking method in examining learning from texts would further deepen our understanding of the mechanisms of learning, and it could be used in developing more coherent texts.

5.4. Reflections on the quality of the studies

One of the strengths of this thesis is the multimethod approach to research on student learning. In addition to traditional self-report questionnaires typical of the SAL tradition (Lonka et al., 2004), more performance and process-oriented measures, such as text intervention and the eye tracking method, were used. The thesis incorporates multilevel studies from group level to individual level study and includes longitudinal and cross-sectional samples. The broad framework of the thesis seemed to pay off; the original idea of a multilevel and multimethod approach has proven fruitful. However, there are some limitations that must be addressed.

First, the data gathering proved to be more difficult than expected. A negative aspect of collecting longitudinal data for Study III was the student drop-out rate (the number of students decreased during the three-year study from 162 to 110). It should be noted that the students who dropped out of Study III did not differ from the other participants in terms of sex, study programme (medicine vs. dentistry) or regulation strategies, so it could be concluded that the sample was representative of the target population. For Study V (the eye tracking study), it was rather difficult to recruit students because the sessions lasted about 90 minutes and took place in students' free time; therefore, the number of student participants was only 39. However, small sample sizes in eye tracking studies are common, as both data gathering and data analysis are very time consuming. The student sample in the eye tracking study (Study V) might have been biased in the sense that perhaps those students who were interested in their learning took part in the study and those who perhaps had difficulties in their learning were left out of the study. But this is a conscious risk in doing research based on voluntary participation.

There were also some problems with the ILS instrument. As Gijbels, Donche, Richardson & Vermunt (2014) conclude, the grounding knowledge base of the inventory was developed two decades ago, so revision of the theoretical components and study designs is needed against the background of 21st century learning environments and learning demands in higher education. This would be especially important when applying the instrument in PBL environments, for instance, which differ from more traditional learning environments for which the instrument was originally developed. Further, the instrument was developed on the basis of interviews with students from open distance and regular universities (Vermunt, 1996) and therefore is quite general in nature. As stated by Vanthournout et al. (2014), the model's primary focus is on more general, less context-specific preferences in learning, as opposed to learning models that are situated to the level of a specific task, course or learning environment. A common feature of SAL models seems to be a focus on much larger units of analysis, such as general approaches to studying, rather than specific phases and strategies, which are the focus that North American SRL models share (Pintrich, 2004). According to Pintrich (2004), a problem with SAL models might be that they opt for a general regulation strategy instead of allowing for the possibility of regulating various cognitive, motivational, behavioural or contextual features. Further, SAL models often link goals and strategies in a rather fixed manner (e.g. extrinsic goals and surface learning strategies vs. intrinsic goals and deep strategies), whereas SRL models allow for the possibility of multiple goals within and across students and diversity in the linkages between goals and strategies (Pintrich, 2004). Using SRL models (e.g. Pintrich, 2000; Zimmerman 2000) would have perhaps given a more detailed view of students' self-regulated learning, but at the same time the multidimensionality of regulation of learning acknowledged in Vermunt's model through the integration of external regulation and lack of regulation dimensions would have been ignored.

Based on the critique of ILS and other SAL models, opting for large grain sizes and general approaches or strategies might explain some difficulties with the ILS instrument and its application to specific educational programmes. Therefore, the model does not necessarily fit very well in all branches of science, such as medicine, which has some unique characteristics compared to other disciplines, at least at Finnish universities (e.g.

highly regulated and scheduled nature of studying, division into preclinical and clinical studies, multidisciplinary character). Although the regulation scales were validated in medical school, students and student counsellors would perhaps benefit more from more context-specific instruments. Further, instead of omitting some of the items, it would perhaps have been more fruitful to try to replace these items by thinking about how external regulation emerges in medical school. Recently, there has been a tendency to develop more domain-specific instruments for measuring medical students' learning (Lonka et al., 2008). However, the focus has not been on the regulation and processing of learning but on study orientations and students' well-being.

In addition, written self-report questionnaires have been criticised for not being the best way to measure the regulation of learning (e.g. Veenman, Prins & Verheij, 2003; Vermetten, Lodewijks & Vermunt, 1999). For example, Vermetten et al. (1999) argue that ILS does not reflect actual learning behaviour but instead reflects students' conceptions of their learning styles. It is important to acknowledge this limitation, even though instruments such as ILS are widely used in educational research. However, other opinions are also to be found. According to Caprara et al. (2008, p. 526), it is not necessarily the self-regulation per se but the belief in one's ability to self-regulate that matters. In the face of difficulties, the belief of self-regulation may act as a supporting force and provide a sense of staying in power. Therefore, some scholars use the term 'perceived self-regulation' in referring to self-regulation measured by data extracted from retrospective accounts, such as self-report questionnaires and inventories (see Helle, Laakkonen, Tuijula, & Vermunt, 2013).

There are certain parts in the thesis that could have been done differently. First, it would have been more fruitful to try to refine the items that had been proved poor in the pretests and not omit them in the first place (e.g. some items concerning external regulation). Second, it would have been more interesting to constantly explore the ILS items in connection with learning of a specific topic. That would have perhaps given more insight to the studies than just comparing self-report measures to each other or to study success measured with a general performance assessment score or exam scores. Last, supplementing the questionnaire data with interviews would perhaps have deepened the picture of students' regulation of learning and given more insight into the manifestation of different regulation strategies.

There are also some limitations in the eye tracking study (Study V) that must be discussed in order to improve future research designs. First, the experimental study design did not allow the participants to read the patient cases as they perhaps normally would do, as the text was structured in a way that going back to previous slides was not possible. This might have affected the participants' reading patterns. Second, it was not controlled whether some of the participants had more practical experience of the topic of the cases than others. Including another kind of medical text, such as a journal article, in the study would have given valuable information about the participants as readers in general. Further, adding another control group to the study, such as first- year medical students, would have strengthened the study by giving more information about the levels of expertise and their connection to reasoning and problem solving. Finally, in order to get evidence for the encapsulation theory, a recall protocol or post hoc explanations of the diagnoses should be added (see, e.g. Jaarsma, Jarodzka, Nap, van Merrienboer, & Boshuizen, 2014, 2015; Rikers, Schmidt, & Boshuizen, 2000; Schmidt & Rikers, 2007; Verkoeijen et al., 2004), as by using only eye tracking measures one cannot form adequate conclusions about the reasoning process (see, e.g. Hyönä, 2010; van Gog, Paas, Merrienböer, & Witte, 2005; van Gog & Scheiter, 2010).

An aspect that could not be captured by this thesis or the ILS is a newer trend in regulation research, namely socially shared regulation or socially shared metacognitive regulation (SSMR) (see Iiskala, Volet, Lehtinen, & Vauras, 2015). Traditionally, research on metacognition and regulation have focused on individual's learning (Iiskala, 2015). Although there has been some research on co-regulation, this has been understood as a transitional process towards self-regulation (e.g. Hadwin & Oshige, 2011; Räisänen et al., in press). In SSMR, the regulation of cognitive processes is shared between learners, as they together regulate their cognitive learning process (see Iiskala, 2015). Although the emphasis of ILS seems to be clearly on individual regulation, it is important to recognise the dimension of shared regulation as well. However, our assessment system is currently based on individual performance. Therefore, taking SSMR into account, one would need to think of new ways of studying and assessing.

5.5. Conclusions and directions for future research

Although medical and teacher education students undergo extremely selective entrance exams, they seem to enter university with rather diverse learning strategies that give them differing possibilities for successful learning. The beginning of university studies can be stressful for many students, as the gap between the pre-university and university experience can be huge, and the cognitive challenges associated with the new learning environment are often accompanied by other challenges in becoming an independent adult (Christie, Tett, Hounsell, & McCune, 2008; Fisher, Cavanagh, & Bowles, 2011; Pampaka, Williams, & Hutcheson, 2012; Wingate, 2007). The beginning of university studies also seems to be quite critical, as it is then the strategies and approaches to the new learning environment are being developed and the strategies that were used in high school, for instance, are found inadequate (Vermunt, 1996).

Therefore, it is important to map students' learning strategies and to encourage them to engage deeply with the learning materials and for them to take responsibility for their own studies. Teaching does not necessarily or straightforwardly result in learning, but the learning outcomes are largely determined by the activities students employ. Instruction should therefore aim at encouraging students to use high-quality learning strategies (Vermunt, 1996). We need modes of studying that enable reflection of one's own learning and that are thus assumed to support self-regulation of learning. Integrating the teaching of learning skills into course contents from the beginning of university studies could be helpful for many (Kirschner et al., 2006), rather than having separate courses on learning skills. Simultaneous teaching of domain-specific knowledge and the learning and thinking strategies students need to construct, change and utilise their knowledge of the subject domain seems to promote the gradual transfer of learning functions from teachers to students (Vermunt & Verloop, 1999). However, university teachers need support, such as systematic pedagogical training, in designing learning environments and modes of assessment that promote student learning (Postareff, 2007; Lindblom-Ylänne, Parpala, & Postareff, 2014). Further, although the transition phase to university is critical in establishing appropriate learning strategies, following up and supporting the development of study skills until graduation is important. Therefore, the self-regulation of learning should not be seen simply as a starting point for university studies but rather as a never-ending process that is in constant interplay with teacher-regulation.

In the future, more domain-specific measurement of learning strategies and approaches would be appropriate. There have already been certain developments in this regard in the medical field (e.g. Lonka et al., 2008), although the focus has not been on the regulation of learning. It seems that instruments developed to measure learning in higher education might be too general in diagnosing differences within very homogenous student populations within an educational programme that differs in many ways from other higher education disciplines. This also makes comparisons between disciplines difficult because the measures of study success may also vary significantly (see De Clercq et al., 2014; Vermunt, 2005). Further, supplementing self-report instruments with interviews or process measures, such as eye tracking indicators, think-aloud protocols or log-file reports of electronic learning environments, could open new insights into learning strategies. For example, it would be interesting to discover whether different regulation or processing strategies could be manifested at the level of eye movements or by utilising log file data to examine whether students with different learning strategies would use electronic learning materials differently. All in all, it would be fruitful to combine the measuring of learning strategies with the learning of specific, meaningful content instead of general performance assessment. The results of these kinds of studies could be used in developing supportive learning materials and environments at university.

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