2018

The antecedents and consequences of students´ autonomous motivation • Lucas Matias Jeno

uib.no

The antecedents and consequences of students´ autonomous motivation

The relation between need-support, motivation, and academic achievement

Lucas Matias Jeno

Thesis for the Degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2018

UNIVERSITY OF BERGEN

The antecedents and consequences of students´ autonomous motivation

The relation between need-support, motivation, and academic

Lucas Matias Jeno

Thesis for the Degree of Philosophiae Doctor (PhD)
at the University of Bergen

2018

Date of defence: 16.02.2018

Year: 2018
Title: The antecedents and consequences of students´ autonomous motivation

Name: Lucas Matias Jeno
Print: Skipnes Kommunikasjon / University of Bergen

Scientific environment

This PhD dissertation was written at the University of Bergen at the Faculty of Mathematics and Natural Sciences at the Department of Biology.

The thesis was funded by the Centre of Excellence in Education initiative to the Centre of Excellence in Biology Education (bioCEED).

Acknowledgements

I love what I do! Writing this PhD dissertation has been an intrinsically motivating journey. However, this journey could not have gone so well without the support of many. First of all, I would like to thank my supervisors. My main supervisor Arild Raaheim has given me informational feedback, space to pursue many research ideas, grant proposals, and research collaborations. He always looks out for me and my well-being, and his educational philosophy has inspired me as a learner and also how I would aspire to be as a supervisor. My co-supervisor Anne Grete Danielsen has been a motivator, statistical aid, and a collaborator who has helped me along the way. Her quick feedback during the day and evening, sometimes night, has provided me with the support needed to finish this dissertation. My last co-supervisor Vigdis Vandvik has truly been a source of inspiration. She always encourages me to apply for grants, collaborate with others, and always have time to answer my questions. I have learnt more from you than I can consciously remember. I have other researcher to thank that has not served as supervisors, but might as well have been; John-Arvid Grytnes, thank you for all the help, all the feedback, and teaching me how to apply to FINNUT. I look forward to future collaborations; Paul Adachi, you are a talented researcher who has helped me with statistical issues, and SDT discussions. Importantly, you are a good friend and I appreciate you welcoming me at the University of Rochester; Edward Deci, thank you for accepting me at the University of Rochester and always taking time to discuss theoretical and philosophical issues. You are a very special man, and I will always remember you and your advices; Sehoya Cotner, you have been a special collaborator and helped me along the way to pursue new and important research areas. You always look after me, and I hope we can continue our collaboration. I have many non-academic people to thank; Oddfrid Førland, I would never have made it without your help. I do not think I can express all the help you have provided me with, and you always have time to help; Cathy Jenks has been an important research assistant. Your excellent revisions have helped me publish, I am certain of it.

I would like to thank the entire bioCEED family, both in Bergen and Svalbard. I have never met so many dedicated people in my life, and it saddens me that I one day would not be working along with you. Thanks to all my research assistants, you have made an important contribution. I would also like to thank EECRG, what a kind, welcoming, and ambitious group of researchers! To all the members of UPP, thank you for the fruitful comments and discussions, it has been important for me. Thanks to the MRG at the University of Rochester for helpful inputs at an early stage of my career. I would like to thank all the people who attend the 10 o´clock coffee at BIO. I have learnt many biological things from you, and it has given me a breather from the analyses and writing. Torstein, I have enjoyed collaborating, discussing and sharing office with you. I consider you as a friend, and I hope we can continue our journey together.

Last but not least, thanks to my family. I would like to express gratitude to my better half, Nina. You are the best person I know, and your support has helped me along this journey. You are the definition of autonomy-support, and proof that autonomy-support works. Thank you, Matias, my son. Thank you for showing me every day how important and fun intrinsic motivation is. Gracias a mis padres, Evangelina y Hernán. Siempre están a mi lado y queriéndome incondicionalmente. Gracias a mi familia en Chile, a la Felixa, a la Catalina, al Daniel, a mis tías/tíos y primos, a mis abuelas que me cuidan desde el cielo.

December 11, 2017

Lucas M. Jeno

Abstract

Higher education has traditionally rested on teacher-centred education. Recently, there has been a shift towards learner-centred education. Innovative teaching tools, active teaching methods, and teachers that encourages a deep approach to learning, are examples of how to facilitate learner-centred education. Central to learner-centred education is increasing student motivation for learning. Moreover, recent systematic reviews and meta-analyses suggest that learner-centred education, compared to teacher-centred education, increase student achievement. Guided by the framework of Self-Determination Theory, this thesis investigates different antecedents for student motivation, and how in turn, autonomous motivation relates to achievement. It is hypothesised that the extent that the environment (i.e., teacher, innovative teaching tools, active teaching methods) promotes a sense of choice and volition in the learning activity, a sense of optimal challenge and feedback, and a sense of caring and nurture, will increase student autonomous motivation and achievement.

Three independent studies were conducted and written up as three papers. Paper I is a national representative cross-sectional investigation of biology students´ prospective achievements and dropout intentions. Results from a Structural Equation Model show support for the proposed hypotheses. Moreover, multi-group analyses show that there are significant differences for level (i.e., BA vs MA) for four paths, but are invariant across genders. Specifically, we found need-support, relatedness, and intrinsic aspiration to be positive predictors of perceived competence and autonomous motivation. Perceived competence and autonomous motivation are positive predictors of achievement and negative predictors of dropout intentions. Extrinsic aspiration is a negative predictor of achievement and a positive predictor of controlled motivation. Controlled motivation is a positive predictor of dropout intentions. Paper II concerns a randomised experiment testing the effect of a mobile-application tool to identify species. Students in the mobile-application condition, relative to students using a traditional textbook, scored higher on intrinsic motivation, perceived competence, and achievement. A path-analysis shows that the mobile-application positively predicts intrinsic motivation and perceived competence. Intrinsic motivation in turn, positively predicts achievement. An indirect effect of the mobile-application to achievement through intrinsic motivation was found. Paper III is a quasi-experiment testing the effect of Team-Based Learning (TBL) relative to traditional lecture-classes. The study is a one-group pre-test/post-test design. Measurement after four weeks of lectures and then after four weeks of TBL shows that the students increased their intrinsic motivation, identified regulation, external regulation, perceived competence, engagement, autonomy-support, need-satisfaction, and perceived learning. The students decreased in amotivation from pre-test to post-test as a function of TBL. A path-analysis using the change scores shows that increases in intrinsic motivation, identified regulation, and perceived competence positively predict engagement, which in turn, positively predicts perceived learning.

In conclusion, the results show that active learning, compared to passive learning, is positively related to achievement. However, the findings also show that it is important to consider the underlying motivational processes that either support or thwart student autonomous motivation. That is, active learning promotes autonomous motivation and increases learning when the students´ basic psychological needs for autonomy, competence, and relatedness are supported. In accordance with Self-Determination Theory, a socio-context could be perceived as informational (need-supportive), controlling (need-thwarting), or amotivational (incompetence), thus teachers and institutions are recommended to consider the need-supportive vs need-thwarting elements within learner-centred approaches. The results from this thesis contribute to the knowledge on what increases student autonomous motivation and how active learning methods impact student motivation. Specifically, the use of a prominent meta-theory of motivation allows for an analysis of which factors facilitate motivation and what the consequences might be. The use of diverse student samples, study design, and statistical analyses provide strong support for the external validity of the thesis.

List of publications

Paper I:

*Jeno, L. M., Danielsen, A. G., & Raaheim, A. (re-submitted to Educational Psychology). A prospective investigation of students´ achievement and dropout in higher education: A Self-Determination Theory approach.

Paper II:

Jeno, L. M., Grytnes, J.-A., & Vandvik, V. (2017). The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self- Determination Theory perspective. *Computers & Education, 107*, 1-12. doi:10.1016/j.compedu.2016.12.011

Paper III:

Jeno, L. M., Raaheim, A., Kristensen, S. M., Kristensen, K. D., Hole, T. N., Haugland, M. J., & Mæland, S. (2017). The relative effect of Team-Based Learning on motivation and learning: A Self-Determination Theory perspective. *CBE-Life Sciences Education, 16*(4), 1-12. doi:10.1187/cbe.17-03-0055

Statement of declaration for the thesis

	Paper I	Paper II	Paper III
Research idea	**LMJ**	**LMJ**, VV, JAG	**LMJ**, AR
Data collection	**LMJ**, TNH, KH	**LMJ**, JAG, LCK	**LMJ**, SMK, KDK
Data analysis	**LMJ**, AGD	**LMJ**	**LMJ**
Data interpretation	**LMJ**, AGD, AR	**LMJ**, JAG, VV	**LMJ**, AR, SMK, KDK, TNH, MJH, SM
Manuscript preparation	**LMJ**, AGD, AR	**LMJ**, JAG, VV	**LMJ**, AR, SMK
Writing of manuscript	**LMJ**, AGD	**LMJ**	**LMJ**, AR
Comments on the manuscript	AGD, AR, CRJ	VV, JAG, CRJ	AR, SMK, KDK, TNH, MJH, SM, CRJ
Approved final version for submission	**LMJ**, AGD, AR	**LMJ**, JAG, VV	**LMJ**, AR, SMK, KDK, TNH, MJH, SM

Note: The order of authors reflects the contribution to the manuscript
LMJ = Lucas M. Jeno; VV = Vigdis Vandvik; JAG = John-Arvid Grytnes; AGD = Anne Grete Danielsen;
SMK = Sara Madeleine Kristensen; KDK = Kjell Daniel Kristensen; TNH = Torstein Nielsen Hole; MJH = Mildrid J. Haugland;
SM = Silje Mæland; LCK = Linn C. Kruger; CRJ = Cathy R. Jenks; KH = Kristin Holterman

Table of contents

Introduction

High-quality teaching and learning encourages a deep approach to learning, as opposed to a surface approach (e.g., Asikainen & Gijbels, 2017; Biggs & Tang, 2011; Bloom, 1956). In large-class lecturing, which has been the norm in higher education since the Middle Ages (Bligh, 1998; Brown & Atkins, 2002), the student is a passive recipient of the information provided by the teacher. Such a passive teaching method encourage the student to adopt a surface approach to learning. In the last 20–30 years, however, there has been a shift in the view of the teachers' role from providing instruction to fostering learning (Barr & Tagg, 1995; Wieman, 2014). That is, there has been a shift from a teacher-centred view of education towards a learner-centred view. In learner-centred education, the students are seen as active learners creating their own knowledge. Active learning, which may be defined as instructional methods that engage students in the learning process, require student participation, engagement, and awareness of the activity (Prince, 2004). Research within the higher education context has found that learner-centred approaches and active learning, compared to teacher-centred and passive learning, are beneficial for student motivation and achievement (e.g., Cavanagh et al., 2016; Hyun, Ediger, & Lee, 2017; Stover & Ziswiler, 2017). Traditional passive learning methods increase fidgeting and mind wandering in class, and inhibit knowledge retention (Farley, Risko, & Kingstone, 2013; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). Conversely, a meta-analysis by Cornelius-White (2007) found that learner-centred approaches are positively related to student participation, satisfaction, and motivation, and negatively associated with dropout and absence. Within the Science, Technology, Engineering, and Mathematics (STEM) subjects, Freeman et al. (2014) found that active learning methods, compared to passive learning, increased achievement by almost one standard deviation, while the failure rate decreased from 34 percent with passive learning to 22 percent with active learning. Hence, there are clear educational benefits of creating learner-centred education and facilitating active learning.

Within learner-centred education, motivation and affect are central for the students' learning process (American Psychological Association, 1997). Motivation, which is the energy and direction of behaviour, is an important construct because it provides an explanation of the underlying human behaviour, behavioural intensity and functioning, and psychological well-being (Baumeister & Vohs, 2007; Diener et al., 2017; Harackiewicz & Priniski, 2018). Within an educational context, motivational research and theory suggest that motivation is highly important for students' effort, persistence, and high-quality learning (Eccles & Wigfield, 2002; Hidi & Harackiewicz, 2000; Pintrich, 2003). Moreover, there is a growing body of research showing the beneficial aspects of motivation on several educational outcomes. For example, across two meta-analyses, Robbins, Lauver, Le, Davis, and Langley (2004) and Richardson, Abraham, and Bond (2012) found that students' academic efficacy and academic goals were the strongest predictors for University Grade Point Average (GPA) and achievement, over and above the effect of high school GPA, Scholastic Aptitude Test (SAT)/American College Test (ACT), and intelligence. Despite the beneficial aspects of student motivation and learner-centred education, educational research has neglected to incorporate psychological perspectives (Alexander & Murphy, 1998). Hence, a motivational perspective could be especially apt given the importance that motivational

theory has had in understanding the quality of behaviour and achievement. The implications of motivational research and theoretical perspectives are important for the application of educational practice, recommendations for teachers, instructional methods, curriculum designs, and policymakers (Kaplan, Katz, & Flum, 2012; Wentzel & Wigfield, 2009).

The main aim of this thesis is to investigate the underlying motivational pulls of students´ motivation and achievement. That is, I investigate the impact of the social context of students that either supports or hinders their motivation for academic achievement. To this end, three independent studies have been conducted to understand the motivational pull in the students´ social context; 1) teachers´ motivational support to achieve and persist at university; 2) the underlying motivational effect of a mobile-application on achievement in species identification; and 3) the motivational effects of Team-Based Learning on engagement and learning. I have employed Self-Determination Theory (SDT) throughout to investigate the motivational pulls of different active learning methods. SDT is a broadly empirically-supported motivational theory (e.g, Pintrich, 2003; Seligman & Csikszentmihalyi, 2000) and is especially useful because of its clear assumptions of what constitutes human nature and which social-contextual factors affect human behaviour (Ryan & Deci, 2017). These clear underlying behavioural assumptions (i.e., motivational pulls) result in SDT making clear predictions of what the educational consequences and outcomes of different teaching and learning situations and interventions could be in order to successfully promote high-quality motivation and learning.

Investigating different motivational pulls in higher education using SDT is timely and important for several reasons. First, there is a decline in motivation among higher education students (Brahm, Jenert, & Wagner, 2016). Understanding which factors enhance student motivation could therefore benefit persistence at tasks, reduce dropout rates, and improve achievement. Second, motivation is a ubiquitous aspect of engagement and learning (Raaheim, 2011). Investigating and comparing the underlying motivational effects of different active learning methods and approaches, and how they might be employed to maximise student achievement, is thus important to guide the implementation of such teaching methods. Third, using a prominent and empirically-supported motivational theory, specifically the conceptual lens of SDT, to analyse antecedents of student motivation, and in turn, the consequences of students´ motivation on educational outcomes, allows us to understand the impact that different teaching practices could have on student motivation and achievement and how to organise instructional methods. Finally, SDT aligns well with the principles in learner-centred education in the view of students as active learners and a deep approach to learning (understood as autonomous motivation in SDT), and the meta-theoretical assumptions of active learning (SDT´s organismic approach to human motivation and learning).

Below I present the recent trends and political changes in Norwegian higher education, and more generally why this thesis is a novel contribution to the learning higher education research and development. In chapter 2, I present the theoretical approach of Self-Determination Theory. In chapter 3, I review the past literature on motivation and

achievement, relating to teachers, mobile learning, and collaborative learning. I close that chapter with a section on the main problems I wish to address, what the materials for the thesis are, and the knowledge gap I wish to close. In chapter 4, I explain the methods, procedures, and statistical strategies employed in the thesis. In chapter 5, the results for each paper are presented. Lastly, in chapter 6, I discuss the results, the importance of the results for educational practice, and reflect upon the limitations and practical implications of this thesis.

Higher education in Norway: evolving views on student motivation and learning
The Bologna process in general, and the introduction of the Quality Reform in particular, has resulted in a major shift of attention within higher education in Norway (see Table 1 for an overview if the main educational reforms and changes). From a focus on "teaching as transformation of knowledge" and summative assessment, towards a focus on active learning and formative assessment. In both primary, secondary and tertiary education, motivational aspects are increasingly being emphasized (Ministry of Education and Research, 2017a). Instead of focusing on subject-specific skills, students need to learn meta-cognitive-, self-regulatory-, and problem-solving skills. Despite this increased focus on motivational aspects, the Norwegian education system confronts several motivational challenges; facilitate and increase student motivation to increase persistence, flexibility and autonomy, and graduate more students within natural sciences (Koutsogeorgopoulou, 2016; OECD, 2014). The Ministry of Education and Research (2017a) calls for a teaching context that promotes a deep approach to learning, as opposed to a surface approach as a mean to increase motivation and lifelong learning skills. In order for students to acquire a deep approach to learning, the Ministry of Education and Research suggest that a) teachers in higher education should facilitate learning, structure, and support around their learning; b) technological tools that can provide formative feedback and engagement in learning; and c) implement active learning methods that can motivate, engage and stimulate deep approach to learning.

There is a clear assumption, then, that motivation is important for a deep approach to learning, and that active learning is important for increasing motivation. However, what is less clear is how motivation can contribute to these processes. Owing to motivation constituting a multifaceted construct, there is a need for a theoretical approach to the analyses of active learning and achievement. That is, a theoretical approach is useful for describing, predicting, and explaining related phenomena (e.g., Fiske, 2004; Trope, 2004). Thus, a theoretical approach of motivation to understand students´ motivation and achievement is important given that motivation is at the core of teaching and learning (Dweck, 2017).

Table 1

Overview over the main educational reforms and white papers in higher education since 2000. Also shown are the major conclusions of these changes and its implications for teaching, assessment, and learning

Educational reforms, white papers, NIFU-reports	Year	Main conclusions	Views on teaching	Implication for assessment	Implication for learning
NIFU-report (1989-1999): Changes in higher education[1]	2000	Large changes in HE; New Public Management (focus on efficiency)	Institutions increasingly focusing on quality in education, but no official definition of quality	Summative assessment;	Increased focus on active learning techniques, but depends on individual institutions definition of quality
White paper 27 (2000-2001): Norwegian qualification framework[2]	2001	Restructure of educational programs	Increased focus on active and self-regulated students; Increased focus new teaching methods and implementation of ICT	Formative assessment such as portfolio, and multiple examinations	Institutions and students have responsibility for learning
Bologna process[3]	2000-2011	Framework for learning outcomes; Easier understanding of Norwegian education and training system internationally	Increased feedback; Increased teacher-student feedback	Knowledge students has attained after the end of a learning process; Alternative assessment methods	Facilitate lifelong learning across institutions and nations; School completion
Implementation of Qualification Framework[3]	2012	Implementation of the National Qualification framework based on the European Qualification framework for Lifelong Learning	Implementation of formalized learning outcomes (knowledge, skills, general competence)	Establish appropriate assessment methods	Learning outcomes of what students should know after a course
White paper 3: New structure in higher education[4]	2008	Establish centres of excellence in education	Stimulate development and innovative teaching methods, and increase the quality of teaching in higher education	Learning outcome, teaching, and assessment aligned	Focus on lifelong learning and active learning; Possibilities of ICT in higher education

Centres of Excellence (bioCEED)[5]	2011-2016	The Norwegian Organ for Quality in Education (NOKUT) funded one Centre in 2011, three Centers in 2013, and four new Centres in 2016. One of the 2013 Centres was Centre of Excellence in Biology Education (bioCEED)	The main goals of bioCEED: a) create a shift from teacher-centered to learner-centered education, b) create and employ innovative teaching methods, c) implement practical training, and d) disseminate best practice	Baseline investigation of biology education	Implements active learning methods, and innovative teaching tools
White paper 16 (2016-2017): Culture for quality in higher education[6]	2017	Increase educational attainment; Focus on status of teaching	Use of technology in teaching; Research-based teaching; Collegial teaching	Feedback and assessment to support motivation and learning; Digital exams	Research-based teaching to increase learning

Note: The text is drawn from White Papers, NIFU-reports, and OECD-reports
[1]Stensaker (2000), [2]Ministry of Education and Research (2001), [3]Ministry of Education and Research (2011), [4]Ministry of Education and Research (2008), [5]bioCEED (2013), [6]Ministry of Education and Research (2017a)

Motivational theory relating to teaching and learning

Motivational theory is important for explaining the initiation, persistence, and quality of the learning process. Contemporary theoretical approaches to motivation and competence, for example Social Cognitive Theory, and goal-directed behaviour, for example Achievement Goal Theory, have proven useful in explaining student achievement (e.g., Eccles & Wigfield, 2002; Hidi & Harackiewicz, 2000; Pintrich, 2003). According to Bandura´s Social Cognitive Theory (1989, 2001), human functioning and well-being is determined by the interaction between personal factors (cognition, affect, biological events), behaviour, and environmental influences. Within Social Cognitive Theory, self-reflection and self-beliefs are assumed to affect behaviour and environment, and in turn be affected by them. The role of self-efficacy – the belief in one´s capabilities to organise and execute the courses of action required to produce given attainments (Bandura, 1997, p. 3) – is thus central to Social Cognitive Theory and its application to the educational domain. According to Bandura (1977, 1997) there are four sources that affect a person's self-efficacy beliefs: actual performance; vicarious experience; verbal persuasion; and physiological indices and states. Within education, self-efficacy has been shown to predict motivation, self-regulation, learning, and achievement (Schunk & Pajares, 2009).

Within the achievement motive tradition, there are two major contemporary theoretical approaches that have been employed extensively in the educational field: Expectancy-Value Theory and Achievement Goal Theory. According to the Expectancy-Value Theory (Eccles et al., 1983; Wigfield, Tonks, & Klauda, 2009), students´ academic achievement, persistence in school, and behavioural choice are determined by the students´ expectancies and value beliefs. Expectancies refer to the expected success in an upcoming task, whereas value beliefs refer to the qualities of each task and how these influence the person's desire to perform the task. Research on Expectancy-Value Theory in the educational domain has found that students´ expectancy relates positively to achievement and persistence (Wigfield, et al., 2009). Achievement Goal Theory is a broad theoretical framework consisting of multiple models and approaches (Maehr & Zusho, 2009). Common to these approaches are assumptions of motivation being a process that varies in type, in the importance of competence, and in the cognitive, affective, and behavioural effects that goals have (Elliott & Dweck, 1988). The two major goal constructs within Achievement Goal Theory are mastery goals (task involvement) and performance goals (ego involvement) (Elliot & Thrash, 2001). Mastery goals are goals that focus on self-improvement and development of competence, whereas performance goals focus on demonstration of competence (i.e., showing others that one is capable). Elliot (1999) refined these goals by adding valence to the goals. Specifically, mastery-approach goals focus on learning and understanding; mastery-avoidance goals refer to not losing skills or competencies; performance-approach goals refer to outperforming others; and performance-avoidance goals refer to not looking incompetent to others. Research on achievement goals has consistently found that the mastery approach is positively associated with beneficial educational outcomes, whereas performance avoidance and performance approach is negatively related (Sommet & Elliot, 2017).

The above reviewed theoretical approaches have consistently shown positive and expected results of motivation on beneficial educational outcomes. However, the theories have theoretical shortcomings that have empirical and practical implications for the educational research in learner-centred education. First, within Self-efficacy (human agency), autonomous actions are not considered in the theory, and thus motivation is only differentiated in quantity (Bandura, 1989; Ryan & Deci, 2006). Second, Expectancy-Value Theory relies on socialisation factors and cultural factors to account for student expectancies and value beliefs. Cultural relativism is the main approach, excluding the universal and evolutionary benefits of basic needs (Ryan & Hawley, 2016). Third, students can have both autonomous and controlled reasons to have mastery and performance approaches (Vansteenkiste, Lens, Elliot, Soenens, & Mouratidis, 2014). Hence, within achievement goal theories, different goals or aims are not differentiated by reasons, thus failing to acknowledge the role of autonomy.

A contemporary, empirically-supported, and organismic meta-theory that employs quantitative and statistical approaches to investigate human motivation to applied areas is Self-Determination Theory (Ryan & Niemiec, 2009). Despite learner-centred education being generally constructivist (Phillips, 1995), SDT seems especially apt to investigate how active learning impacts and affects student achievement (Jeno, 2015). Due to the theory's applicability across domains, such as sports (Standage & Ryan, 2012), counselling (Ryan & Deci, 2008), parenting (Joussemet, Landry, & Koestner, 2008), work organisation (Deci, Olafsen, & Ryan, 2017), healthcare (Ryan, Patrick, Deci, & Williams, 2008), the gaming industry (Rigby & Przybylski, 2009), and education (Deci, Vallerand, Pelletier, & Ryan, 1991), its empirical support is specifically strong and robust. Furthermore, its broad conceptualisation and theorisation provides opportunities for testing its assumptions and predictions of factors that enhance or inhibit student motivation, and, in turn, the effect of motivations within a given domain. In this thesis, both the theoretical approach and methodological approach are guided by the work of SDT. The central philosophical and theoretical assumptions of SDT are presented in detail below.

Self-Determination Theory
Self-Determination Theory is a macro-theory of human motivation and personality that embraces an organismic and dialectic perspective (Deci & Ryan, 1985; Ryan & Deci, 2002). SDT assumes that all humans have an innate and natural propensity to be active, growth-oriented, and to develop a unifying sense of self (Ryan & Deci, 2002). For instance, children have a natural tendency to explore novel and interesting objects and situations; students learn for the pure pleasure of learning and interest; and adults pursue hobbies and self-chosen behaviours. SDT further acknowledges that social-contextual factors may influence, impede, or thwart this innate tendency. Thus, SDT assumes a dialectic relationship between intra-individual factors (innate and natural propensities) and inter-personal climate (social context or situations that support or thwart these propensities).

Self-Determination Theory comprises six mini theories, each explaining a specific phenomenon of human nature. The six mini-theories are Basic Needs Theory (BNT),

Cognitive Evaluation Theory (CET), Organismic Integration Theory (OIT), Goal Content Theory (GCT), Causality Orientation Theory (COT), and Relationship Motivation Theory (RMT). This thesis employs four of these mini-theories, which are presented below.

Basic Needs Theory

According to Basic Needs Theory (BNT; Deci & Ryan, 1985), humans have three basic psychological needs; for autonomy (DeCharms, 1968), competence (White, 1959), and relatedness (Baumeister & Leary, 1995). Satisfaction of these needs is theorised to be necessary for psychological well-being, optimal development, and integrity, while thwarting of these needs, conversely, is detrimental for well-being, optimal functioning, and integrity (Ryan & Deci, 2017). Autonomy refers to perceiving that an individual is the origin of that person´s behaviour. There are three processes that are needed to experience autonomy; first, one must experience that the initiation of a behaviour is endorsed by oneself. That is, one has to perceive that the cause of behaviour is internal (internal locus of causality), as opposed to perceiving that the cause is external, or governed by alien forces (external locus of causality; Ryan & Lynch, 2003). Second, one needs to experience volition, that is, freedom in pursuing activities. Third, one needs to experience meaningful choices in relation to activities, as opposed to experiencing rigidness and inflexibility (Reeve, 2009a). Competence may be defined as feeling efficacious in the interaction with the environment and experiencing the opportunity to exercise and express one´s capabilities. The need for competence is satisfied when the individual is engaged in an optimal challenging activity, and when the social context affords positive feedback and structure (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005; Furrer, Skinner, & Pitzer, 2014). Relatedness relates to the feeling of being connected and cared for by others, and having a sense of belongingness to others or to one´s community. The need for relatedness is satisfied when individuals feel respected by others, accepted in a social group, and perceive that others care for them unconditionally (Baumeister & Leary, 1995).

According to BNT, the three basic psychological needs are assumed to be universal and are evident and invariant across all cultures, ages, and genders. There are several criteria that are used to identify the basic psychological needs. First, satisfaction of the needs is positively associated with well-being and optimal functioning, while thwarting is negatively associated with well-being and optimal functioning. Second, the needs must specify content for experiences and behaviour that will satisfy the needs (i.e., there must be specific experiences and behaviours adopted to be healthy). Third, the needs must be essential to predict and interpret empirical phenomena. Fourth, in line with organismic assumptions, the needs must be growth-oriented and not deficit needs.

Goal Content Theory

According to Goal Content Theory (GCT), people´s life aspirations can be differentiated into two types: intrinsic and extrinsic aspirations (Ryan & Deci, 2002; Vansteenkiste, Niemiec, & Soenens, 2010). Intrinsic aspiration is characterised by pursuing goals such as personal growth, close relationships, community contribution, and physical health, and is positively associated with basic need-satisfaction. Extrinsic aspiration on the other

hand, is characterised by pursuing wealth, fame, and image, and is positively related to need-frustration. According to GCT, pursuing, valuing, or prioritising intrinsic goals, relative to extrinsic goals, is associated with wellness and optimal functioning, whereas extrinsic goals are associated with ill-being (Ryan & Deci, 2017). Additionally, intrinsic goals are assumed to predict both need-satisfaction and autonomous motivation. In contrast, extrinsic goals are assumed to predict need-frustration and controlled motivation. In line with the assumptions of GCT, a meta-analysis found that materialistic pursuits were negatively associated with well-being measures (Dittmar, Bond, Hurst, & Kasser, 2014). In an educational context, it has been suggested that a social context that matches students´ personal goals yields optimal results (Pervin, 1968; Schneider, 1987). According to SDT, intrinsic goals are more need-satisfying than extrinsic goals, and students with extrinsic goals will benefit more from a context that supports their basic psychological needs and that are intrinsic, as opposed to contexts that match their extrinsic goals (Vansteenkiste, Soenens, Verstuyf, & Lens, 2009). Because extrinsic goals are a means to an end, they promote a narrow focus on, and a superficial approach to, learning (Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005), and thus are assumed to not benefit educational outcomes.

Cognitive Evaluation Theory

Within SDT, Cognitive Evaluation Theory (CET) addresses the factors that facilitate and undermine intrinsic motivation (Deci, Koestner, & Ryan, 1999; Ryan & Deci, 2017). Intrinsic motivation is defined as behaviours done because they are inherently interesting or enjoyable, whereas extrinsic motivation are behaviours done because they lead to a separable outcome (Ryan & Deci, 2000a). Specifically, intrinsically motivated behaviours are characterised by an internal locus of causality (I-PLOC) and perceived competence. In contrast, extrinsic motivation has an external locus of causality (E-PLOC). According to CET, any events or activities of relative salience have three functional significance, or psychological meanings, depending on the recipient's perception (Deci & Ryan, 1985). That is, with respect to the satisfaction or thwarting of the basic psychological needs for autonomy, competence, and relatedness, the perception of the social context is determined by the functional significance of these events (Ryan & Weinstein, 2009). First, the informational aspect provides effectance-relevant feedback in the context of autonomy and choice. As an example, the functional significance of a teaching method would, on average, be perceived as informational with respect to the psychological needs if it provided feedback and activities that are optimally challenging, and if it was perceived as choiceful, volitional, and self-directed. An informational functional significance is more likely to enhance intrinsic motivation and autonomous motivation (Deci & Ryan, 1985). Second, the controlling aspect provides pressure, compliance, or defiance to think or behave in particular ways. For instance, a learning activity that pressures or forces students to behave or learn in a specific fashion, or which provides high-stake or summative feedback is likely to thwart the needs for autonomy and competence, and in turn, enhance controlled motivations. Third, the amotivational aspect provides incompetence and non-self-determination, accompanying helplessness, depression, and self-disparagement. For example, a teaching activity that is overly challenging, whereby a perception is generated that one does not have the competence to achieve the intended results, and/or does not promote value or autonomy, tends to

enhance amotivation. Hence, a test, reward, or feedback can have an informational, a controlling, or an amotivating functional significance (Ryan & Brown, 2005). Presenting a controlling aspect to an initially intrinsic motivational activity prompts a shift from an internal perceived locus of causality to an external perceived locus of causality. The initiation of the regulation (i.e., the behaviour) is perceived as coming from external to oneself. A meta-analysis of 128 experiments by Deci, et al. (1999) found, in line with the assumptions of CET, that tangible rewards given contingently reduce intrinsic motivation, whereas positive feedback enhances intrinsic motivation.

Within an educational context, teachers and learning contexts can either be need-supportive or controlling, with respect to the satisfaction or thwarting of the basic psychological needs. Need-supportive teachers are defined as those that show interpersonal sentiment and behaviour during instruction to identify, nurture, and develop students´ inner motivational resources (Reeve, 2009b, p. 160). Need-supportive teachers and contexts support students´ basic psychological needs for autonomy, competence, and relatedness by acknowledging the students´ negative affect, trying to understand the students' internal frame of reference, providing students with a meaningful rationale when showing motivating behaviour, relying on informational non-controlling language, and basing teaching, feedback, and activities around the students´ interests, self-directed goals, and aspirations. Conversely, controlling teachers are defined as those that show interpersonal sentiment and behaviour during instruction that pressure students to think, feel, or behave in a specific way (Reeve, 2009b, p. 160). Controlling teachers thwart the students´ psychological needs for autonomy, competence, and relatedness by taking their own perspective, using controlling language (e.g., "should", "must"), intruding in the students´ learning, relying on instrumental sources of motivation, employing authoritarian power to overcome negative affect, and providing controlling feedback, or guilt-inducing criticism. On average, results from field studies, cross-sectional studies, and laboratory experiments show that a controlling social context tends to diminish intrinsic motivation and well-being, whereas a need-supportive social context tends to enhance intrinsic motivation, creativity, and well-being (Deci & Ryan, 1987).

Organismic Integration Theory

Organismic Integration Theory (OIT) describes the organismic tendencies within humans to integrate experiences into a coherent self (Ryan & Deci, 2002). This internalisation process is facilitated by the satisfaction of the basic psychological needs for autonomy, competence, and relatedness. Internalisation is defined as the active process through which an individual acquires an attitude, belief, or behavioural regulation and progressively transforms it into a personal value, goal, or organisation (Deci & Ryan, 1985, p. 130). Thus, self-regulation is when a regulation has been internalised and has become integrated with the self, and the regulation emanates autonomously from the self (Ryan & Deci, 2002). As opposed to other motivational theories, SDT differentiates not only between classes of motivation (i.e., intrinsic and extrinsic motivation), but also between types of extrinsic motivation that vary in quality and autonomy (Ryan & Deci, 2000a). SDT recognises five types of regulations that vary from least autonomous to fully autonomous (see Figure 1). Amotivation is a type of motivation with non-regulation and that is non-self-determined. Students that are amotivated are characterised as passive with

a lack of intention to act. Amotivation stems from the perception of being unable to achieve desired outcomes, a lack of perceived competence or value of the activity or outcome (Abramson, Seligman, & Teasdale, 1978; Bandura, 1997; Ryan & Deci, 2000b). Hence, amotivation is the state when individuals lack motivation and intention to act. External regulation is the least autonomous extrinsic motivation and behaviours are done in order to obtain a reward or avoid a punishment (i.e., the behaviours are performed to obtain or avoid external contingencies). External regulation is characterised by an external locus of causality and very low degree of choice and volition. For example, students studying to obtain a high grade in order to pursue a high salary career are considered externally regulated.

Introjected regulation is a partially internalised regulation in which the behaviour has been taken in, but not truly accepted as one´s own. The perceived locus of causality is somewhat external, and behaviours are undertaken in order to avoid shame or guilt, or to attain a feeling of self-worth or enhance the ego. Introjected regulation is based on affective and evaluative contingencies within the individual (i.e., introject regulation is a form of self-control characterised by personal judgement and evaluations; Ryan & Deci, 2017, p. 185). For instance, students that are introjection regulated may study for an exam because they want to outperform other students.

Identified regulation is a partly autonomous extrinsic motivation in which the behaviour has been internalised. The behaviour is consciously valued and personally important for the individual's self-selected goals. Identified regulation is characterised by more choice and volition and the perceived locus of causality is somewhat internal to the individual. An example of identified regulation is when students study because it is personally important for them to obtain a good job in order to help, for example, animals and society.

Integrated regulation is the most autonomous extrinsic motivation in which the behaviours have been identified and brought into congruence with existing personally-endorsed values, goals, and needs that already are part of the self. The perceived locus of causality is internal, and the behaviour is characterised by a very high degree of choice and volition. An example of an integrated regulated student is when the student has endorsed both the importance of studying wholeheartedly and the absence of conflict with other abiding identifications (Ryan & Deci, 2017, p. 188). That is, the student accepts authentically that they might lose quality time with their friends in order to study to become a biologist, which is what defines the student´s life and other aspects of their life.

Whereas autonomy and competence are most important for intrinsically motivated behaviours, relatedness has been shown to be the most important factor for internalisation and self-regulation (Ryan & Deci, 2002). It is important to note that the internalisation process is not developmental or stage-like: the students do not move through the different regulations in a stepwise fashion, but instead move dynamically between the regulations. Young children usually do not reach integrated regulation because it requires mindful reflection (Deci & Ryan, 1985).
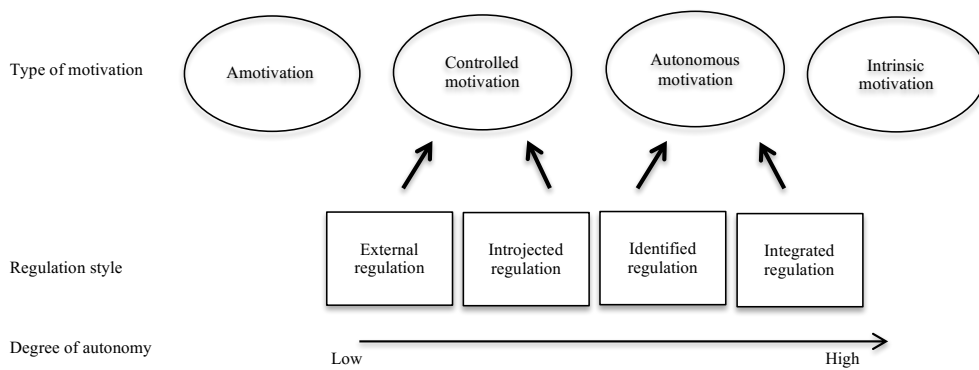
Figure 1. Different types of motivation and the different regulation styles. The regulation styles and motivations are ranked by the degree of autonomy from low to high. Adapted from Ryan and Deci (2000a, p. 61) and Jeno (2015).

Previous research on the effects of social context on motivation

This chapter presents relevant previous research conducted within a SDT perspective. The chapter is divided into three sections, reflecting the papers in this thesis, and highlights the contribution the thesis makes to filling knowledge gaps in higher education teaching and learning, and to the field of Self-Determination Theory more generally. It is acknowledged that there is a large body of research on some of these topics (i.e., achievement, dropout, well-being, mobile-learning) in the broader motivational literature. However, given the specific theoretical positioning of this thesis and the clear assumptions of SDT, the review below is centred on SDT-research.

Several systematic searches were conducted in order to find relevant studies. The databases searched were ERIC, Web of Science, Google Scholar, and Idunn. Keywords were variations of autonomous/controlled motivation; achievement/learning; dropout/persistence intentions; school satisfaction; autonomy/need support; active/passive learning; learner-centred education; goal aspirations; mobile learning/electronic learning; team based learning. Each search was also paired with (AND) self-determination theory/motivation. Searches were also made on the Self-Determination Theory's web-page for relevant studies and requests made on the SDT list-server for unpublished studies (grey literature).

Teachers´ need-support

SDT asserts that support of autonomy, competence, and relatedness enhances student autonomous motivation (Niemiec & Ryan, 2009). Within the classrooms and learning contexts, the teacher is an authority figure that can either support or stifle students´ growth-oriented propensities for learning and integration, and thus interfere or support the internalisation process. Among the early studies investigating which factors facilitate autonomous motivation, Deci, Eghrari, Patrick, and Leone (1994) find that autonomy support is positively related to choice, usefulness, and interest/enjoyment. Black and Deci (2000) investigated chemistry instructors' need-support on student autonomous motivation, perceived competence, anxiety, and achievement. Results show that need-support uniquely accounts for the explained variance in student achievement. Moreover, the relation between student autonomous motivation and achievement is moderated by instructor need-support. Newer studies seem to corroborate previous studies. For instance, need-support from the teacher is positively related to need-satisfaction (Diseth, Breidablik, & Meland, 2017; Haerens et al., 2017; Rocchi, Pelletier, Cheung, Baxter, & Beaudry, 2017) and uniquely accounts for medical students´ achievement (Feri, Soemantri, & Jusuf, 2016). In a national representative study among folk high-school students, Waaler, Halvari, Skjesol, and Bagøien (2013) find that teacher need-support and student intrinsic goal expectancy at time 1 positively predict autonomous motivation, which in turn, positively predicts effort in activity and well-being at time 2. In a study among university students in Germany and the United States, researchers find that feedback from teachers is a positive predictor of perceived competence, and a controlling social context is a negative predictor of autonomous motivation and perceived competence (Levesque, Zuehlke, Stanek, & Ryan, 2004). The benefits of need-support on students' motivation have been found among kindergarten children (Koestner, Ryan, Bernieri, & Holt, 1984), children in elementary school (Grolnick & Ryan, 1987; Ryan &

Grolnick, 1986), students in secondary school (Diseth, Danielsen, & Samdal, 2012), and students in college (Reeve, Jang, Hardre, & Omura, 2002; Reeve, Nix, & Hamm, 2003). In general, the results show strong support for the positive effect of need-support on motivation and achievement.

There have been several motivational models based on SDT proposed and applied to the educational domain (see for instance; Guay & Vallerand, 1997; Hardre & Reeve, 2003; Jeno & Diseth, 2014; Ntoumanis, 2005; Vallerand, Fortier, & Guay, 1997). However, the limitations of these studies are the exclusion of goal aspiration and investigation within higher education. For example, Jeno and Diseth (2014) conducted a full motivational model of SDT in Norway among 316 upper-secondary students from a single school. The path-analysis shows that autonomy-support positively predicts need-satisfaction, self-determined motivation, and perceived school performance. The sample was, however, limited to upper-secondary students, and did not include goal aspirations.

Within Norway, one line of research has integrated SDT-based concepts and other theoretical frameworks (e.g., Danielsen, 2010; Danielsen, Breivik, & Wold, 2011; Danielsen, Samdal, Hetland, & Wold, 2009; Diseth, et al., 2012; Diseth & Samdal, 2014). Diseth, et al. (2012) conducted a study among 240 secondary school students in Norway. The students responded on items measuring need-support, achievement goals, self-efficacy, life satisfaction, and academic achievement level. Results from a path-analysis show that need-support positively predicts self-efficacy. Competence support uniquely and positively predicts mastery, and relatedness uniquely and positively predicts life satisfaction. Self-efficacy in turn, positively predicts mastery goals, performance goals, and achievement level. Mastery goals positively predict achievement level and life satisfaction. Lastly, performance goals positively predict life satisfaction. In general, these studies find support for an integrative model in which the results show that need-support enhances mastery goals (i.e., autonomous motivation), self-efficacy (i.e., perceived competence), and life satisfaction (hedonic well-being). Due to the lack of studies integrating aspiration along with need-support and need-satisfaction in the investigation of dropout and achievement, the aim of Paper I was to investigate how underlying motivational factors (i.e., intrinsic aspiration, need-support, need-satisfaction) predicts autonomous motivation, and in turn achievement and persistence.

Mobile learning
As in daily life, technology in education has become an important aspect of information, communication, and learning (McCombs & Vakili, 2005; Morgan, Morgan, Johansson, & Ruud, 2016). An investigation of how technology impacts student motivation is important for understanding student motivation and learning. A review of the mobile learning literature revealed a large body of research. For instance, a systematic review of 164 studies shows that 86 percent of the reviewed studies have positive research outcomes, whereas only 1 percent have negative research outcomes on different measures (Wu et al., 2012). A meta-analysis by Schmid et al. (2014) on the effectiveness of technology in higher education reveals that technologies developed for education purposes (i.e., support for cognition and learning) have a moderate positive effect on student achievement, compared to technologies that were developed to deliver

information, which only have a small positive effect. Positive effects of mobile learning on student achievement have also been found among students in nursing (Pitts et al., 2015), statistics (Ling, Harnish, & Shehab, 2014), learning cultures (Hwang & Chang, 2011), physiotherapy (Fernández-Lao et al., 2016), and bird-watching (Y. S. Chen, Kao, & Sheu, 2003). Few studies within SDT have focused on how mobile learning facilitates autonomous motivation and achievement. However, many such studies have been conducted within the gaming and electronic learning literature, which, in part, could support our reasoning of the need-supportive benefits of mobile learning. Below I synthesise the research and also present some studies on mobile learning and achievement and related fields.

Using a SDT perspective, Choi, Noh, and Park (2014) conducted an analysis of the effects of a smoking cessation app. The researchers investigated the extent to which the apps satisfy the basic psychological needs and, in turn, stimulate autonomous motivation. Furthermore, the analyses assessed how goal aspirations are framed. Results show that 94.3 percent of the apps had at least one feature of basic psychological needs. Extrinsic goals (money) were found in 53.7 percent of the apps, followed by health (32 percent), time (7.4 percent), and appearance (1.1 percent). Of apps that had at least one SDT feature that tapped each basic need (n=18), four were among the top five. In two online courses, it was found that perceived need-support predicted need-satisfaction, student autonomous motivation, and number of hours studying (K.-C. Chen & Jang, 2010). The results indicate that need-satisfying elements could be found without interpersonal contact and that perceived need-supportive elements may have positive outcomes.

In a recent study, Fathali and Okada (2017) performed a study on second-language learners and technology. A total of 164 undergraduate students from a Japanese university attending an English course participated in the study. Results from a path-analysis show that perceived competence and perceived autonomy predict intentions (out-of-class language learning intentions) and achievement, whereas relatedness only predicts intentionality. Similar results have been found in the gaming environment (Ryan, Rigby, & Przybylski, 2006; Tamborini, Bowman, Eden, Grizzard, & Organ, 2010; Tamborini et al., 2011) and in electronic learning (Hartnett, 2015; Roca & Gagné, 2008; Sørebø, Halvari, Gulli, & Kristiansen, 2009).

In contrast to previous studies on mobile learning, R. L. Thomas and Fellowes (2016) find no significant difference between biology students using a mobile bird identification app and students using a traditional bird identification guide, while Felisoni and Godi (2018) find that mobile phone usage enhances multi-tasking, which in turn, has a negative effect on academic achievement. Koh et al. (2010), using a SDT approach to investigate how 3D simulation affects students' motivation to learn and their performance, find no difference in need-satisfaction between the experimental and control condition. Due to the controversies around the benefits of mobile learning on achievement, the aim of Paper II was to investigate if need-supportive elements in a mobile-application promote motivation and, in turn, achievement, as theorised by SDT.

Collaborative learning

Within biological work, research, and education, collaboration is an essential feature of fieldwork, laboratory work, and interdisciplinary science practices. Vermeulen, Parker, and Penders (2013) suggest that ecology (within biology) has progressed from a single-investigator to a transdisciplinary, cross-sectoral, and collaborative basic and applied science. This increase in collaboration, which is only expected to grow, is due to increased research funding, greater attention to the field, and changes in work habits among biologists (Vermeulen, et al., 2013). Collaborative learning has different methods and approaches, and may be applied in different ways to activate students. Research conducted within the educational domain using one such approach, team-based learning (TBL), as a teaching method is presented below. To my knowledge, no studies have used a SDT-approach to investigate the effectiveness of TBL in higher education, hence I present studies that indirectly suggest the enhancement of autonomous motivation and achievement, both from the TBL and the SDT literature.

Several studies within the TBL tradition have been conducted to test the effect on student achievement or satisfaction of teaching method. Park, Kim, Park, and Park (2015) conducted a quasi-experimental study of 74 second-year nursing students using a one-group pre-post design. A post-test questionnaire measured the students´ perceived team-efficacy (confidence in the group's ability to accomplish collective tasks), perceived team skills (team-adaptability skills, team-interpersonal skills), and academic performance using the iRATS, tRATS, and examination scores (mid-term and final examination). Results show that there was a significant increase from pre-test to post-test (as a function of TBL) in team-efficacy and team skills; there was a significant increase in academic performance for both iRAT and tRAT scores; and there is a positive association between team-efficacy and iRAT and examination scores. In a study among medicine students, Ozgonul and Alimoglu (2017) find that the introduction of TBL in a medical ethics course lasting two weeks, increased the students´ in-class engagement and course-satisfaction, relative to a lecture-course. Moreover, although there were non-significant results from a post-experimental multiple-choice test, two follow-up tests showed that students in the TBL course scored higher on the test compared to the lecture-course. In a similar vein, Alvarez-Bell, Wirtz, and Bian (2017) find that chemistry students report more positive feelings towards the course and perceived instructional guidance after the course was redesigned to a TBL course. However, results find no support for higher self-regulation, teamwork, and engagement.

Adjacent studies grounded within SDT may provide support for the assumption that TBL facilitates autonomous motivation and achievement. Benware and Deci (1984) conducted an experiment investigating the difference between learning to teach others (active learning conducive to intrinsic motivation) and learning to take a test (passive learning conducive to extrinsic motivation). Results show that students in the active learning condition, compared to the passive learning condition, have significantly higher interest, enjoyment, and conceptual learning. Recently, quasi-experimental studies have found that service learning courses enhance perceived autonomy support, autonomous motivation, and internalisation (Levesque-Bristol & Stanek, 2009), and that problem-based learning increases relatedness (Wijnen et al., 2017).

In general, studies find support for the effectiveness of TBL and educational outcomes (Sisk, 2011). However, some studies have found contradictory and mixed results. McInerney and Dee Fink (2003) conducted a study among college students and find no significant difference on the results of the final examination. In a study among grade 7 students in biology, Jarjoura, Tayeh, and Zgheib (2014) find no significant difference on achievement between a TBL-based condition and a lecture-based condition. Finally, Tucker and Brewster (2015) conducted a study among undergraduate criminal justice courses investigating the effectiveness of TBL. Compared to the lecture group, the TBL group had significantly higher mean scores on student involvement and student preparation. However, no differences are found for overall satisfaction or student performance.

As the review above illustrates, a limitation of the research to date is that much research conducted within TBL have focused on the effectiveness rather than the underlying processes of TBL. Hence, there is a gap in the literature where motivational effects have not been differentiated (e.g., Alvarez-Bell, et al., 2017). This is important because it allows the analysis of how active teaching methods relate to student engagement and learning. Given these contradictory findings, the aim of Paper III was to investigate whether an if so, how and why and under which conditions, TBL increases engagement and learning.

The PhD project
The literature review shows that there is strong research support for the general perception that active learning positively predicts student achievement. However, the review also identified several limitations and knowledge gaps. First, few learner-centred studies have employed the organismic approach of SDT. Much research has been conducted on the effect of active students, as opposed to passive students, and since learning-centred education has generally been understood from a constructivist approach (e.g., Jeno, 2015), less emphasis has been placed on the motivational and psychological effects of learning-centred education (Alexander & Murphy, 1998). Therefore, I investigate the factors that facilitate student autonomous motivation (viewed as active learning and a deep approach to learning) and the effect of autonomous motivation on achievement. Hence, a secondary aim of the thesis is to address the consequences of student autonomous motivation on achievement.

There has been little research in higher education in Norway concerning the motivational effects on achievement. Of the few identified studies, many are qualitative (e.g., Backåberg, Rask, Gummesson, & Brunt, 2015; Ladstein & Toft, 2013) or related to a specific practice such as outdoor sport activity or internships (e.g., Andreasen & Høigaard, 2017; Løvoll, Røysamb, & Vittersø, 2017). Specifically, effect studies have been lacking. In this thesis, I extend this line of research by investigating an integrative model of SDT in a Norwegian higher education context. All three papers employ a SDT perspective in the development of the research design and interpretation of the results. The results provide an important contribution to the SDT literature within the education sector, and the motivational perspective will be a strong contribution to the learner-centred education literature. The changes in the views of teaching and learning in

Norway in recent years from controlling learning to facilitating learning, and the increased focus on how to promote active learning, has created a renewed focus on the importance of motivation in learning. Thus, the results of this thesis may contribute to policymakers, higher education sector, and teachers, practical implications on how to organise and create the conditions to enhance quality-motivation and active learning from the lens of SDT.

The research topics I investigate in this thesis are:

1. The underlying pulls of student motivation and achievement
    a) Teacher-impact on student motivation and achievement
    b) The effect of a mobile-application tool on student motivation and learning
    c) The effect of a collaborative teaching method on student motivation and learning

2. The effect of student autonomous motivation on achievement

To investigate these research topics, three studies with different methodological designs were conducted, which allowed different research questions to be addressed, and make inferences about both relationship directionality (path-analysis, SEM) and causality (experiments).

The aim of Paper I (research topic 1a and 2) was to investigate the underlying motivational factors of dropout and achievement, by testing a comprehensive motivational model based on SDT. Paper I is a cross-sectional study based on a national survey concerning the education of biology students (see Hole et al., 2016). Social context impacts student motivation and achievement in many ways. As an example, the teacher-student relationship, alienation and not belonging, student goals, and the university's ability to provide challenging tasks and learning activities are all important in predicting positive educational outcomes (Wigfield, Cambria, & Eccles, 2012). Given the increased focus on lifelong learning (Ministry of Education and Research, 2017b), high-quality teaching (Ministry of Education and Research, 2017a), and the importance of social context in educational participation and academic success (Xie, Fang, & Shauman, 2015), a national representative study among higher education students was needed to understand better the motivational pull of achievement and dropout.

The aim of Paper II (research topic 1b and 2) was to test the effect of a mobile application tool on students´ motivation, perceived value of species identification, and achievement. Paper II is based on an experiment testing the effectiveness of an innovative active learning tool. The identification of species is a foundation of biological knowledge and competence, and crucial for the management of biodiversity nationally and globally (IEEM, 2011). Traditionally, species identification is taught using dichotomous keys found in floras or other printed identification literature. These books can get rather bulky, as they often contain detailed information of hundreds or thousands of species, and the keys are hard work for a beginner, as the discrimination between species is based on textual descriptions of morphological features, containing many

specialised terms. ArtsApp (bioCEED, 2017) was developed as an alternative identification tool for smartphones. In ArtsApp, the identification process is more dynamic. Students can choose where, i.e., with which trait, to start the identification process and they can also proceed through the identification process as they choose. ArtsApp provides the students with feedback during the identification processs, optional explanations of each species and trait, non-text context such as pictures and photos, and is geographically "smart" in that it excludes species that are not found nearby and therefore probably not relevant. Use of smartphones might provide enjoyment and interest (intrinsic motivation), and the identification process of ArtsApp might provide feedback and optimal challenges (competence-support) which could facilitate student achievement. Owing to the accessibility of smartphones in education (dscout, 2016; Felisoni & Godi, 2018; Slettemeås & Kjørstad, 2016), it is highly important to investigate the effect of mobile learning.

The aim of Paper III (research topic 1c and 2) was to explain the underlying motivational processes of different learning methods, and whether the implementation of TBL, relative to lectures, increase students´ engagement and learning. Paper III is based on a quasi-experiment investigating the effect of an active teaching method. Collaborative and cooperative learning, which is considered an active learning method (Prince, 2004), has been shown in meta-analyses and systematic reviews to have a positive effect on student achievement (Salas et al., 2008; Slavin, Lake, Hanley, & Thursto, 2014; Springer, Stanne, & Donovan, 1999). One collaborative teaching method that has received much attention, and which is considered learner-centred, is Team-Based Learning (TBL; see Paper III for a description of the teaching method). TBL is a teaching method with specific guidelines for how to conduct a teaching session. Moreover, within TBL there are processes that allow for competence-support (feedback through the readiness assurance process) and relatedness-support (collaboration in teams) that is conducive to satisfaction of the basic needs for competence and relatedness. In contrast, there might be thwarting of the need for autonomy (few choices around the decision-making process and peer-assessment). Given the vast use of TBL as a teaching method (e.g., Sisk, 2011), it is important to investigate the motivational pull of TBL in student engagement and learning.

Methods

This chapter describes the study systems, samples, measurements, ethics, and analytical strategies are in each of the the three papers. See Table 2 for an overview.

Study systems and samples

The participants across the three studies conducted for this thesis consisted of students in higher education. In Paper I, the sample consisted of biology students (*n*= 454 undergraduate, *n*= 297 graduate students) from a comprehensive biology education. I used a national representative sample retrieved from the bioCEED Survey 2015 (Hole, et al., 2016). The data was collected between mid February to late March 2015. In Paper II, the participants were second-year biology students (*n*= 71 undergraduate students). The data is based on a randomized experimental study. The students were recruited during a mandatory field course in mid June 2015. In Paper III, the participants consisted of second-year physiotherapy students (*n*=64). The data is based on a convenience sample. The students were recruited from a mandatory course in physiological neurology, and the data was collected between late August to mid October 2016.

Measurements

All scales used to measure motivational constructs in the present project were based on the assumptions of SDT. The scales were either retrieved from www.selfdeterminationtheory.org (Selfdeterminationtheory, 2017) where most scales are freely available, or they were retrieved from published manuscripts. Translation of the scales from English to Norwegian was done by the first author of the papers. The scales were then back-translated from Norwegian to English by an English-speaking editor. In instances of discrepancies between the first and second translation, a discussion was invoked in order to grasp both the psychological meaning of the item, and the grammatical wording. All scales were adapted for the purpose of the study. These procedures have been done in previous studies (Deci et al., 2001) and are in line with recommendations when working with scales in other languages (Harkness & Schoua-Glusberg, 1998). This procedure was done for all scales employed in the thesis.

Reliability and validity

Several measures were adopted to handle reliability and validity issues. Reliability, which is the consistency that a measurement instrument assesses a given construct, (Crano, Brewer, & Lac, 2015, p. 45), is quantified by internal consistency, interrater reliability, and temporal stability. Across the three papers, internal consistency was measured by means of the common approach of Cronbach´s alpha. Values around .90 are considered excellent, values around .80 are considered very good, whereas values around .70 are considered adequate (Kline, 2011). However, according to Crano, et al. (2015), the value depends on the amount of error the researcher is willing to accept. In Paper I, all measures were around .70. For Paper II, all measures except for controlled motivation had Cronbach values > .70. Finally, in Paper III, all measures had values above .70, except for external regulation which scored a Cronbach´s alpha of .59 for the pre-test measure, and just below the cut-off point at the post-test measurement. Additionally, for Paper II, interrater reliability was calculated for the two independent raters that coded the

students´ responses on the achievement test. The result produced high interrater reliability for the achievement measure.

Validity, which is the degree of relationship between a measurement instrument and the construct intended to asses (Crano, et al., 2015, p. 45), is an umbrella construct including several types of validity affecting the results of the study (Clark-Carter, 2010). The main types of validity are face validity, construct validity, content validity, and criterion-related validity. Face validity refers to the degree to which the item being measured is what the researchers intended. Construct validity refers to a measure measuring a theoretical construct well. Content validity refers to the degree a measure covers the complete range of behaviour of the construct being measured. Lastly, criterion-related validity refers to a measure´s ability to produce similar results to an existing measure. Relevant for the present thesis are issues relating to face, construct, and content validity. Face validity was addressed by providing the participants with general information about the purpose of the study, but not general enough to allow the students to understand the study's hypotheses; research assistants were not made aware of the study's hypotheses before collecting data (Paper II), or were trained to be neutral when administering data collection (Paper III); and anonymity and/or complete confidentiality were given to the students in order to promote honest answers to the questionnaires. Construct validity was handled by using previously validated scales derived from different research using a SDT approach, with appropriate scales chosen based on the purpose of each study. For instance, in Paper III, the situational measure of student motivation was assessed as opposed to the contextual measure of a course in Paper I. Content validity was addresses by using appropriate versions of each scale in the questionnaire. However, due to space constraints (Paper I), some scales had fewer items than the original. This has been noted as a limitation in the paper.

Ethical considerations
Several ethical considerations were taken into account in order to protect the participants in the studies. All studies received ethical approval from the Norwegian Centre for Research Data (NSD). The students in all studies were given information prior to their consent where it was stated that participation was voluntary. For Paper II, the student data were completely anonymous. For Papers I and III, the students´ personal numbers or student numbers were collected in order to retrieve their prospective grades in biology (Paper I) and connect individual answers for pre-test measures and post-test measures (Paper III). The students were informed that their personal number and student number would not be linked to their answers, they would be kept safe, and deleted after the necessary data were collected, or at the end of the project. Before all studies were conducted, measurements and study designs were piloted (Papers II and III). The pilot studies employed recommended "thinking-out-loud" procedures for feedback on the studies (Clark-Carter, 2010; Crano & Brewer, 2008).

Statistical strategies
All analyses were conducted using the statistical programs IBM SPSS 23 and IBM AMOS 23 (Arbuckle, 2013). For descriptive analyses such as reliability analyses, factor analyses, Pearson´s correlations, and multiple regression, and inferential statistics such as

independent samples t-test, one-way ANOVA, and paired sample t-test, SPSS was used. For multivariate analyses such as Structural Equation Modeling and path-analyses, AMOS was employed.

For all studies, the same criteria for normality, power, and effect size were employed. Normality was assessed in each study, incorporating the assumptions for each analysis, by reviewing standard deviations, skewness, and kurtosis. According to O´Keefe (2007), there are three factors concerning power; sample size, alpha level, and effect size of a population. To ensure sufficient power, power analyses were conducted for Papers II and III (the sample for Paper I is nationally representative and thus has sufficient power). Due to few studies assessing SDT principles in mobile-learning and TBL context, pilot-studies were carried out to guage power. All alpha-levels were set to $\alpha = .05$. Effect sizes in the thesis follow Cohen´s (1988) suggestions for interpretation: effect sizes are considered small at .2, medium at .6, and large at .8.

Different strategies were employed to handle missing data as there are a range of imputation techniques to account for missing data and values. Compared to traditional methods (listwise and pairwise deletion, mean substitution), modern methods (multiple imputation (MI), full-information maximum likelihood (FIML)) can be employed not only when data are missing completely at random (MCAR), but also when data are missing at random (MAR; Little, Jorgensen, Lang, & Moore, 2013). Modern techniques to handle missing data produce less bias parameters and better estimates of uncertainty (Graham, 2009). For Papers I (SEM-model) and III (path-analysis), FIML was employed to handle the missing values, as recommended for such multivariate models (Byrne, 2016; Little, et al., 2013). For Paper II, MI was used to create five imputations for three missing values. This is recommended when the missing values are less than 5 percent and when the data are missing at random (Schafer, 1999).

Study design and analytical strategies for Paper I

A cross-sectional design was used to test how well a SDT-based model fits a national representative sample of biology students. In such a design, data collection is gathered at one time point, without controlling for confounding variables, and thus not infer cause and effect (Greer & Mulhern, 2002). However, two measures were adopted to strengthen the design of this study. First, the study collected the students´ prospective academic achievements for that semester. This allowed the assessment of student motivation early in the semester and the ability to predict prospective achievement. Second, based on theorisation and previous research (Byrne, 2016; Kline, 2011), a structural equation model allowed the specification of a "causal" assumption of cause and effect between the students´ social context, their motivations, and in turn, their achievement.

Structural Equation Modeling (SEM) is a statistical analysis that takes a confirmatory approach in analysing hypothetical causal structural (regressions) equations (Byrne, 2016). SEM consists of both the measurement model and a structural model. Several conventional goodness-of-fit indices and cut-off criteria are used to measure how well the data fit the hypothetical model (Hu & Bentler, 1999). Specifically, a comparative fit

index (CFI) above .90, root mean square error of approximation (RMSEA) below .08, and a chi-square/degree of freedom ratio (χ^2/df) below 2, are considered acceptable.

Study design and analytical strategies for Paper II

An experiment (randomised controlled trial) was carried out to analyse the mean differences between the study conditions on student intrinsic motivation, perceived competence, and achievement, employing an independent t-test. An independent sample t-test is a statistical analysis employed when comparing the mean of an outcome between two groups where the outcomes are likely to be caused by the manipulation. A t-test, rather than a one-way ANOVA, was appropriate because the independent variable (condition: experiment vs control group) had only two levels.

Hierarchical regression analysis, which is a type of general multiple regression, is a procedure for entering independent variables into the equation in a specific order. This entering should be based on theoretical or logical rationales, not statistical (Tabachnick & Fidell, 2007). By entering different variables in steps, hierarchical regression analysis allows the analysis of the independent contribution of the variables when controlling for the variables in the previous step. Hierarchical regression analysis gives the model's total explained variance in the dependent variable, and the total explained variance of the independent variables for each step. In contrast to a full SEM, path-analyses only include a structural model and not a measurement model. Thus, path-analysis employs manifest variables, as opposed to latent variables, which is the case in the experiment. The same goodness-of-fit indices as mentioned above are used to evaluate the model fit.

Study design and analytical strategies for Paper III

The quasi-experiment in Paper III used a one-group pre-test/post-test design to test for differences between mean scores of student motivation, need-satisfaction, engagement, and achievement in lectures and in Team-Based Learning. Quasi-experiment refers to an experimental design in which the aim is to describe causal hypotheses about manipulated outcomes (Shadish, Cook, & Campbell, 2002). In contrast to a true experiment, a quasi-experiment lacks randomisation of individuals to study conditions. Quasi-experiments may lack control groups due to practical constraints such as funding, ethics, administrative reasons, or logistical constraints (Shadish, et al., 2002). There are a couple of reasons why a quasi-experiment was chosen. First, the lack of an equivalent control group meant it would be difficult to conclude that any finding was due to between-group differences and not within-group variability, although similar approaches have been taken using active learning methods and the same overarching theoretical perspective (e.g., Levesque-Bristol & Stanek, 2009). Second, central to TBL is the requirement for teams to participate over longer periods of time, but due to the few mandatory classes, short class periods, few participants, and difficulties of changing course descriptions, it was not possible to conduct a true experiment.

In order to test for mean differences between pre-test and post-test, a number of repeated sample t-tests were conducted. A repeated sample t-test is a statistical analysis that compares the same individual across two time-points. Path-analysis was then used to analyse the change scores from pre-test to post-test. Specifically, we calculated the

regressed standardised residuals from the post-test scores on the scores of the pre-test for all variables. Then, a path-analytical model was specified in which all predictor variables predict engagement, which in turn, predicts perceived learning. A path-analytical model allowed a test of how well a SDT-based model could explain changes between pre-test and post-test scores, and also a test of any mediation between the SDT-based constructs, engagement, and perceived learning. This procedure has been previously done in studies with a SDT-perspective (e.g., Ryan, et al., 2006). The same criteria as in Papers I and II were used to evaluate model fit.

Table 2

Overview of the methods used in the three papers in the thesis

	Paper I	Paper II	Paper III
Sample characteristics			
Programme	BSc and MSc in Biology	BSc course in Biology	BSc course in Biology/Physical therapy
Sample size	754	71	64
Student level	BSc and MSc	BSc	BSc
Design	Cross-sectional	Randomised experiment	Quasi-experiment
Spatial extent	Institutions in Norway	Research University	University College
Analyses			
SEM	x		
Path-analysis		x	x
Regression analysis		x	
t-test		x	
Repeated sample t-test			x
MANOVA	x		
One-way ANOVA	x		
Motivational measures			
LCQ	x	x	x
BPNS	x		x
AI	x		
SIMS			x
SRQ-L	x	x	
IMI		x	
PC	x	x	x
Engagement			x
Educational measures			
Dropout intentions	x		
Achievement	x	x	x
Species identification		x	

Note: LCQ (learning climate questionnaire) was used to measure the students´ perception of their teacher as autonomy supportive. BPNS (basic psychological needs scale) was used to measure students´ satisfaction of the psychological needs for autonomy, competence, and relatedness. AI (aspiration index) was used to measure the students´ intrinsic and extrinsic aspirations for starting at the university. SIMS (situational motivation scale) was used to measure students´ situational motivation for attending class. SRQ-L (self-regulation questionnaire-learning version) was used to measure students´ reason for learning in biology courses. IMI (intrinsic motivation inventory) was used to measure students´ post-experimental experience of intrinsic motivation. PC (perceived competence) was used to measure students´ feeling of competence within a learning context or activity. Dropout was measured as self-reported intentions. Engagement was used to measure students´ agentic, behavioural, emotional, and cognitive engagement. Achievement was measured as final semester grades in biology (Paper I), achievement on a nine-question test developed for the experiment (Paper II), and as self-reported learning (Paper III)

Results

This chapter presents the results from the different studies included in this thesis. See Figure 2 for an overview of the results. Paper I is a national representative cross-sectional study of biology students in Norway. Paper II is a randomised experiment of biology students´ achievement in identifying species. Paper III is a quasi-experiment of students´ change in motivation, engagement, and learning from lecture to Team-Based Learning (TBL).

	Paper I	Paper II	Paper III
Social context	Teachers	Arts App	Team-Based Learning
Need-supportive behaviours	Provides choice; Provides informational feedback; Frames intrinsic goals; Accepts negative affect; Provides meaningful rationale	Provides choice; Effectance-relevant feedback; Optimal challenges	Provides structure; Effectance-relevant feedback; Active learning tasks; Facilitates learning
Outcomes	Higher autonomous motivation; Higher perceived competence; Lower dropout intentions; Higher achievement	Higher intrinsic motivation; Higher perceived competence; Higher achievement	Higher intrinsic motivation and identified regulation; Higher external regulation; Higher perceived competence; Higher need-satisfaction; Higher engagement and perceived learning

Figure 2. Overview of the studies in the thesis, the social context, hypothesised need-supportive behaviours, and results on the educational outcomes

Paper I

The main aim of Paper I was to investigate whether a full Self-Determination Theory-based model could predict biology students´ prospective achievement and dropout intentions in higher education. Results from the SEM analysis found support for a SDT-based model (see Figure 3 and Paper I); specifically, the model significantly explains a substantial amount of variance in student prospective achievement and dropout intentions. As expected, autonomous motivation and perceived competence positively predict student achievement and negatively predict dropout intentions. Controlled motivation positively predicts dropout intentions and is unrelated to student achievement. Lastly, student extrinsic aspiration is a negative predictor of achievement. Student perceived competence and autonomous motivation are explained by the positive direct effect of teacher need-support and relatedness satisfaction, while only autonomous motivation is explained by the positive effect of student intrinsic aspiration. Controlled motivation is explained by the positive effect of student extrinsic aspiration.

Several significant indirect effects are also found. First, need-support positively and indirectly predicts student achievement, through perceived competence and autonomous motivation. Furthermore, need-support positively predicts perceived competence and autonomous motivation, which in turn, negatively predict dropout intentions. Relatedness positively predicts achievement, through the effect of perceived competence. Relatedness

also negatively predicts dropout, mediated by autonomous motivation and perceived competence. Intrinsic aspiration positively predicts achievement and negatively predicts dropout intentions through autonomous motivation. Lastly, extrinsic aspiration positively predicts controlled motivation, which in turn, positively predicts dropout intentions.

Student university well-being (University satisfaction) was also measured but omitted from the manuscript in the manuscript review process (see Table 3). The results are included here for completion, and show the expected directionality in that University satisfaction is positively related to autonomous motivation, perceived competence, relatedness, and need-support, and negatively related to dropout intentions. The results have implications for how institutions should consider the motivational pull of social context in relation to achievement and dropout. For instance, institutions need to consider student aspiration and relatedness, in addition to the effect of teacher need-support.

Table 3

Relationships between the study variables in paper I and University satisfaction (a proxy of University well-being)

	University satisfaction
Achievement	.09
Dropout intentions	-.18**
Autonomous motivation	.15**
Controlled motivation	-.06
Perceived competence	.21**
Relatedness	.22**
Need-support	.28**
Intrinsic aspiration	.02
Extrinsic aspiration	-.02

Note: ** significant at $p < .01$. University satisfaction were omitted from Paper I due to suggestions from a reviewer
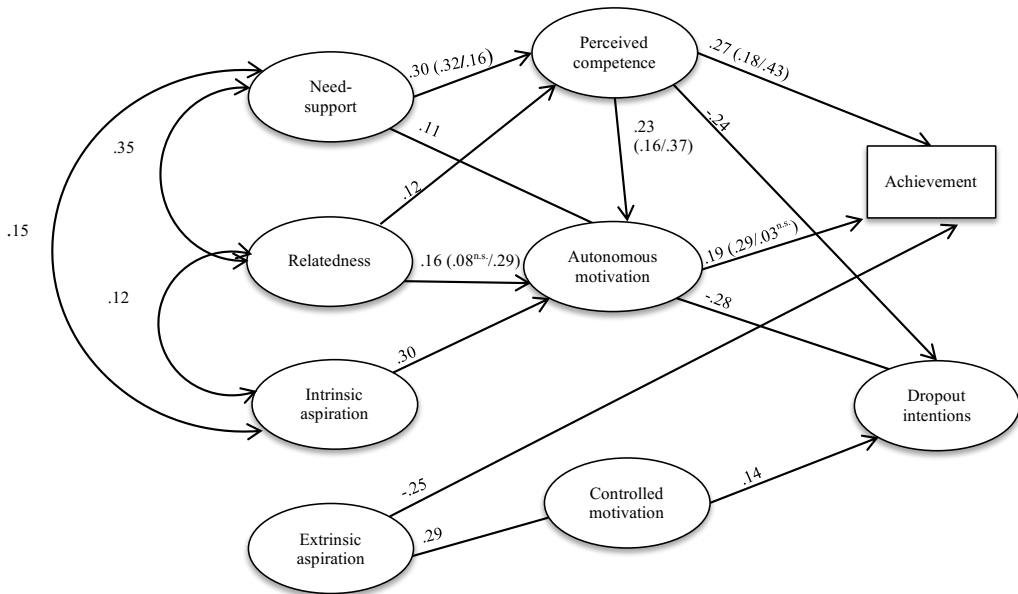
Figure 3. Final motivational model with standardised regression coefficients for total sample (Bachelor and Master students). For clarity, the measurement model is not shown. Additionally, only significant different paths between Bachelor and Master students are shown. Non-significant paths for multi-groups analysis for either Bachelor or Master students are indicated (n.s.).

Paper II

The main aim of Paper II was to test experimentally whether a technological mobile-application tool could increase student intrinsic motivation and perceived competence for species identification, and in turn, achievement in identifying species, compared to students using a traditional textbook method. Several main effects were found. First, students assigned to the mobile application-condition had significantly higher intrinsic motivation, perceived competence, and achievement scores, compared to the students assigned to the textbook-condition. Second, using a path-analytical model (see Figure 4 and Paper II), we found that the mobile application-condition positively predicts student perceived competence and intrinsic motivation. Only intrinsic motivation, in turn, significantly and positively predicts student achievement. Lastly, hierarchical regression analysis was used to analyse which factor accounted for the explained variance in student interest in identification of species and importance of knowing species. The results show that intrinsic motivation predicts interest in identification of species in all five steps, whereas the traditional textbook method became significant only when controlling for student intrinsic motivation and autonomous motivation. In importance of knowing species, intrinsic motivation, autonomous motivation, and the textbook method are significant in the last step. For both dependent variables, teacher autonomy support is unrelated. The results have important implications for how to facilitate undergraduate students´ intrinsic motivation and perceived competence. Specifically, using mobile-technologies that have inherent need-supportive elements could promote interest and enjoyment in the learning process for initially uninteresting learning activities.
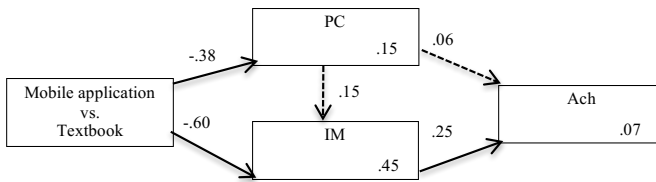
Figure 4. Mobile-application coded=1, Textbook coded=2. Path-analysis with standardised estimates. IM = Intrinsic motivation, PC = Perceived competence, Ach = Achievement. Stippled arrows indicate non-significant paths. Total effects (R^2) are shown in mediators and dependent variables

Paper III

The main aim of Paper III was to investigate whether collaborative learning, specifically Team-Based Learning, could increase student motivation, engagement, and perceived learning. Results show that student intrinsic motivation, identified regulation, external regulation, perceived competence, perceived need-support, need-satisfaction, engagement, and perceived learning significantly increased. Further, student amotivation significantly decreased from pre-test to post-test. Lastly, results from the path-analytical model (see Figure 5 and Paper III) show that increases in perceived competence and intrinsic motivation positively predict increased engagement. Increases in external regulation positively predict increases in engagement and increases in engagement positively predict increases in perceived learning. A test for indirect effects shows that increases in perceived competence indirectly predict increases in perceived learning through engagement. There is a significant and positive indirect effect for intrinsic motivation and perceived learning through engagement. Increases in external regulation predict increases in perceived learning mediated by engagement. The results have pedagogical implications for how teachers organise different teaching methods. For instance, a coerced teaching method might enhance external regulation, but could also increase autonomous motivation, competence, engagement, and learning if there are novel, optimally challenging, and interesting learning tasks within the teaching method.
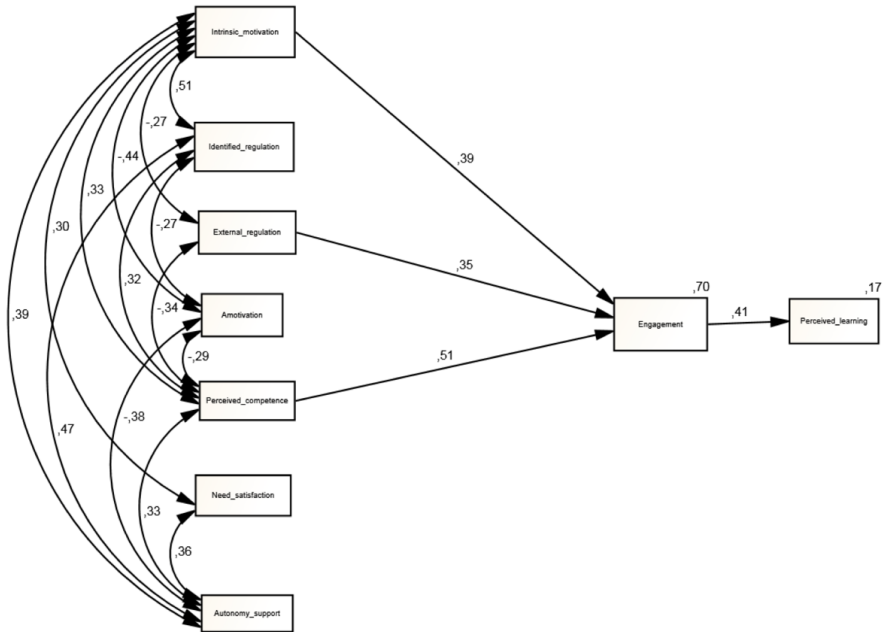
Figure 5. The model show all the study variables predicting students´ perceived learning, indirectly through engagement. All variables are significant at $p< 0.05$, except amotivation ←→ identified regulation, amotivation←→ perceived competence, external regulation ←→intrinsic motivation, need satisfaction←→intrinsic motivation, which are significant at $p<0.10$. For clarity, only significant paths are shown.

Discussion

The main aims of this thesis were to address factors that facilitate student active learning and to assess what the effects of student active learning are on educational outcomes. By applying the motivational approach of Self-Determination Theory (SDT), it is possible to analyse what factors predict active students (i.e., autonomous motivation) and how, in turn, active students relate to different outcomes. Results from the three papers seem to corroborate the theoretical assumptions of SDT.

Antecedents

In line with the assumptions of the thesis, innovative teaching tools and active teaching methods facilitated student autonomous motivation. Specifically, two learner-centred approaches were investigated, a mobile-application tool (Paper II) and Team-Based Learning (TBL; Paper III). In addition, the propensity of teachers to facilitate or inhibit student autonomous motivation was also investigated (Paper I).

The basic premise of learner-centred approaches is to facilitate student engagement and interaction with the learning process and material (Prince, 2004). ArtsApp (Paper II) is one such approach that enables interaction with learning material. It might be argued that employing a textbook to interact with learning material (identification of species) is a similar learner-centred approach. However, the two tools differ in the extent to which they satisfy the basic need for learners to experience choice about what and how to learn (Ferguson, 2010, p. 3). Based on the results of Paper II and the theoretical assumptions of SDT, one conclusion is that learners needs to feel choice (i.e., autonomy) *when* learning. SDT suggests that a social context that supports, as opposed to controls, the basic psychological needs and which nurtures the students´ inner motivational resources such as their interest, values, goals, and aspirations, is more likely to create the conditions for curious, active, and engaged students (Reeve, 2006). Identification of species with ArtsApp allows students' choice during the identification process. The conveying of choices allows the satisfaction of the psychological need for autonomy. Moreover, the constant feedback and dynamic identification which facilitates optimal challenges, satisfies the students´ basic psychological need for competence. Importantly, the simultaneous satisfaction of the needs for competence and autonomy allows the experience of intrinsic motivation. Hence, the in-built need-supportive functions in the mobile-application tool enhance student intrinsic motivation and perceived competence.

Conversely, teaching methods that do not afford autonomy in the learning process, might hinder autonomy (Paper III). For example, the immediate feedback process within TBL allows for the support for competence. Scratching the IF-AT cards allows for challenge that nurtures the need for competence. Peer-discussion during the team application allows for use of previous knowledge in a new and creative fashion, which is a central part of mastery and development of learning (Bandura, 1997; Csikszentmihalyi, et al., 2005). Thus, the feedback structure within TBL reduces discrepancy between knowledge and goals, which might enhance the students´ self-regulatory skills (e.g., Hattie & Timperley, 2007) and promote the students´ rote learning and conceptual understanding (Bloom, 1984).

Even though previous empirical work has found support for student satisfaction and enhanced achievement scores with TBL compared to traditional lectures (see; Carmichael, 2009; Gomez, Wu, & Passerini, 2010; P. A. Thomas & Bowen, 2011), few studies have investigated the underlying motivational pull that might either promote or thwart motivation. Modules within TBL (e.g., multiple-choice test, significant cases) may afford autonomy *when* learning. However, the inherent structures within TBL, such as creating teams, assessing learning, mandatory participation, and evaluation of peer-performance, might be experienced as controlling, as opposed to informational. For instance, it is argued that structure (relative to chaos) is a central part of experiencing competence in the classroom (Skinner & Belmont, 1993). Research on structure, which refers to the amount of information in the context about how to effectively achieve desired outcomes (Skinner & Belmont, 1993, p. 572) and autonomy-support, has shown that high levels of perceived teacher autonomy-support and structure is optimal for student motivation, engagement, and learning (see; Haerens, et al., 2017; Jang, Reeve, & Deci, 2010). However, Vansteenkiste et al. (2012) find in a person-centred approach that a cluster of low autonomy-support and high structure is associated with higher levels of controlled motivation. This exemplifies the need for autonomy *and* competence in order to truly reflect internalised self-regulation. That is, need-satisfaction is necessary for integration internalisation and wellness (Ryan & Deci, 2017).

Within the educational domain, the teacher is the facilitator of learner-centred education and active learning (Michael, 2006). Moreover, the teacher is an important authority figure that could promote autonomous motivation (Ryan & Deci, 2017). Teachers that are need-supportive create conditions that nurture the students´ inner motivational resources by listening, creating time for independent work, providing opportunity for the students to talk, praising signs of improvement and mastery, encouraging effort, being responsive to questions and comments, offering progress-enabling hints, and acknowledging the students´ perspective and experiences (Reeve & Jang, 2006, p. 214). Results from Paper I show that teacher need-support is positively associated with relatedness, intrinsic aspiration, perceived competence, autonomous motivation, and achievement. Furthermore, need-support is negatively associated with dropout intentions and unrelated to extrinsic aspiration and controlled motivation. Need-support directly predicts perceived competence and autonomous motivation. In Paper II, however, need-support does not uniquely account for the explained variance in interest for species identification and importance of knowing species. These findings might suggest that teachers are more distal when it comes to domain-specific interest in species. That is, need-supportive teachers in classrooms may not contribute to need-satisfaction when students are in the field.

Consequences
Self-Determination Theory suggests that when student motivation is intrinsic, the learning is more creative, conceptual, and engaging (Deci & Ryan, 1985). In a similar vein, when a learning activity is self-regulated and well-internalised, the behaviour (albeit an extrinsic motivation) is personally valued and important, and, congruent with other aspects of the self, the learning is more conceptual. This is because SDT asserts that when students´ have an internal locus of causality, act choicefully, and adopt behaviours

that are optimally challenging, they are more likely engaging in a learning activity out of autonomous reasons (Ryan & Deci, 2009). In contrast, when students perceive that their behaviour is coerced or pressured, the locus of causality for the target activity is perceived to be external to the student (DeCharms, 1968).

Results across the three papers seem to support this; for example, student autonomous motivation is positively related to achievement (Papers I–III) and negatively related to dropout intentions (Paper I). The different papers were not able to differentiate between rote-learning and conceptual understanding, however. For instance, in Paper III, it would have been interesting to assess whether intrinsic and identified regulation were more associated with higher scores on the significant cases, compared to external regulation and amotivation. It would also have been interesting to analyse whether external regulation was more associated with the individual quizzes. Similarly, whether a differentiation in identification of species (Paper II), for example differences in fact-finding in the mobile-application or textbook ("how many sedges exist in Norway?"; a measure of rote-learning) versus identifying a particular species (a proxy of conceptual learning), could have accounted for different levels of intrinsic motivation.

These results may have important implications for how higher education assesses students. Exams that are based on "one-size-fits-all" may not be sensitive for any particular student's level of competence. That is, one size fits all exams (typically school exams) may be either too challenging or too easy. Hidi and Harackiewicz (2000) argue that extrinsic motivators may be used to develop interest and long-term motivation. However, such exams and extrinsic motivators may be detrimental for student motivation (Ryan & Brown, 2005). Moreover, when teachers are need-supportive (Paper I) or when courses employ active-learning methods (Papers I and II), they promote more autonomously motivated students, which, in turn, are less grade-focused and more learning and growth-minded. Attaching high-stakes to tests is likely to put pressure on students to achieve and promote introjection, as opposed to autonomous motivation. Based on SDT, tests could be used informationally to improve learning and not just measure learning (i.e., portfolio-based assessment).

Institutional support of motivation and learning
Forest (2007) argues that many societal processes such as globalisation, market forces, and information technologies, affect the content of learning in higher education, but not how it is delivered. This has important implications for teaching and learning. From this thesis, several implications for the Norwegian higher education system can be drawn.

Large-class lecturing remains the standard teaching method despite research suggesting that it promotes passive learning (Biggs & Tang, 2011). There exist several learner-centred approaches that could facilitate active learning students. For example, problem-based learning, case-based learning, flipped-classroom, workplace learning, and peer instructions (DeLozier & Rhodes, 2017; Michael, 2006; Prince, 2004). Such active learning methods could be used to promote student autonomous motivation and achievement (cf. Papers II and III). However, there could be institutional and administrative factors that are inherently demotivating and thus experienced as ego-

depleting. For instance, non-academic processes (frustration of tedious, complex and laborious procedures) and assessment (summative assessment) may impact student motivation and internalisation (Nukpe, 2012). How can higher education institutions facilitate student motivation? The proximal solution is the teacher (Papers I and III). On the other hand, there could be institutionalised factors that inhibit teachers from being need-supportive: for example, there might be pressure both from the top and the bottom that is more conducive towards control rather than autonomy (Pelletier & Sharp, 2009). Students that are listless, apathetic, and disengaged may promote more controlling behaviour from the teacher, which in turn, may enhance the controlling motivation and amotivation within students. Moreover, administrative pressures such as time and curriculum constraints, high standards, accountability for student results, and pressure to conform to certain teaching methods may all thwart the psychological needs of the teachers, which in turn, control student motivation.

How can the higher education system create the conditions in which education has high learning quality (i.e., increase autonomous motivation and engagement, facilitate deep learning) and solve its educational challenges (i.e., graduate more students with natural sciences, reduce dropout, increase flexibility and autonomy)? Ryan and Deci (2009) suggest that there are two approaches with respect to need-satisfaction and need-support, top-down and bottom-up. A bottom-up approach is where teachers and administrators participate in a change process facilitated by a SDT expert. The expert conveys SDT principles in which the institution develops and implements these principles in teaching and learning. A bottom-up approach may be time-consuming, expensive, and difficult to implement in large institutions (Deci, 2009). A top-down approach, on the other hand, is a structured approach with specific policies, procedures, and curricula designed to promote need-satisfaction. When all levels within an institution (i.e., Head of Department, Head of Administration, administration, teachers, students) internalise the value of its importance (i.e., the change), successful implementation is more likely (Deci, 2009). When implementing learner-centred education, higher education institutions should strive to support the psychological needs of the teachers. By conducting seminars with active teaching methods where teachers can choose different seminars affords satisfaction of the need for autonomy. Allowing teachers to collaborate in teaching courses and to discuss obstacles and issues facilitates the satisfaction of relatedness. Lastly, providing teachers with in-class feedback on teaching methods and demonstrating different methods of teaching may support the need for competence.

Another approach within a learning situation may be the implementation of technology. Use of technologies in higher education has become an increasing trend (Altbach & Forest, 2007). Video-learning, "clickers", smartboard, and smartphones (Paper II) are examples of technologies that institutions may incorporate to enhance participation, relevance, and interest. However, technology and pedagogy has to be coherent in order to promote learning (Schmid, et al., 2014). That is, it is not the technology per se that contributes to the effect of student motivation and learning, rather it is the degree of need-satisfaction afforded within the technology that facilitates need-satisfaction, and in turn, enhances intrinsic motivation and perceived competence. Rigby and Przybylski (2009) argue that SDT provides an interesting framework to investigate the effects of

technology on behavioural outcomes. Specifically, ICT may enhance autonomous motivation for learning when satisfying autonomy (sense of ownership and control of one´s behaviour), competence (sense of self-efficacy and high effectiveness), and relatedness (sense of connectedness and belonging to a group; Koh, 2016). In the example of the the mobile-application tool (Paper II), it is argued that ArtsApp (the mobile-application tool) increases the students´ intrinsic motivation and perceived competence because it supports their basic needs for autonomy and competence (Rigby & Ryan, 2017), whereas Lids Flora lacks the ability to afford choice (autonomy) or provide ongoing feedback and information (competence). In summary, technologies may impact student motivation and competence. In line with SDT, the inherent functions of the technologies could be interpreted as intrinsically motivating to the extent that they are perceived as informational (relative to controlling and amotivational). For instance, a study by Jeno, Adachi, Grytnes, Vandvik, and Deci (2017) shows that the need-supportive elements of a mobile-application tool enhances need-satisfaction and intrinsic motivation, which in turn, increases positive affect and reduces negative affect (well-being). Thus, an informational context supports the basic needs for autonomy, competence, and relatedness and promotes intrinsic and autonomous motivation (relative to controlled motivation), which in turn, facilitates learning.

Limitations and strengths
There are several limitations worth mentioning when interpreting the results of this thesis. First, the theoretical approach of the present project has solely relied on the framework of SDT. Future studies should include other theoretical perspectives to further understand antecedent and mediating factors that might impact student outcomes. By including other theoretical frameworks, the results could have accounted for more of the explained variance in the outcome measures (see for instance; Seifert, 2004). For example, work by Diseth, et al. (2012), Danielsen, et al. (2009), and Diseth and Samdal (2014) have used several theoretical approaches to account for the explained variance in student well-being and achievement by combining SDT, Achievement Goal Theory, and Self-Efficacy Theory. Moreover, the thesis could have employed a learner-centred model to understand the motivational pull of active learning. For instance, constructivistic models focus on learner interactions with subject-matter, construct knowledge and meaning through communities of practices, and self-directive learning (Green & Gredler, 2002; O´Donnell, 2012). According to Lambert and McCombs (1998), however, a learner-centred model is supported by current constructivist, social constructivist, and intrinsic motivation theories. Hence, a learner-centred model seems to overlap with the theoretical assumptions of SDT. Moreover, according to Ryan and Deci (2017), the strength of a theory, as opposed to models, is that theories organise and synthesise larger systematic philosophies. In contrast, the limitations of models are that hypothetical relations between variables and constructs are proposed, with a poor foundation in the philosophies from which they are derived, and they are "ambiguous with respect to their implications across varied levels of analysis" (Ryan & Deci, 2017, p. 6).

Second, across all studies, self-reported measures of student motivation and outcomes have been employed, as opposed to behavioural measures of student motivation and outcomes. It may be argued that this is a limitation because subjective self-reports could

be unreliable compared to objective behavioural measures. However, this can be turned around: from a SDT-perspective, self-reports (i.e., from students) are more important than objective measures because the students´ perception of need-satisfaction is more important than objective measures (Ntoumanis, 2005; Vallerand, et al., 1997). An interesting future research direction would be to combine approaches: employ objective measures (i.e., observations, free-choice measures, diary-studies) alongside self-reports to test whether, and under what circumstances, these coincide and/or differ.

Third, the use of path-analysis may be inappropriate in studies with low sample size (Papers II and III). As a statistical procedure, SEM is considered a large-sample procedure (Kline, 2011). Wolf, Harrington, Clark, and Miller (2013) argue that a large sample size may be needed to achieve adequate statistical power and stability for model fit in SEM models. However, no conventional guidelines exist (O´Rourke & Hatcher, 2013), and suggestions have varied from an N/q ratio between 20:1 (Jackson, 2003) and 5:1 (Bentler & Chou, 1987). According to Iacobucci (2010), a large sample size is needed for unreliable and vague measures, but a small sample size is adequate for reliable measures with strong effects. The validity of Papers II and III, despite low sample sizes, is strengthened by (i) both Papers using measures retrieved from well-validated scales and taking an empirically-supported theoretical approach (Deci, et al., 1999; Sheldon, Osin, Gordeeva, Suchkov, & Sychev, 2017) and (ii) strong and consistent effects in both Papers (low sample size is more likely to result in Type II errors and/or in inconsistent effects if there are spurious correlations).

Lastly, the measurement of achievement has been assessed by means of standardised grades (Paper I), a material test (Paper II), and self-reported perceived learning (Paper III). There may be much variability in the different assessment methods and thus it may be inappropriate to infer any general relationship between motivation and achievement. However, by definition, achievement is defined as the students´ attainment based on their performance, as opposed to ability or potential (Wallace, 2009). According to Sadler (1987), there might be different ways of assessing achievement, such as norm-referenced assessment, which is the standardisation of grades along a Gaussian curve or other distributions; criterion-referenced assessment, which is the actual achievement of a student and employs measures that are interpretable in terms of performance standards; and standard-referenced assessment, which is an assessment of achievement using several smaller objective measurements, weighting and summing them up, and then teachers or other competent people make qualitative judgements about the achievement-level. Much of the higher education system, and school institutions in general, are based on norm-referenced assessment. According to the assumptions of SDT, feedback such as grades can have two functional significances: informational and controlling. Thus, within SDT, a grade can be used to provide competence-relevant feedback (=informational) or used to evaluate, compare, and screen (=controlling) (Ryan & Weinstein, 2009). Ryan and Deci (2017) note that tests may provide information to students if given in an autonomy supportive context. In Paper III, the information given to the students of the scratch cards (test) provided effectance-relevant feedback, but not summative. The aims of the different studies were not to evaluate the impact of the tests on motivation, but rather to investigate how motivation affected the results on the tests. For instance, in

Paper II, we were interested in how a need-supportive teaching method (ArtsApp) affected intrinsic motivation and perceived competence, which in turn, affect results on an achievement test, relative to a traditional teaching method that, on average, could be perceived as more controlling.

The thesis also has several strengths. In particular, I would like to highlight the benefits of the heterogeneous methodology, and of assessing of both motivation and achievement within the individual studies. The use of cross-sectional and experimental designs, for example, has enabled tests of the assumptions of SDT and learner-centred principles through several statistical procedures. Specifically, when using a cross-sectional design (Paper I), the ability to include the students´ prospective achievement has provided some support for temporal causality. By using an experimental design (Paper II) it was possible to infer cause and effect between the experimental condition and outcome, while the ability to assess change scores (Paper III) allowed a longitudinal investigation of the students´ perception of different types of teaching methods. It would, of course, have been interesting to take this triangulation of methods further within each paper, which may have increased the explanatory power in the different studies and models. Follow-up interviews, for example, could have helped understand the students´ phenomenological experience of learner-centred approaches. Such a notion is in line with the philosophical assumptions of SDT and the self (Ryan & Niemiec, 2009).

Another strength is the diverse use of student populations, which is important for the ecological validity. The use of biology students sampled nationally (Paper I), and from within a cohort of bachelor students within the biology programme in Bergen (Paper II) as well as physiotherapy students (Paper III) provides stronger support for the external validity of the thesis. That is, the results of the thesis may be more easily generalised across similar student samples. For instance, the results from this thesis may be applicable to other STEM subjects such as engineering, chemistry, and mathematics that employ field learning, lab-work, and/or taxonomy. Health professions similar to physical therapy (e.g., dentistry, medicine, nursing), may have stronger generalisability of the results than social sciences.

The results from this thesis provide support from a national representative sample of biology students as well as course-specific samples. This is especially important for two reasons: SDT is a theory that suggests that all humans have innate and universal psychological needs and thus are invariant across gender, culture, and socio-economic status. SDT emphasises that the needs are universal, for although "they may have different expressions or different vehicles through which they are satisfied, their core character is unchanging" (Ryan & Deci, 2002, p. 7). For the proposed motivational model for achievement and dropout it was therefore necessary to validate it nationally for all the higher education institutions that provide general biology. Courses within an institution differ in terms of teachers, syllabi, materials, rooms, and context, so providing practical support in field courses (Paper II) and theoretical courses (Paper III) is important for the implementation of SDT principles in higher education.

Conclusions

This thesis contributes new knowledge within learner-centred research on higher education. The results suggest that support of the basic psychological needs for autonomy, competence, and relatedness is important for facilitating autonomous types of motivation. Interpersonal climates facilitated by teachers, and teaching methods such as mobile-application tools and Team-Based Learning, should have elements of need-support in order to enhance autonomous motivation. Autonomous motivation may have positive effects on achievement and persistence due to endorsement of behaviour and an internal locus of causality. In summary, this thesis provides a novel approach to learner-centred education in understanding its motivational effects on student achievement that has previously been under-studied.

Practical implications

This work identifies several practical implications from the results of the three papers. First, the project has found different antecedents to facilitate student autonomous motivation. Based on the results, higher education institutions are recommended to consider the students´ inner motivational resources in developing teaching and learning. For instance, institutions are encouraged to consider student aspirations when entering a course. This is important because aspirations may be related to achievement and dropout. Moreover, there are multiple benefits to nurturing student autonomous motivation, and it is recommended for teachers to employ a need-supportive motivational style. This is achieved by satisfying the basic psychological needs for autonomy, competence, and relatedness by trying to understand the students´ internal frame of reference, to acknowledge negative feelings, and provide students with a meaningful rationale. To achieve high quality learning, teachers are recommended to base their teaching around their students´ interest, provide optimal challenges, and informational feedback. Last, the thesis identifies two learner-centred teaching methods that might enhance student achievement: mobile-learning and Team-Based Learning. However, an important conclusion is that not all teaching methods are created equally. Technological tools and teaching methods should be developed and evaluated in light of the three basic psychological needs for autonomy, competence, and relatedness, and assessed as to whether the functional significance of the method is informational, controlling, or amotivational. The consequences of the functional significance are strongly associated with the quality of motivation, learning, and wellness.

Future studies

Based on the results from the present project, it would be interesting to see if the results from the three studies could be replicated. A limitation of Paper I was the cross-sectional design. Future studies should extend this by conducting a longitudinal study and testing how the motivational dynamics fluctuate across a semester or a Bachelor/Master's degree. This would be useful for assessing how variation in motivation predicts student achievement and dropout. Papers II and III tested the motivational and learning outcomes of mobile-learning and Team-Based Learning. It would be beneficial to replicate the studies with different active teaching methods because there might be different motivational pulls within each method which might support or control the learners' psychological needs. For example, does flipped-classroom, problem-based learning, and

clickers promote optimal challenges, choice, and relatedness associated with need-support? Moreover, although the present study found that ned-support, relatedness, and autonomous motivation are positively associated with university satisfaction, future studies should include a measure of psychological well-being in active learning methods. This is potentially important to further explain the different motivational pulls of learner-centred education and preventing dropout, ill-being, and academic failure. Last, future studies should investigate how different active learning methods (e.g., mobile-application tools, TBL) affect students with different abilities and resources. That is, do active learning methods promote autonomous motivation and increase student achievement over and above previous achievement (high achievers vs. low achievers) and socio-economic status?

References

Abramson, L. Y., Seligman, M. E. P., & Teasdale, J. D. (1978). Learned helplessness in humans: Critique and reformulation. *Journal of Abnormal Psychology, 87*(1), 49-74.

Alexander, P. A., & Murphy, P. K. (1998). The research base for apa's learner-centered psychological principles. In N. M. Lambert & B. L. McCombs (Eds.), *How students learn: Reforming schools through learner-centered education* (pp. 25-60). Washington, DC: American Psychological Association.

Altbach, P. G., & Forest, J. J. F. (2007). Introduction. In J. J. F. Forest & P. G. Altbach (Eds.), *International Handbook of Higher Education* (Vol. 18, pp. 1-4). Dordrecht, The Netherlands: Springer.

Alvarez-Bell, R. M., Wirtz, D., & Bian, H. (2017). Identifying keys to success in innovative teaching: Student engagement and instructional practices as predictors of student learning in a course using a team-based learning approach. *Teaching & Learning Inquiry, 5*(2), 128-146. doi:10.20343/teachlearninqu.5.2.10

American Psychological Association. (1997). *Learner-centered psychological principles: A framework for school reform & redesign*. Washingtion, DC: American Psychological Association.

Andreasen, J. K., & Høigaard, R. (2017). Praksisopplæringen i grunnskolelærer- utdanningene – en studie om veiledningskvalitet. *Uniped, 40*(3), 222-234. doi:10.18261/ISSN.1893-8981-2017-03-04

Arbuckle, J. L. (2013). *Amos 22 user's guide*. Chicago, IL: SPSS.

Asikainen, H., & Gijbels, D. (2017). Do students develop towards more deep approaches to learning during studies? A systematic review on the development of students' deep and surface approaches to learning in higher education. *Educational Psychology Review, 29*, 205-234. doi:10.1007/s10648-017-9406-6

Backåberg, S., Rask, M., Gummesson, C., & Brunt, D. (2015). Video-based feedback combined with reflective enquiry – An interactive model for movement awareness among nursing students. *Nordic Journal of Digital Literacy, 10*(4), 246-264.

Bandura, A. (1977). Self-Efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1989). Human agency in Social Cognitive Theory. *American Psychologist, 44*(9), 1175-1184.

Bandura, A. (1997). *Self-Efficacy. The exercise of control*. New York: W. H. Freeman and Company.

Bandura, A. (2001). Social Cognitive Theory: An agentic perspective. *Annual Review of Psychology, 52*(1), 1-26.

Barr, R. B., & Tagg, J. (1995). From teaching to learning - A new paradigm for undergraduate education. *Change, 27*(6), 12-26.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497-529.

Baumeister, R. F., & Vohs, K. D. (2007). Self-regulation, ego depletion, and motivation. *Social and Personality Psychology Compass, 1*(1), 115-128.

Bentler, P. M., & Chou, C.-P. (1987). Practical issues in structual modeling. *Sociological Methods & Research, 16*(1), 78-117.

Benware, C. A., & Deci, E. L. (1984). Quality of learning with an active vesus passive motivational set. *American Educational Research Journal, 21*(4), 755-765.

Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university* (4 ed.). Berkshire/New York: McGraw-Hill Education.

bioCEED. (2013). Senter for fremragende utdanning - bioCEED. Retrieved from
        http://www.nokut.no/no/Sentre-for-fremragende-utdanning-SFU/Sentre/bioCEED/
bioCEED. (2017). ArtsApp. Retrieved from https://bioceed.w.uib.no/artsapp/
Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students'
        autonomous motivation on learning organic chemistry: A Self-Determination Theory
        perspective. *Science Education, 84*, 740-756.
Bligh, D. (1998). *What´s the use of lectures?* San Francisco: Jossey-Bass Publishers.
Bloom, B. S. (1956). *Taxonomy of educational objectives. Handbook 1: Cognitive domain*.
        London: David McKay Company, Inc.
Bloom, B. S. (1984). The 2sigma problem: The search for methods of group instruction as
        effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4-16.
Brahm, T., Jenert, T., & Wagner, D. (2016). The crucial first year: A longitudinal study of
        students' motivational development at a Swiss Business School. *Higher Education*, 1-20.
        doi:10.1007/s10734-016-0095-8
Brown, G., & Atkins, M. (2002). *Effective teaching in higher education* (3 ed.). London/New
        York: Routledge.
Byrne, B. M. (2016). *Structural equation modeling with AMOS. basic concepts, applications and
        programming* (3 ed.). New York: Routledge.
Carmichael, J. (2009). Team-Based Learning enhances performance in introductory biology.
        Journal of College Science Teaching, 38(4), 54-61.
Cavanagh, A. J., Aragón, O. R., Chen, X., Couch, B. A., Durham, M. F., Bobrownicki, A., . . .
        Graham, M. J. (2016). Student buy-in to active learning in a college science course. *CBE-
        Life Sciences Education, 15*(4), 1-9. doi:10.1187/cbe.16-07-0212
Chen, K.-C., & Jang, S.-J. (2010). Motivation in online learning: Testing a model of self-
        determination theory. *Computers in Human Behavior, 26*, 741-752.
        doi:10.1016/j.chb.2010.01.011
Chen, Y. S., Kao, T. C., & Sheu, J. P. (2003). A mobile learning system for scaffolding bird
        watching learning. *Journal of Computer Assisted Learning, 19*(3), 347-359.
Choi, J., Noh, G.-Y., & Park, D.-J. (2014). Smoking cessation apps for smartphones: Content
        analysis with the self-determination theory. *Journal of Medical Internet Research, 16*(2),
        e44. doi:10.2196/jmir.3061
Clark-Carter, D. (2010). *Quantitative psychological research. The complete student's
        companion*. New York: Psychology Press.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2 ed.). Hillsdale, New
        Jersey: Lawrence Erlbaum Associates.
Cornelius-White, J. (2007). Learner-centered teacher-student relationships are effective: A meta-
        analysis. *Review of Educational Research, 77*(1), 113-143.
        doi:10.3102/003465430298563
Crano, W. D., & Brewer, M. B. (2008). *Principles and methods of social research* (2 ed.). New
        Jersey: Lawrence Erlbaum Associates Publishers.
Crano, W. D., Brewer, M. B., & Lac, A. (2015). *Principles and methods of social research* (3
        ed.). New York: Routledge.
Csikszentmihalyi, M., Abuhamdeh, S., & Nakamura, J. (2005). Flow. In A. J. Elliot & C. S.
        Dweck (Eds.), *Hanbook of Competence Motivation* (pp. 598-608). New York: The
        Guilford Press.
Danielsen, A. G. (2010). Lærerens møte med elevene og selvregulert læring på ungdomstrinnet.
        Norsk Pedagogisk Tidsskrift, 94(6), 462-475.
Danielsen, A. G., Breivik, K., & Wold, B. (2011). Do perceived academic competence and
        school satisfaction mediate the relationships between perceived support provided by

teachers and classmates, and academic initiative? *Scandinavian Journal of Educational Research, 55*(4), 379-401. doi:10.1080/00313831.2011.587322

Danielsen, A. G., Samdal, O., Hetland, J., & Wold, B. (2009). School-related social support and students' perceived life satisfaction. *The Journal of Educational Research, 102*, 303–318.

DeCharms, R. (1968). *Personal causation: The internal affective determinants of behavior*. New York: Academic Press.

Deci, E. L. (2009). Large-scale school reform as viewed from the self-determination theory perpective. *Theory and Research in Education, 7*(2), 244-253. doi:10.1177/1477878509104329

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The Self-Determination Theory perspective. *Journal of Personality, 62*(1), 119-142.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*(6), 627-668.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*(10), 1-25. doi:10.1146/annurev-orgpsych-032516-113108

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Deci, E. L., & Ryan, R. M. (1987). The support of autonomy and the control of behavior. *Journal of Personality and Social Psychology, 53*(6), 1024-1037.

Deci, E. L., Ryan, R. M., Gagné, M., Leone, D. R., Usanov, J., & Kornazheva, B. P. (2001). Need satisfaction, motivation, and well-being in the work organization of a former eastern bloc country: A cross-cultural study of self-determination. *Personality and Social Psychology Bulletin, 27*(8), 930-942.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self- determination perspective. *Educational Psychologist, 26*(3 & 4), 325-346.

DeLozier, S. J., & Rhodes, M. G. (2017). Flipped classrooms: A review of key ideas and recommendations for practice. *Educational Psychology Review, 29*, 141-151. doi:10.1007/s10648-015-9356-9

Diener, E., Heintzelman, S. J., Kushlev, K., Tay, L., Wirtz, D., Lutes, L. D., & Oishi, S. (2017). Findings all psychologists should know from the new science on subjective well-being. *Canadian Psychology, 58*(2), 87-104. doi:10.1037/cap0000063

Diseth, Å., Breidablik, H. J., & Meland, E. (2017). Longitudinal relations between perceived autonomy support and basic need satisfaction in two student cohorts. *Educational Psychology*, 1-17. doi:10.1080/01443410.2017.1356448

Diseth, Å., Danielsen, A. G., & Samdal, O. (2012). A path analysis of basic need support, self-efficacy, achievement goals, life satisfaction and academic achievement level among secondary school students. *Educational Psychology*, 335-354. doi:10.1080/01443410.2012.657159

Diseth, Å., & Samdal, O. (2014). Autonomy support and achievement goals as predictors of perceived school performance and life satisfaction in the transition between lower and upper secondary school. *Social Psychology of Education, 17*(2), 269-291.

Dittmar, H., Bond, R., Hurst, M., & Kasser, T. (2014). The relationship between materialism and personal well-being: A meta-analysis. *Journal of Personality and Social Psychology, 107*(5), 879-924. doi:10.1037/a0037409

dscout. (2016). Mobile touches: dscout´s inaugural study on humans and their tech: dscout, Inc.

Dweck, C. S. (2017). From needs to goals and representations: Foundations for a unified theory of motivation, personality, and development. *Psychological Review, 124*(6), 689-719. doi:10.1037/rev0000082

Eccles, J. S., Adler, T. E., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives*. San Francisco, CA: W. H. Freeman and Company.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109-132.

Elliot, A. J. (1999). Approach and avoidance motivation and achievement goals. *Educational Psychologist, 34*(3), 169-189. doi:10.1207/s15326985ep3403_3

Elliot, A. J., & Thrash, T. M. (2001). Achievement goals and the hierarchical model of achievement motivation. *Educational Psychology Review, 13*(2), 139-156.

Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54*(1), 5-12.

Farley, J., Risko, E. F., & Kingstone, A. (2013). Everyday attention and lecture retention: the effects of time, fidgeting, and mind wandering. *Frontiers in Psychology, 4*, 1-9. doi:10.3389/fpsyg.2013.00619

Fathali, S., & Okada, T. (2017). A self-determination theory approach to technology-enhanced out-of-class language learning intention: A case of Japanese EFL learners. *International Journal of Research Studies in Language Learning, 6*(4), 53-64. doi:10.5861/ijrsll.2016.1607

Felisoni, D. D., & Godi, A. S. (2018). Cell phone usage and academic performance: An experiment. *Computers & Education, 117*, 175-187. doi:10.1016/j.compedu.2017.10.006

Ferguson, K. J. (2010). Facilitating student learning. In W. B. Jeffries & K. N. Hugget (Eds.), *An Introduction to Medical Learning* (pp. 1-10). New York: Springer.

Feri, R., Soemantri, D., & Jusuf, A. (2016). The relationship between autonomous motivation and autonomy support in medical students' academic achievement. *International Journal of Medical Education, 7*, 417-423. doi:10.5116/ijme.5843.1097

Fernández-Lao, C., Cantarero-Villanueva, I., Galiano-Castillo, N., Caro-Morán, E., Díaz-Rodríguez, L., & Arroyo-Morales, M. (2016). The effectiveness of a mobile application for the development of palpation and ultrasound imaging skills to supplement the traditional learning of physiotherapy students. *BMC Medical Education, 16*(274), 1-7. doi:10.1186/s12909-016-0775-1

Fiske, S. T. (2004). Mind the gap: In praise of informal sources of formal theory. *Personality and Social Psychology Review, 8*(2), 132-137.

Forest, J. J. F. (2007). Teaching and learning in Higher Education. In J. J. F. Forest & P. G. Altbach (Eds.), *International Handbook of Higher Education* (Vol. 18, pp. 347-375). Dordrecht, The Netherlands: Springer.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS, 111*(23), 8410-8415. doi:10.1073/pnas.1319030111

Furrer, C. J., Skinner, E. A., & Pitzer, J. R. (2014). The influence of teacher and peer relationships on students' classroom engagement and everyday motivational resilience. *National Society for the Study of Education, 113*(1), 101-123.

Gomez, E. A., Wu, D., & Passerini, K. (2010). Computer-supported team-based learning: The impact of motivation, enjoyment and team contributions on learning outcomes. *Computers & Education, 55*, 378-390. doi:10.1016/j.compedu.2010.02.003

Graham, J. W. (2009). Missing data analysis: Making It work in the real world. *Annual Review of Psychology, 60*, 549-576. doi:10.1146/annurev.psych.58.110405.085530

Green, S. K., & Gredler, M. E. (2002). A review of analysis of constructivism for school-based practice. *Social Psychology Review, 31*(1), 53-70.

Greer, B., & Mulhern, G. (2002). *Making sense of data and statistics in psychology*. London: Palgrave MacMillan.

Grolnick, W. S., & Ryan, R. M. (1987). Autonomy in children's learning: An experimental and individual difference investigation. *Journal of Personality and Social Psychology, 52*(5), 890-898. doi:10.1007/s11218-013-9244-4

Guay, F., & Vallerand, R. J. (1997). Social context, student's motivation, and academic achievement: Toward a process model. *Social Psychology of Education, 1*, 211-233.

Haerens, L., Vansteenkiste, M., Meester, A. D., Delrue, J., Tallir, I. B., Broek, G. V., . . . Aelterman, N. (2017). Different combinations of perceived autonomy support and control: identifying the most optimal motivating style. *Physical Education and Sport Pedagogy*, 1-21. doi:10.1080/17408989.2017.1346070

Harackiewicz, J. M., & Priniski, S. J. (2018). Improving student outcomes in Higher Education: The science of targeted intervention. *Annual Review of Psychology, 69*(11), 1-27. doi:10.1146/annurev- psych- 122216- 011725

Hardre, P. L., & Reeve, J. (2003). A motivational model of rural students' intentions to persist in, versus drop out of high school. *Journal of Education Psychology, 95*(2), 347-356. doi:10.1037/0022-0663.95.2.347

Harkness, J. A., & Schoua-Glusberg, A. (1998). Questionnaire in translation. *ZUMA-Nachrichten Spezial, 3*(1), 87-127.

Hartnett, M. (2015). Influences that undermine learners' perceptions of autonomy, competence and relatedness in an online context. *Australasian Journal of Educational Technology, 31*(1), 86-99.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81-112.

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research, 70*(2), 151-179. doi:10.3102/00346543070002151

Hole, T. N., Jeno, L. M., Holtermann, K., Raaheim, A., Velle, G., Simonelli, A. L., & Vandvik, V. (2016). *bioCEED Survey 2015*. Retrieved from University of Bergen, Bora - Bergen Open Research Archive: http://hdl.handle.net/1956/11952.

Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives, Structural Equation Modeling. *A Multidisciplinary Journal, 6*(1), 1-55.

Hwang, G.-J., & Chang, H.-F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education, 56*, 1023-1031. doi:10.1016/j.compedu.2010.12.0 02

Hyun, J., Ediger, R., & Lee, D. (2017). Students´ satisfaction on their learning process in active learning and traditional classrooms. *International Journal of Teaching and Learning in Higher Education, 29*(1), 108-118.

Iacobucci, D. (2010). Structural equations modeling: Fit indices, sample size, and advanced topics. *Journal of Consumer Psychology, 20*, 90-98. doi:10.1016/j.jcps.2009.09.003

IEEM. (2011). Ecological skills shaping the profession for the 21st century.

Jackson, D. J. (2003). Revisiting sample size and number of parameter estimates: Some support for the N:q hypothesis. *Structural Equation Modeling: A Multidisciplinary Journal, 10*(1), 128-141. doi:10.1207/S15328007SEM1001_6

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*(3), 588-600. doi:10.1037/a0019682

Jarjoura, C., Tayeh, P. A., & Zgheib, N. K. (2014). Using Team-Based Learning to teach grade 7 biology: Student satisfaction and improved performance. *Journal of Biological Education*, 1-19. doi:10.1080/00219266.2014.967277

Jeno, L. M. (2015). Encouraging active learning in Higher Education: A Self-Determination Theory perspective. *International Journal of Technology and Inclusive Education, 5*(1), 716-721.

Jeno, L. M., Adachi, P. J. C., Grytnes, J.-A., Vandvik, V., & Deci, E. L. (2017). The effects of m-learning on motivation, achievement, and well-being: A Self-Determination Theory approach. *Submitted for publication*.

Jeno, L. M., & Diseth, Å. (2014). A self-determination theory perspective on autonomy support, autonomous self-regulation, and perceived school performance. *Reflecting Education, 9*(1), 1-20.

Joussemet, M., Landry, R., & Koestner, R. (2008). A Self-Determination Theory perspective on parenting. *Canadian Psychology, 49*(3), 194-200. doi:10.1037/a0012754

Kaplan, A., Katz, I., & Flum, H. (2012). Motivation theory in educational practice: Knowledge claims, challenges, and future directions. In K. R. Harris, S. Graham & T. Urdan (Eds.), *APA educational psychology handbook, Vol 2: Individual differences and cultural and contextual factors* (pp. 165-194). Washington, DC, US: American Psychological Association.

Kline, R. B. (2011). *Principles and practice of structural equation modeling*. New York: The Guilford Press.

Koestner, R., Ryan, R. M., Bernieri, F., & Holt, K. (1984). Setting limits on children's behavior: The differential effects of controlling vs. informational styles on intrinsic motivation and creativity. *Journal of Personality, 52*(3), 233-248.

Koh, C. (2016). Translating motivational theory into application of information technology in the classroom. In W. C. Liu, J. C. K. Wang & R. M. Ryan (Eds.), *Building autonomous learners. Perspectives from Research and Practice using Self-Determination Theory* (pp. 245-258). Singapore: Springer.

Koh, C., Tan, H. S., Tan, K. C., Fang, L., Fong, F. M., Kan, D., . . . Wee, M. L. (2010). Investigating the effect of 3D simulation-based learning on the motivation and performance of engineering students. *Journal of Engineering Education, 99*(3), 237-251.

Koutsogeorgopoulou, V. (2016). *Addressing the challenges in higher education in Norway*. (Working Papers, No. 1285). Paris: OECD Publishing.

Ladstein, S., & Toft, G. O. (2013). Maur eller penger: Hvorfor velge og gjennomføre et nettstudium i naturfag? *Uniped, 36*(1), 59-72. doi:10.3402/uniped.v36i1.20955

Lambert, N. M., & McCombs, B. L. (1998). Introduction: Learner-centered schools and classrooms as a direction for school reform. In N. M. Lambert & B. L. McCombs (Eds.), *How students learn: Reforming schools through learner-centered education* (pp. 1-22). Washington, DC: American Psychological Association.

Levesque, C., Zuehlke, A. N., Stanek, L. R., & Ryan, R. M. (2004). Autonomy and competence in German and American university students: A comparative study based on Self-Determination Theory. *Journal of Educational Psychology, 96*(1), 68-84. doi:10.1037/0022-0663.96.1.68

Levesque-Bristol, C., & Stanek, L. R. (2009). Examining self-determination in a service learning course. *Teaching of Psychology, 36*, 262-266. doi:10.1080/00986280903175707

Ling, C., Harnish, D., & Shehab, R. (2014). Educational apps: Using mobile applications to enhance student learning of statistical concepts. *Human Factors and Ergonomics in Manufacturing & Service Industries, 24*(5), 532-543.

Little, T. D., Jorgensen, T. D., Lang, K. M., & Moore, E. W. G. (2013). On the joys of missing data. *Journal of Pediatric Psychology, 39*(2), 151-162. doi:10.1093/jpepsy/jst048

Løvoll, H. S., Røysamb, E., & Vittersø, J. (2017). Experiences matter: Positive emotions facilitate intrinsic motivation. *Cogent Psychology, 4*(1340083), 1-15. doi:10.1080/23311908.2017.1340083

Maehr, M. L., & Zusho, A. (2009). Achievement Goal Theory. The past, present, and future. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 77-104). New York: Routledge.

McCombs, B. L., & Vakili, D. (2005). A learner-centered framework for e-learning. *Teacher College Record, 107*(8), 1582-1600.

McInerney, M. J., & Dee Fink, L. (2003). Team-Based Learning enhances long-term retention and critical thinking in an undergraduate microbial physiology course. *Microbiology Education, 4*, 3-12.

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*(4), 159-167. doi:10.1152/advan.00053.2006.

Ministry of Education and Research. (2001). *Gjør din plikt - Krev din rett. Kvalitetsreform av høyere utdanning. St.meld. nr. 27 (2000-2001)*. Oslo: Ministry.

Ministry of Education and Research. (2008). *NOU 2008:3 Sett under ett. Ny struktur i høyere utdanning*. Oslo.

Ministry of Education and Research. (2011). *Nasjonalt kvalifikasjonsrammeverk for livslang læring (NKR)*. Oslo: Ministry.

Ministry of Education and Research. (2017a). *Kultur for kvalitet i høyere utdanning. St.meld 16 (2016-2017)*. Oslo: Ministry.

Ministry of Education and Research. (2017b). *Lærelyst - tidlig innsats og kvalitet i skolen*. Oslo: Ministry.

Morgan, K., Morgan, M., Johansson, L., & Ruud, E. (2016). A systematic mapping of the effects of ICT on learning outcomes. Oslo: Knowledge Center for Education.

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence and relatedness in the classroom. Applying self-determination theory to education practice. *Theory and Research in Education, 7*(2), 133-144. doi:10.1177/1477878509104318

Ntoumanis, N. (2005). A prospective study of participation in optional school physical education using a self-determination theory framework. *Journal of Educational Psychology, 97*(3), 444-453. doi:10.1037/0022-0663.97.3.444

Nukpe, P. (2012). Motivation: theory and use in Higher Education. *Investigations in university teaching and learning, 8*, 11-17.

O´Donnell, A. M. (2012). Constructivism. In K. R. Harris, S. Graham & T. Urdan (Eds.), *APA educational psychology handbook, Vol 1: Theories, constructs, and critical issues* (pp. 61-84). Washington, DC, US: American Psychological Association.

O´Keefe, D. J. (2007). Post hoc power, observed power, a priori power, retrospective power, prospective power, achieved power: Sorting out appropriate uses of statistical power analyses. *Communication Methods and Measures, 1*(4), 291-299.

O´Rourke, N., & Hatcher, L. (2013). *A step-by-step approach to using SAS for factor analysis and structural equation modeling* (2 ed.). Cary, NC, USA: SAS Institute Inc.

OECD. (2014). *OECD skills strategy diagnostic report: Norway*. Paris: OECD Publications.

Ozgonul, L., & Alimoglu, M. K. (2017). Comparison of lecture and team-based learning in medical ethics education. *Nursing Ethics*, 1-17. doi:10.1177/0969733017731916

Park, H.-R., Kim, C.-J., Park, J.-W., & Park, E. (2015). Effects of team-based learning on perceived teamwork and academic performance in a health assessment subject. *Collegian, 22*, 299-305. doi:10.1016/j.colegn.2014.05.001

Pelletier, L. G., & Sharp, E. C. (2009). Administrative pressures and teachers' interpersonal behaviour in the classroom. *Theory and Research in Education, 7*(2), 174-183. doi:10.1177/1477878509104322

Pervin, L. A. (1968). Performance and satisfaction as a function of individual-environmental fit. *Psychological Bulletin, 69*(1), 56-68.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5-12.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*, 667-686. doi:10.1037/0022-0663.95.4.667

Pitts, K., Pudney, K., Zachos, K., Maiden, N., Krogstie, B., Jones, S., . . . Turner, I. (2015). Using mobile devices and apps to support reflective learning about older people with dementia. *Behaviour & Information Technology, 34*(6), 613-631. doi:10.1080/0144929X.2015.1015165

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223-231.

Reeve, J. (2006). Teachers as facilitators: What autonomy-supportive teachers do and why their students benefit. *Elementary School Journal, 106*(3), 225-236.

Reeve, J. (2009a). *Understanding motivation and emotion* (5 ed.). Iowa: John Wiley & Sons Inc.

Reeve, J. (2009b). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist, 44*(3), 159-175. doi:10.1080/00461520903028990

Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98*(1), 209-218. doi:10.1037/0022-0663.98.1.209

Reeve, J., Jang, H., Hardre, P. L., & Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. *Motivation and Emotion, 26*(3), 183-207.

Reeve, J., Nix, G. A., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology, 95*(2), 375-392. doi:10.1037/0022-0663.95.2.375

Richardson, M., Abraham, C., & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin, 138*(2), 353–387. doi:10.1037/a0026838

Rigby, C. S., & Przybylski, A. K. (2009). Virtual worlds and the learner hero. How today's video games can inform tomorrow's digital learning environments. *Theory and Research in Education, 7*(2), 214-223. doi:10.1177/1477878509104326

Rigby, C. S., & Ryan, R. M. (2017). Time well-spent? Motivation for entertainment media and its eudaimonic aspect through the lens of Self-Determination Theory. In L. Reinecke & M. B. Oliver (Eds.), *The Routledge handbook of media use and well-being international perspectives on theory and research on positive media effects* (pp. 34-48). New York: Routledge.

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology, 26*(2), 234-242. doi:10.1002/acp.1814

Robbins, S. B., Lauver, K., Le, H., Davis, D., & Langley, R. (2004). Do psychological and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin, 130*(2), 261-288. doi:10.1037/0033-2909.130.2.261

Roca, J. C., & Gagné, M. (2008). Understanding e-learning continuance intention in the workplace: A self-determination theory perspective. *Computers in Human Behavior, 24*, 1585-1604. doi:10.1016/j.chb.2007.06.001

Rocchi, M., Pelletier, L., Cheung, S., Baxter, D., & Beaudry, S. (2017). Assessing need-supportive and need-thwarting interpersonal behaviours: The Interpersonal Behaviours

Questionnaire (IBQ). *Personality and Individual Differences, 104*, 423-433. doi:10.1016/j.paid.2016.08.034

Ryan, R. M., & Brown, K. W. (2005). Legislating competence. High-stake testing policies and their relations with psychological theories and research. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of Competence and Motivation* (pp. 354-372). New York: The Guilford Press.

Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54-67. doi:10.1006/ceps.1999.1020,

Ryan, R. M., & Deci, E. L. (2000b). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. doi:10.1037110003-066X.55.1.68

Ryan, R. M., & Deci, E. L. (2002). An overview of Self-Determination Theory: An organismic-dialectical perspective. In E. L. Deci & R. M. Ryan (Eds.), *Handbook of Self-Determination Research* (pp. 3-36). New York: The University of Rochester Press.

Ryan, R. M., & Deci, E. L. (2006). Self-regulation and the problem of human autonomy: Does psychology need choice, self-determination, and will? *Journal of Personality, 74*(6), 1557-1585. doi:10.1111/j.1467-6494.2006.00420.x

Ryan, R. M., & Deci, E. L. (2008). A Self-Determination Theory approach to psychotherapy: The motivational basis for effective change. *Canadian Psychology, 49*(3), 186-193. doi:10.1037/a0012753

Ryan, R. M., & Deci, E. L. (2009). Promoting self-determined school engagement. Motivation, learning, and well-being. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 171-195). New York: Routledge.

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory. Basic psychological needs in motivation, development, and wellness*. New York: The Guilford Press.

Ryan, R. M., & Grolnick, W. S. (1986). Origins and pawns in the classroom: Self-report and projective assessments of children's perceptions. *Journal of Personality and Social Psychology, 50*(3), 550-558.

Ryan, R. M., & Hawley, P. H. (2016). Naturally good?: Basic psychological needs and the proximal and evolutionary bases of human benevolence. In K. W. Brown & M. R. Leary (Eds.), *The Oxford Handbook of Hypo-egoic Phenomena*. New York: Oxford University Press.

Ryan, R. M., & Lynch, M. F. (2003). Motivation and classroom management. In R. Curren (Ed.), *A Companion to the Philosophy of Education* (pp. 260-271). Oxford: Blackwell Publishing Ltd.

Ryan, R. M., & Niemiec, C. P. (2009). Self-Determination Theory in schools of education. Can an empirically supported framework also be critical and liberating? *Theory and Research in Education, 7*(2), 263-272.

Ryan, R. M., Patrick, H., Deci, E. L., & Williams, G. C. (2008). Facilitating health behaviour change and its maintenance: Interventions based on Self-Determination Theory. *The European Health Psychologist, 10*, 2-5.

Ryan, R. M., Rigby, C. S., & Przybylski, A. K. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30*, 347-363. doi:10.1007/s11031-006-9051-8

Ryan, R. M., & Weinstein, N. (2009). Undermining quality teaching and learning. A self-determination theory perspective on high-stake testing. *Theory and Research in Education, 7*(2), 224-233. doi:10.1177/1477878509104327

Raaheim, A. (2011). *Læring og undervisning*. Bergen: Fagbokforlaget.

Sadler, D. R. (1987). Specifying and promulgating achievement standards. *Oxford Review of Education, 13*(2), 191-209.

Salas, E., DiazGranados, D., Klein, C., Burke, C. S., Stagl, K. C., Goodwin, G. F., & Halpin, S. M. (2008). Does team training improve team performance? A meta-analysis. *Human Factors, 50*(6), 903-933. doi:10.1518/ 001872008X375009

Schafer, J. L. (1999). Multiple imputation: A primer. *Statistical Methods in Medical Research, 8*, 3-15.

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Surkes, M. A., . . . Woods, J. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education, 72*, 271-291. doi:10.1016/j.compedu.2013.11.002

Schneider, B. (1987). E=f(P,B): The road to a radical approach to person-environment fit. *Journal of Vocational Behavior, 31*, 353-361.

Schunk, D. H., & Pajares, F. (2009). Self-Efficacy Theory. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 35-54). New York: Routledge.

Seifert, T. L. (2004). Understanding student motivation. *Educational Research, 46*(2), 137-149. doi:10.1080/0013188042000222421

Selfdeterminationtheory. (2017). Questionnaires. Retrieved 01.12, 2014, from http://selfdeterminationtheory.org/questionnaires/

Seligman, M. E. P., & Csikszentmihalyi, M. (2000). Positive psychology. An introduction. *American Psychologist, 55*(1), 5-14. doi:10.1037//0003-066X.55.1.5

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Belmont, CA: Wadsworth, Cengage Learning.

Sheldon, K. M., Osin, E. N., Gordeeva, T. O., Suchkov, D. D., & Sychev, O. A. (2017). Evaluating the dimensionality of Self-Determination Theory's relative autonomy continuum. *Personality and Social Psychology Bulletin, 43*(9), 1215-1238. doi:10.1177/0146167217711915

Sisk, R. J. (2011). Team-Based Learning: Systematic research review. *Journal of Nursing Education, 50*(2), 665-669. doi:10.3928/01484834-20111017-01

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology, 85*(4), 571-581.

Slavin, R. E., Lake, C., Hanley, P., & Thursto, A. (2014). Experimental Evaluations of Elementary Science Programs: A Best-Evidence Synthesis. *Journal of Research in Science Teaching, 51*(7), 870-901. doi:10.1002/tea.21139

Slettemeås, D., & Kjørstad, I. (2016). *Nyheter i en digitalisert hverdag. En landsdekkende undersøkelse av ungdom og unge voksnes medierelaterte praksiser og nyhetskonsum via smarttelefon, sosiale medier og nyhetsaggregatorer*. (Oppdragsrapport nr. 10 - 2016). Oslo: SIFO.

Sommet, N., & Elliot, A. J. (2017). Achievement goals, reasons for goal pursuit, and achievement goal complexes as predictors of beneficial outcomes: Is the influence of goals reducible to reasons? *Journal of Educational Psychology, 109*(8), 1141-1162. doi:10.1037/edu0000199

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69*(1), 21-51.

Standage, M., & Ryan, R. M. (2012). Facilitating self-regulatory processes to support and maintain health and well-being. In G. C. Roberts & D. C. Treasure (Eds.), *Advances in motivation in sports and exercise* (pp. 233-270). Champaign, IL: Human Kinetics.

Stensaker, B. (2000). *Høyere utdanning i endring. Dokumentasjon og drøfting av kvalitetsutvikling ved seks norske universiteter og høgskoler 1989-1999*. (Report 6). Oslo: NIFU.

Stover, S., & Ziswiler, K. (2017). Impact of active learning environments on community of inquiry. *International Journal of Teaching and Learning in Higher Education, 29*(3), 4458-4470.

Sørebø, Ø., Halvari, H., Gulli, V. F., & Kristiansen, R. (2009). The role of self-determination theory in explaining teachers' motivation to continue to use e-learning technology. *Computers & Education, 53*(4), 1177-1187.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5 ed.). Boston: Pearson Education.

Tamborini, R., Bowman, N. D., Eden, A., Grizzard, M., & Organ, A. (2010). Defining media enjoyment as the satisfaction of intrinsic needs. *Journal of Communication, 80*, 758-777.

Tamborini, R., Grizzard, M., Bowman, N. D., Reinecke, L., Lewis, R. J., & Eden, A. (2011). Media enjoyment as need satisfaction: The contribution of hedonic and nonhedonic needs. *Journal of Communication, 61*, 1025-1042.

Thomas, P. A., & Bowen, C. W. (2011). A controlled trial of team-based learning in an ambulatory medicine clerkship for medical students, teaching and learning in medicine. *Teaching and Learning in Medicine, 23*(1), 31-36. doi:10.1080/10401334.2011.536888

Thomas, R. L., & Fellowes, M. D. E. (2016). Effectiveness of mobile apps in teaching field-based identification skills. *Journal of Biological Education*. doi:10.1080/00219266.2016.1177573

Trope, Y. (2004). Theory in social psychology: Seeing the forest and the trees. *Personality and Social Psychology Review, 8*(2), 193-200.

Tucker, J. M., & Brewster, M. P. (2015). Evaluating the effectiveness of team-based learning in undergraduate criminal justice courses. *Journal of Criminal Justice Education, 26*(4), 446-470. doi:10.1080/10511253.2015.1052000

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*(5), 1161-1176.

Vansteenkiste, M., Lens, W., Elliot, A. J., Soenens, B., & Mouratidis, A. (2014). Moving the achievement goal approach one step forward: Toward a systematic examination of the autonomous and controlled reasons underlying achievement goals. *Educational Psychologist, 49*(3), 153-174. doi:10.1080/00461520.2014.928598

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini-theories of self-determination theory: An historical overview, emerging trends, and future directions. In T. C. Urdan & S. A. Karabenick (Eds.), *Advances in motivation and achievement, v. 16A—The decade ahead: Theoretical perspectives on motivation and achievement* (pp. 105-165). London: Emerald Group Publishing Limited.

Vansteenkiste, M., Sierens, E., Goossens, L., Soenens, B., Dochy, F., Mouratidis, A., . . . Beyers, W. (2012). Identifying configurations of perceived teacher autonomy support and structure: Associations with self-regulated learning, motivation and problem behavior. *Learning and Instruction, 22*, 431-439. doi:10.1016/j.learninstruc.2012.04.002

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the motivational impact of intrinsic versus extrinsic goal framing and autonomy-supportive versus internally controlling communication style on early adolescents' academic achievement. *Child Development, 76*(2), 483-501.

Vansteenkiste, M., Soenens, B., Verstuyf, J., & Lens, W. (2009). 'What is the usefulness of your schoolwork?' The differential effects of intrinsic and extrinsic goal framing on optimal

learning. *Theory and Research in Education, 7*(2), 155-163. doi:10.1177/1477878509104320

Vermeulen, N., Parker, J. N., & Penders, B. (2013). Understanding life together: A brief history of collaboration in biology. *Endeavor, 37*(3), 162-171. doi:10.1016/j.endeavour.2013.03.001

Wallace, S. (Ed.). (2009). *Oxford Dictionary of Education*. Oxford: Oxford University Press.

Wentzel, K. R., & Wigfield, A. (2009). Introduction. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 1-8). New York: Routledge.

White, R. W. (1959). Motivation reconsidered: The concept of competence. *Psychological Review, 66*, 297-333.

Wieman, C. E. (2014). Large-scale comparison of science teaching methods sends clear message. *PNAS, 111*(23), 8319-8320. doi:10.1073/pnas.1407304111

Wigfield, A., Cambria, J., & Eccles, J. S. (2012). Motivation in education. In R. M. Ryan (Ed.), *The Oxford Handbook of Human Motivation* (pp. 463-478). Oxford: Oxford University Press.

Wigfield, A., Tonks, S., & Klauda, S. L. (2009). Expectancy-Value Theory. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 55-75). New York: Routledge.

Wijnen, M., Loyens, S. M. M., Wijnia, L., Smeets, G., Kroeze, M. J., & Molen, H. T. V. d. (2017). Is problem-based learning associated with students' motivation? A quantitative and qualitative study. *Learning Environments Research*, 1-21. doi:10.1007/s10984-017-9246-9

Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models: An evaluation of power, bias, and solution propriety. *Educational and Psychological Measurement, 73*(6), 913-934. doi:10.1177/0013164413495237

Wu, W.-H., Wu, Y.-C. J., Chen, C.-Y., Kao, H.-Y., Lin, C.-H., & Huang, S.-H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59*(2), 817-827.

Waaler, R., Halvari, H., Skjesol, K., & Bagøien, T. E. (2013). Autonomy support and intrinsic goal progress expectancy and its links to longitudinal study effort and subjective wellbeing: The differential mediating effect of intrinsic and identified regulations and the moderator effects of effort and intrinsic goals. *Scandinavian Journal of Educational Research, 57*(3), 325-341. doi:10.1080/00313831.2012.656284

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual Review of Psychology, 41*, 331-358. doi:10.1146/annurev-soc-071312-145659

II

The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self-Determination Theory perspective

CrossMark

Lucas M. Jeno [a, *], John-Arvid Grytnes [b], Vigdis Vandvik [a]

[a] bioCEED- Centre of Excellence in Biology Education, Department of Biology, University of Bergen, Norway
[b] Ecological and Environmental Change Research Group, Department of Biology, University of Bergen Norway

ABSTRACT

Biology students traditionally use a textbook in the field and on courses to identify species, but now a new mobile-application tool has been developed as an alternative. Guided by Self-Determination Theory (SDT) we conducted an experimental study to test the effect of the mobile-application, relative to the traditional textbook, on students' intrinsic motivation, perceived competence, and achievement. Seventy-one students were randomly assigned to either an experimental condition (mobile application - ArtsApp) or control condition (textbook - Lids flora). As hypothesised, the students using ArtsApp had higher intrinsic motivation, perceived competence, and achievement, compared to the textbook control group, with medium to large effect sizes. Furthermore, using the mobile application, relative to the textbook, predicted intrinsic motivation, which in turn, predicted higher achievement scores in a path analysis. Lastly in a hierarchical regression analysis, intrinsic motivation and autonomous motivation accounted over and above in students' interest for species identification, and importance of knowing species. These results are in line with SDT's theorising: emphasising that when students act out of interest, choice, and have an internal locus of causality, they achieve better outcomes, presumably because these satisfy students' psychological needs for autonomy, competence, and relatedness. Factors facilitating this are interest, choice, and feedback, which we argue are in-built functions in the mobile application as opposed to the textbook, and which might account for the positive results. Further studies with several student-groups and complex designs are needed before inferring causality across educational levels. Based on the present study, we recommend that biology teachers in higher education employ mobile application tools in species identification due to increases in motivation and a higher degree of accurate identification of sedges.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The ability to correctly identify a particular plant or animal to species is the foundation of biodiversity science. Biodiversity research is increasingly critical in a world subject to unprecedented rates of climate change, habitat loss, and other

* Corresponding author. Thormøhlensgate 53 A/B, 5006 Bergen, Norway.
E-mail address: Lucas.Jeno@uib.no (L.M. Jeno).

environmental pressures (Rockström et al., 2009), as we urgently need to understand the impact of these drivers on our biodiversity and ecosystems. Providing the future workforce with the skills and competences necessary to meet society's needs in this area is a key deliverable of the educational system, and it is therefore a paradox that there is now a decreasing focus on learning plant and animal taxonomy at all educational levels (Lawler, 2016; Parkin, 2016). This declining interest in species knowledge and its underlying skills is, in part, a result from a shift towards an increased focus on what is seen as 'higher-order cognition' throughout the educational system (Bloom, 1956), reflecting the view that biodiversity knowledge and especially species identification skills are based on rote learning and rather simple cognitive processes. Investigating factors that increase species identification knowledge in general, the motivation for identifying plant and animal species, and the importance of knowing species is thus necessary. The main goal of the present study is to test the effect of a mobile application tool for the identification of species amongst biology students by assessing how the use of the mobile application affects the students' achievement, their motivational predictors for achievement, and their perceived value of species identification. Several reports state that STEM (Science, Technology, Engineering and Mathematics) education and research areas are highly important domains to invest in for the future, both across the world and in Norway in particular (Maltese & Tai, 2011; Ministry of Education and Research, 2015a, 2015b). However, amongst the OECD countries, Norway scores the lowest in student motivation and perception of usefulness in their education (OECD, 2014). With an increasing amount of electronic possibilities as teaching methods, textbooks may be seen as old-fashioned, and using mobile applications could be a way to increase students' motivation and achievement.

1.1. Mobile-learning, motivation and achievement

Electronic-learning (e-learning) and mobile-learning (m-learning) has transformed the traditional learning context from classroom to a virtual space (Gikas & Grant, 2013; Hashemi, Azizinezhad, Najafi, & Nesari, 2011; Tham & Werner, 2005). A survey conducted by the National Institute for Consumer Research (SIFO) shows that 74 percent of the Norwegian population has access to a smartphone and 46 percent have access to a tablet (Slettemeås, 2014), and this number is only expected to increase. Moreover, across the OECD countries, 96 percent of 15-year-old students have a computer, smartphone or tablet at home (OECD, 2015). The increased use of smartphones and tablets in the population in general raises the possibilities for supporting learning and motivation in the educational domain. There have been several studies on the effectiveness of mobile learning, relative to traditional learning methods. For instance, in a quasi-experimental study on plants among elementary-school students, Huang, Lin, and Cheng (2010) found support for a mobile learning system (MLS). One group of students was introduced to a mobile learning system (experimental condition), while a control group was introduced to a guidebook. Both groups were asked to observe and find plant characteristics and morphology. The study showed that the MLS had a statistically significant effect on students' attitudes towards outdoor plant learning and pre-test/post-test achievement scores compared to the guidebook. Noguera, Jiménez, and Osuna-Pérez (2013) did a similar study with physiotherapy students learning manual therapy. Students were randomly assigned to two conditions, either an experimental condition (mobile application) or a control condition (traditional teaching session). Using a comparative crossover design, it resulted in students in the experimental condition scoring higher in general on a post-experimental test. The effects of m-learning have also been found in studies where students learn about culture (Hwang & Chang, 2011), bird observation (Y. S. Chen, Kao, & Sheu, 2003), statistical concepts (Ling, Harnish, & Shehab, 2014), and dementia (Pitts et al., 2015). A meta-analysis by Wu et al. (2012) found that studies on mobile learning primarily focus on evaluating the effectiveness of mobile learning and that these studies employed mobile phones as a learning system. Importantly, the results show that 86 percent of the studies report positive results of the research outcomes, as opposed to one percent who reported negative outcomes. A recent meta-analysis by Schmid et al. (2014) investigating the effect of technology among higher education students, finds support for the effectiveness of technology in education.

Several reports within the educational domain argue that an integration of digital competence in education is highly important for future employability and knowledge acquisition (Erstad, Amdam, Arnseth, & Silseth, 2014; Ministry of Education and Research, 2015b). Tømte and Olsen (2013), in a report on how technology contributes to increased learning outcomes in higher education, find that students perceive that technology contributes to flexibility in their studies. In light of this, it might be argued that mobile-devices could have several motivational benefits for the student, for example, freedom, ownership, communication, enjoyment, and accessibility (Jones & Issroff, 2007). Studies investigating the effect of technology have previously found support for this reasoning (Law, Lee, & Yu, 2010; Martens, Gulikers, & Bastiaens, 2004; Pitts et al., 2015; Sha, Looi, Chen, & Zhang, 2012). Hence, the benefits of mobile learning are that students are given more volition and are more active in their learning. One theory that has proved especially useful in analysing motivational factors, student motivation, and achievement in education is the Self-Determination Theory (SDT: Deci & Ryan, 1985).

According to SDT, students have three inherent basic psychological needs for autonomy, competence, and relatedness (Deci & Ryan, 1985; Ryan & Deci, 2000b). Satisfaction of the basic needs is theorised to be positively associated with psychological well-being, whereas thwarting of the needs is detrimental to well-being, and associated with psychological ill-being. A basic tenet of SDT is that the satisfaction of the basic psychological needs is necessary for intrinsic motivation, i.e. those behaviours that are performed for the inherent satisfaction of the activity, as opposed to extrinsic motivation which is carried out for some instrumental reason (Ryan & Deci, 2002). SDT differentiates between two classes of motivation: autonomous and controlled. Autonomous motivation is a behaviour that is performed out of volition and self-endorsement. Controlled motivation, on the other hand, is regulated by rewards and punishment, or by introjection (ego-involved or

avoidance of self-derogation) (Niemiec & Ryan, 2009). In general, research finds that intrinsic motivation and autonomous motivation are positively related to beneficial outcomes, whereas controlled motivation is not (Deci & Ryan, 2008; Fortier, Vallerand, & Guay, 1995; Koestner, Ryan, Bernieri, & Holt, 1984; Ryan & Deci, 2009). Lastly, SDT has a dialectic approach and assumes environmental support (psychological need support) for autonomous motivation, while environmental control (psychological need thwarting) of students' behaviour is predicted to frustrate the basic psychological needs that lead to controlled motivation. The notion of support has been found meta-analytically and is necessary across all educational levels (Deci, Koestner, & Ryan, 1999).

Some studies have tested the effect of mobile-learning on motivation directly. Koh et al. (2010) find that students who were in the experimental-condition relative to students in the control-condition, scored higher on an achievement test, had higher autonomous motivation and meta-cognition, and experienced higher psychological need satisfaction. Roca and Gagne (2008) conducted a study investigating the antecedents of acceptance and intentions of use of e-learning. Results indicated that perceived competence and autonomy predicted the participants' perceived usefulness, playfulness and ease of use, which in turn predicted intentionality. A similar study found support for these relationships among teachers (Sørebø, Hallgeir Halvari, Gulli, & Kristiansen, 2009). Ryan, Rigby, and Przybylski (2006) performed a range of studies, both experimental and cross-sectional, investigating need satisfaction and its contribution to gaming experiences. Results indicated that across all studies, the participants' need satisfaction of autonomy and competence predicted a unique proportion of their enjoyment and preference for future play. Tamborini, Bowman, Eden, Grizzard, and Organ (2010) replicated the results in a similar experiment showing that all three needs mediated perceived game skills, co-playing, natural mapping, and enjoyment.

1.2. Overview of study

Results generally show that technology supports learning, over and above traditional methods. Further, students may be interested in, and motivated for, technology (Jeno, 2015; Jones & Issroff, 2007), thus m-learning and intrinsic motivation for learning a task may have a synergetic effect resulting in enhanced learning. The present study aims to investigate how a mobile application tool vs. a traditional identification tool relates to and affects students' achievement scores, intrinsic motivation, and perceived competence. The mobile application is a newly developed identification tool named "ArtsApp". The structure of ArtsApp generates more choices and also more volition than the traditional textbook. In line with SDT, choice and volition promotes a perception of satisfaction of the need for autonomy. Furthermore, the information provided during the identification process is, to a larger extent in the application than the textbook, competence-supportive due to feedback and a game-like experience during the identification process. In light of this, the following hypotheses are put forth: 1) ArtsApp contributes to higher achievement scores, perceived competence and intrinsic motivation compared to the traditional identification tool; 2) intrinsic motivation and perceived competence have an indirect effect between the identification tool used (ArtsApp, textbook) and achievement; and 3) intrinsic motivation, autonomous motivation, and autonomy support explain a unique proportion of interest in species identification and the importance of knowing species.

Within a Norwegian context, research guided by SDT has found support for SDT's basic assumption in elementary school (Olaussen, 2009), secondary education (Diseth, Danielsen, & Samdal, 2012), and upper secondary education (Jeno & Diseth, 2014). However, few studies have thus far employed a SDT perspective in higher education in Norway. As the reviews above show, generally few studies have tested how m-learning affects learning using SDT as a theoretical framework, although there have been some studies in other domains such as ICT (Legrain, Gillet, Gernigon, & Lafreniere, 2015), health studies with virtual clinicians (Williams et al., 2014), online gaming (Wang, Tao, Fan, & Gao, 2015), and online learning (K.-C. Chen & Jang, 2010; Hartnett, George, & Dron, 2011). Our study is important in further understanding how m-learning can affect student achievement, and why some mobile applications could contribute to learning gains and others might not.

1.3. Materials

The Norwegian flora is well-known and relatively species poor, but with some notable exceptions, such as the sedges (Latin: *Carex*). There are over 2000 different species of sedge across the world: 97 of them are found in mainland Norway. For new undergraduate biology students, sedges may look like grasses and other graminoids but once learned it is easy to distinguish them. Many students struggle to identify the sedges to species, and lack motivation to even try to identify this group. Traditionally, teaching and identification of sedges has been carried out using classical identification keys in the Norwegian standard plant identification book "Lids Flora" (Lid & Lid, 2005). The identification process in Lids Flora is hierarchical and makes use of dichotomous "keys". These require the students to first identify which family the plant belongs to, then, based on characteristics of the individual, students have to choose between two possibilities before moving to the next identification question. To find the right species among the 104 Norwegian species, a student usually has to go through 8—10 questions, often involving microscopic and hard-to-distinguish characteristics before ultimately finding the right species. These keys are often comprehensive and require solid knowledge of technical terms and morphology. In addition to being comprehensive and complex, the students do not see the flora as well suited to fieldwork or other practical work.

An alternative to this traditional textbook method is "ArtsApp", which was developed jointly by bioCEED—Centre of Excellence in Biology Education, the Norwegian Biodiversity Information Centre, and the Centre for Science Education. ArtsApp is available for Android smartphones and can be freely downloaded at Google play (bioCEED, 2015). ArtsApp is a mobile application that allows students to identify sedge species more dynamically with the ability to choose which of all the

characteristics of the species to determine first, and can thus start with the easier characteristics instead of having to move down in a given order. ArtsApp contains pictures of the characteristics in question, in addition to the textual descriptions (Fig. 1a and b). ArtsApp also keeps track of your progress in terms of how many species you have excluded and how many you have left to choose between before ending up with an identification. ArtsApp can also be geographically 'smart' in that it can exclude species that are not found, and therefore not relevant, in your study area.

2. Method

2.1. Participants and procedure

The participants were 71 Second-year bachelor students at a large university in Norway, 35 percent males and 65 percent females, with a mean age-class of 21–22 years ($SD = 0.97$). The students were recruited during a field course as part of a mandatory biology course. Ninety-four students were asked to participate, with the possibility to win cinema tickets for participating. Written information about the purpose of the study was given to the students before starting the experiment. All the students were assured that their answers would be treated confidentially and they were informed that the study had obtained approval by the Norwegian Social Science Data Services for research (NSD). Finally, students were told that they could withdraw from the study at any time without consequences. Students who wanted debriefing had the opportunity to talk to a trained research assistant, or contact the first author for more information. Using these methods, we obtained a response rate of 75 percent. All the students were given the correct answers to the identification questions in plenum at the end of the field course. The experiment was conducted over three days due to time constraints of the field course.

The experimental procedure was as follows: participants were introduced to general species identification processes on the first day of the course. This general introduction included both the traditional "Lids Flora" (Lid & Lid, 2005) textbook method and the new "ArtsApp" digital method on smartphones or tablets. After this general introduction we conducted the experiment. A trained research assistant, unaware of the study hypotheses, randomly assigned the participants to one of the two conditions − the experimental condition (ArtsApp − mobile application) or the control condition (Lids Flora − textbook). The participants were then given an envelope containing information about the study, the test, and the post-experimental questionnaire. All the participants were given the following information: "In front of you there are two pieces of paper. Part 1 is the identification questions. Below that, is part 2, a questionnaire. Please start with part 1, the identification questions". The participants who were assigned to the control condition were then given the following instructions: "Kindly answer all the questions by using the textbook Lids Flora. You can use as long time as you want. If you are not able to answer a question, simply move to the next. When you are done with the questions you can start with part 2, the questionnaire. Please respond to all the questions and be as sincere as possible". Participants who were assigned to the experimental condition were given the following instructions: "Kindly answer all the questions by using your smartphone or tablet and the
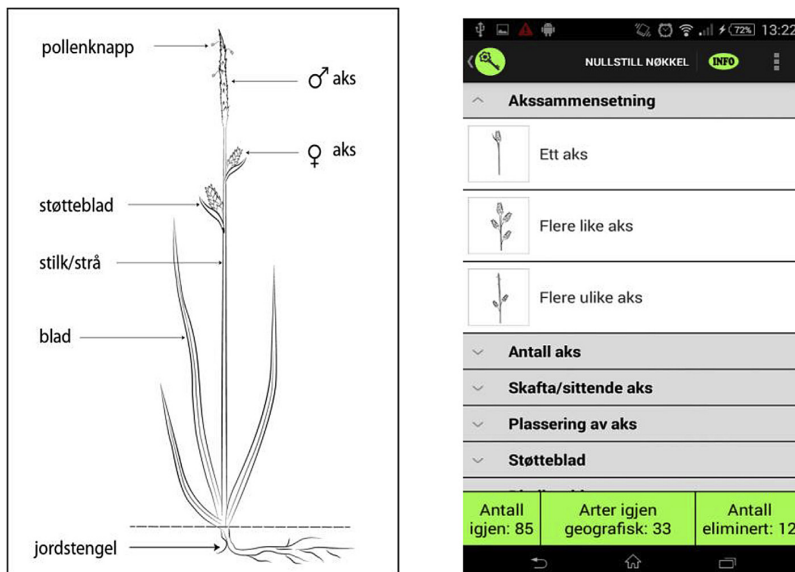

Fig. 1. Screenshots of ArtsApp: a) structure of the sedge, b) different ways to identify a species and showing at the bottom how many species are left, how many are left according to geographical location, and how many species have been eliminated.

application ArtsApp. You can use as long time as you want. If you are not able to answer a question, simply move to the next. When you are done with the questions you can start with part 2, the questionnaire. Please respond to all the questions and be as sincere as possible". All the participants in the control condition were provided with a textbook; participants in the experimental condition who did not have their own smartphone or tablet were given a tablet they could use during the experiment.

2.2. Measures

2.2.1. Intrinsic motivation

In order to measure a participant's intrinsic motivation for species identification when using the textbook or mobile application, the interest/enjoyment subscale within the Intrinsic Motivation Inventory (IMI) was employed. The IMI subscale consists of 7 items (e.g. "I enjoyed identifying species using ArtsApp/Lids Flora"), and has previously been used when assessing participants' intrinsic motivation after experiments. Previous studies have found reliable and valid psychometrics for this subscale (Deci, Eghrari, Patrick, & Leone, 1994; McAurley, Duncan, & Tammen, 1989; Ryan, Connell, & Plant, 1990). The composite variable showed high reliability ($\alpha = 0.95$, $M = 4.36$, $SD = 1.69$). A principal component analysis was performed to investigate the underlying factorial structure of the scale. The results revealed a one-factor solution with eigenvalues exceeding 1, explaining 75.7 percent of the variance, with factor loadings above 0.6.

2.2.2. Perceived competence

To assess students' perceived competence for identifying species, the subscale of perceived competence within IMI was employed. This subscale measures how efficacious participants perceive themselves and has been shown to be a good measure for perceived competence (Plant & Ryan, 1985; Ryan, Mims, & Koestner, 1983), consistent with SDT (Deci & Ryan, 1985). The scale consists of 5 items (e.g. "I think I am pretty good at identifying species"). The subscale showed good reliability ($\alpha = 0.84$, $M = 2.98$, $SD = 1.14$). Factor analysis (PCA) produced a one-factor solution with eigenvalues above 1 explaining 64.77 percent of the variance.

2.2.3. Autonomy support

To measure students' perception of autonomy support from their course teacher, the Learning Climate Questionnaire (LCQ) was chosen (e.g. "I feel that my instructor provides me [with] choices and options"). The LCQ indicates the student's perception of how much autonomy has been provided by the teachers. The scale has 6 items ($\alpha = 0.83$, $M = 4.85$, $SD = 0.99$). Factor analysis (PCA) revealed a one-factor structure for 5 items with eigenvalues above 1, explaining 60 percent of the variance. One item was omitted due to low factor loadings.

2.2.4. Self-regulation

The Learning Self-Regulation Questionnaire (SRQ-L) was employed to measure students' autonomous and controlled motivation for learning biology. The scale was adapted for the purpose of this study and consists of two subscales, three items for autonomous motivation ("I participate in class because it's a good way to improve my understanding of biology") and three items for controlled motivation ("I participate in class because I want others to see I am intelligent"). The respondents were asked to answer on a 7-point Likert-scale ranging from not at all true to very true. Autonomous motivation produced adequate alpha levels $\alpha = 0.71$ ($M = 6.3$, $SD = 0.74$). Controlled motivation produced low alpha levels $\alpha = 0.55$ ($M = 2.6$, $SD = 1.06$) below the cut-off of 0.70, which might be a concern. However, according to Cronbach (1951) and Vallerand, Fortier, and Guay (1997), scales with few items underestimate the inter-correlations between the items. The same item average with more items would have yielded an adequate alpha-level in our study.

2.2.5. Species identification questions

5 items were included concerning species identification and preference when keying. Three were control items: previous experience with species identification, previous experience with identification of sedges, and preference of identification tool (ArtsApp vs. Lids Flora). Two questions were measures of interest for identifying species and importance of knowing species.

2.2.6. Achievement

A nine-question test was used to measure students' achievement levels. The questions were developed by a biologist specialised in identifying species. Six of the items were multiple-choice concerning characteristics of sedges and three questions were about three different sedges given to the students to identify. The sedges were picked by a biologist, and presented during the experiment to the students by a research assistant unaware of the research hypothesis. Two independent raters (biologists) scored the students' answers on a sheet. Different numbers of points were given depending on the difficulty of the question. For instance, a correct answer identifying the sedges gave more points than multiple-choice items. Furthermore, students could receive partial points for making an identification of a very similar sedge. The scores on the achievement test ranged from 0 to 26. An inter-rater reliability test was conducted and showed high agreement with $\alpha = 0.97$. The nine questions on the test were combined to an observed composite variable labelled "achievement" in order to assess an overall achievement level.

2.3. Analytical strategy

All data analyses were performed with IBM SPSS 23 and IBM AMOS 23. To test for indirect effects in our model, we employed structural equation modelling (SEM). Several goodness-of-fit indices can be used to evaluate acceptable model fit in SEM. The most recommended indices are CFI, NFI, TLI, RMSEA, and χ^2/df ratio. According to Byrne (2016), CFI (Comparative Fit Index), NFI (Normed Fitted Index), and TLI (Tucker-Lewis Index) measure how well the hypothesised model fits the independent model or sample data. RMSEA (Root Mean Square Estimate Approximation) is a measure of how well the model would fit if optimal parameters were available (Byrne, 2016), while the χ^2/df is a representation of the difference between the unrestricted and restricted covariance matrix. According to Hu and Bentler (1999), CFI, NFI, and TLI > 0.95 are viewed as indicators of good model fit, while RMSEA < 0.05 is recommended (Bentler, 1990; Browne & Cudeck, 1992). A χ^2/df < 2 and χ^2 p > 0.05 indicate excellent model fit. Recently, however, values for CFI, NFI, and TLI >0.90, and RMSEA <0.08 are considered as acceptable model fit (Byrne, 2016; Kline, 2011).

There was one missing value each for perceived competence, intrinsic motivation, achievement, importance of knowing species, and interest in identifying species. Multiple imputations were carried out to account for this in the primary analyses. A total of five imputations were conducted using the pooled mean for each value. Such procedures have been recommended when the missing data are at random and are few (Schafer & Graham, 2002; Schafer, 1999). The final sample size is thus 71 for all study-variables. All variables approximated a normal distribution as shown by acceptable skewness, kurtosis, and standard deviation (Table 1). Reliability analyses and factor analyses were conducted to investigate the study measures' internal consistency and showed satisfactory values. There was a wide range in achievement indicating that the test was able to differentiate between students with different skill levels.

3. Results

3.1. Preliminary analyses

Descriptive analyses of the study variables are presented in Table 1. The majority of the students (71.8%) had no prior experience with identifying species before the experiment and very few of the students (4.2%) had experience with this particular group (sedges). A large majority of the participants preferred the mobile application to the textbook as the primary identification tool (mobile application = 71.8%, textbook = 19.7%). Students with previous experience of identifying species in general had a higher mean achievement score (experience M = 7.82, SD = 3.75, no experience M = 6.5, SD = 3.27), although the difference is not significant, t (69) = 1.45, p > 0.05. No significant difference is found between students with experience of species identification for intrinsic motivation (t(68) = -0.187, p > 0.05) or perceived competence (t(68) = -0.017, p > 0.05). We find no significant difference between those students with previous experience in identifying sedges and those with no experience in achievement (t (69) = 0.899, p > 0.05) for intrinsic motivation (t(68) = 0.142, p > 0.05) or in perceived competence (t(68) = 0.158, p > 0.05). Further, no significant difference in achievement is found between students who preferred the mobile application or the textbook (t (63) = 0.089, p > 0.05)) for intrinsic motivation (t(62) = 0.375, >0.05) or in perceived competence (t(62) = 0.674, p > 0.05). A test of homogeneity was conducted to test for gender effect on the three dependent variables − achievement, interest in species identification, and importance of knowing species. No gender effect was found (p's > 0.05), thus gender was collapsed across all variables for subsequent analyses.

3.2. Primary analyses

To test our first hypothesis, we compared the relative effect of the mobile application vs. textbook on intrinsic motivation, perceived competence, and achievement scores. Several independent sample t-tests were conducted. Fig. 2 a−c presents the results of the comparison along with mean scores and standard deviations. The t-tests suggest a significant difference between participants in the experimental (mobile application) and control (textbook) condition for all variables: participants using the mobile application have higher intrinsic motivation (M = 5.44, SD = 1.23) compared to using the textbook (M = 3.24, SD = 1.31; t (69) = 7.24, p < 0.001), perceived competence (mobile application; M = 3.41, SD = 1.19, textbook; M = 2.54,

Table 1
Descriptive statistics of the study variables.

Measures	M	Variable range	Min.	Max.	Range	SD	Skewness	Kurtosis
Achievement	6.88	0−26	0.50	16.50	16.0	3.44	0.72	0.19
Intrinsic motivation	4.36	1−7	1.0	7.0	6.0	1.69	−0.23	−0.97
Perceived competence	2.98	1−7	1.0	5.80	4.80	1.13	0.29	−0.42
Autonomy support	4.85	1−7	3.0	7.0	4.0	0.99	0.03	−0.58
Autonomous motivation	6.30	1−7	4.33	7.0	2.67	0.74	−0.92	0.14
Controlled motivation	2.69	1−7	1.0	5.0	4.0	1.06	0.37	−0.52
Importance of knowing species	5.64	1−7	2.0	7.0	5.0	1.20	−0.88	0.40
Interest in identification of species	4.38	1−7	1.0	7.0	6.0	1.47	−0.42	−0.56

Note: All variables shown are treated as continuous variables. n = 71 for all variables.

$SD = 0.89$; $t(69) = 3.44$, $p < 0.001$), and achievement scores (mobile application; $M = 7.78$, $SD = 3.21$, textbook; $M = 5.95$, $SD = 3.46$; $t(69) = 3.41$, $p < 0.05$). The results indicate that the experimental-condition (use of mobile application), relative to the control-condition (use of textbook), has a strong effect size (Cohens's d) on intrinsic motivation ($d = 1.73$) and perceived competence ($d = 0.82$), and a medium to strong effect on achievement ($d = 0.54$).

To test our second hypothesis, we performed a path analysis to test for the multivariate relation of the indirect effect of experiment vs. control condition on achievement through intrinsic motivation and perceived competence (Fig. 3). Five thousand bootstrap samples were conducted using maximum likelihood (ML). Model fit for our model was excellent ($p > 0.05$, $\chi2/df = 1.0226$, CFI = 1.00, NFI = 0.98, TLI = 0.99, RMSEA = 0.019, 95% CI = 0.000–0.318). The model as a whole predicts 7 percent of the variance in achievement scores, with a significant total indirect effect ($p < 0.008$). Results from the model indicate that experimental condition (mobile application) predicts students' intrinsic motivation ($\beta = -0.60$, CI: -0.75 to -0.41) and perceived competence ($\beta = -0.38$, CI: -0.58 to -0.15), but only intrinsic motivation significantly predicts achievement scores ($\beta = 0.25$, CI: 0.018–0.44). Given these significant paths, we then conducted a Sobel test (Sobel, 1982) with unstandardised regression weights and standard errors to test the specific indirect effect of condition (mobile
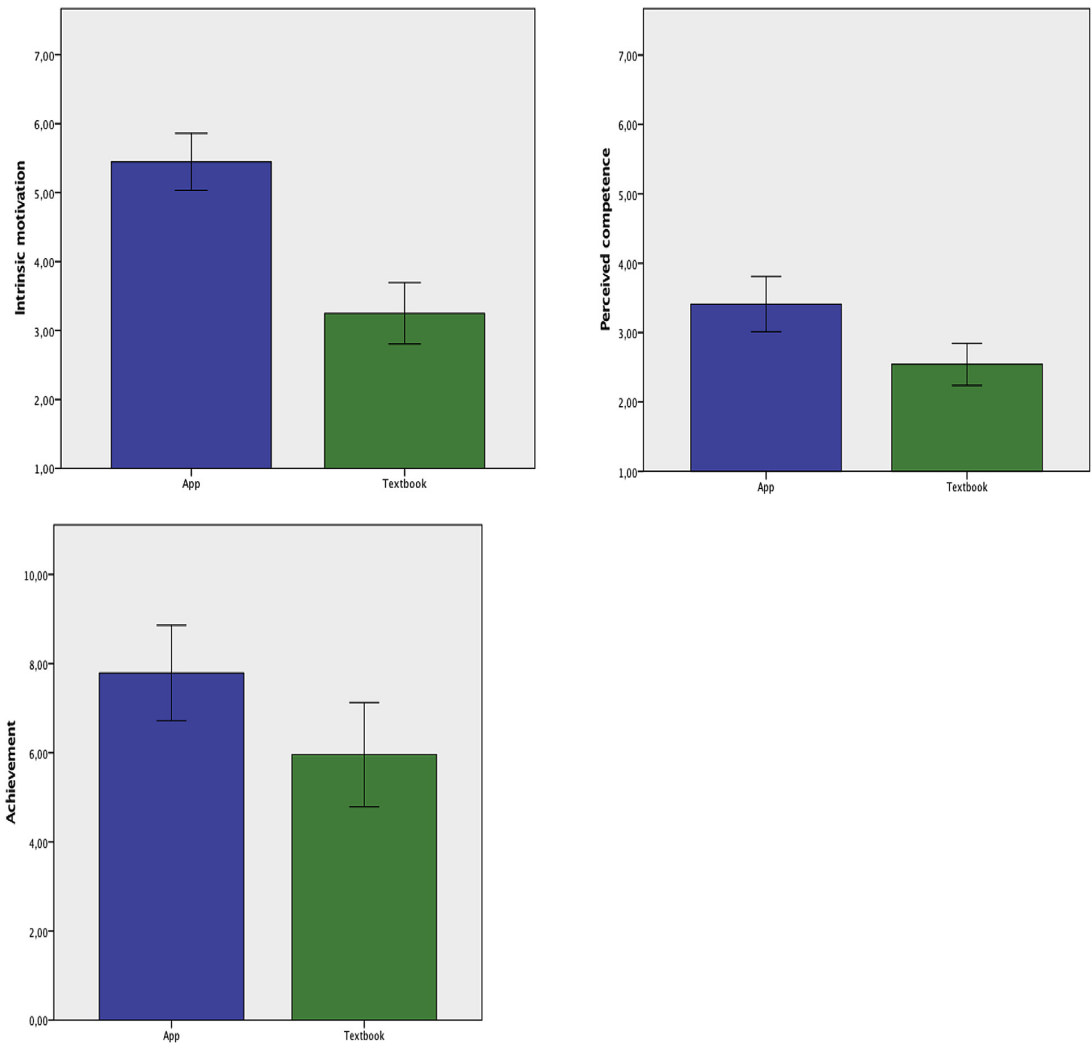

Fig. 2. a–c: Comparison of the mean results between the experimental condition (mobile application) and control condition (textbook) on the dependent variables.
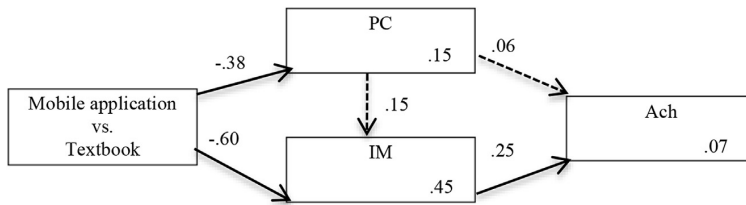
Fig. 3. Path-analysis with standardised estimates. IM = Intrinsic motivation, PC = Perceived competence, Ach = Achievement. Stippled arrows indicate non-significant paths. Total effects (R^2) are shown in mediators and dependent variables.

application vs. textbook) → intrinsic motivation → achievement. The results show that the mobile application indirectly predicts achievement, via intrinsic motivation ($z = -1.93$, $p < 0.05$).

To test our third hypothesis of how different motivational constructs explain participants' interest in identification of species and the importance of knowing species, we conducted a hierarchical multiple regression analysis. The results show, for interest in identification species, that models 2−5 are significant. All predictors except for autonomy support accounted for a unique and significant proportion of students' interest in identification of species (Table 2). Specifically, intrinsic motivation explains an additional 14.2 percent (sig. F change = 0.001), while autonomous motivation contributes an extra 5.7 percent of the explained variation (sig. F change = 0.002). For importance of knowing species only intrinsic motivation (beta = 0.33, $p < 0.05$) and autonomous motivation (beta = 0.39, $p < 0.001$) are significant contributors in explaining independent variance in the dependent variable. Specifically, intrinsic motivation explains an additional 6.6 percent in the model (sig. F change = 0.03), while autonomous motivation explains 12.4 percent (sig. F change = 0.002).

4. Discussion

The present study investigated the relative effect of a mobile application vs. a traditional identification tool on students' achievement and motivation in species identification using a Self-Determination Theory approach. We find a significant difference in intrinsic motivation and perceived competence between students using the mobile application compared to students using the textbook, both with a substantial effect size. Students also scored significantly higher on the achievement test when using the mobile application compared to the textbook, with a medium effect size. Thus the first hypothesis of the study, that ArtsApp contributes to higher achievement scores, perceived competence, and intrinsic motivation compared to the traditional identification tool is supported. Several interpretations can be made to account for these effects. First, the results may be a result of ArtsApp's in-built functions, which allow students more choice and effectance-relevant feedback, as

Table 2
The results of the hierarchical regression analysis along with the five predictors of our two dependent variables. Condition = Mobile application vs. textbook, IM = Intrinsic motivation, Aut. Sup = Autonomy support, Con. Mot = Controlled motivation, Aut. Mot = Autonomous motivation. $n = 71$, *$p = 0.05$, **$p = 0.01$, ***$p = 0.001$.

Hierarchical regression analysis								
Dependent variables:	Predictor variables	Interest in identification of species			Predictor variables	Importance of knowing species		
		F	R^2	β		F	R^2	β
	Step 1	0.006	0.000		Step 1	0.206	0.003	
	Condition			−0.010	Condition			0.055
	Step 2	5.646**	0.142**		Step 2	2.501	0.069	
	Condition			0.319*	Condition			0.278
	IM			0.501***	IM			0.340*
	Step 3	4.348**	0.163**		Step 3	1.915	0.079	
	Condition			0.254	Condition			0.231
	IM			0.437**	IM			0.294
	Aut. Sup			0.153	Aut. Sup			0.109
	Step 4	4.554**	0.216**		Step 4	2.039	0.110	
	Condition			0.249	Condition			0.227
	IM			0.429**	IM			0.288
	Aut. Sup			0.057	Aut. Sup			0.036
	Con. Mot			0.251*	Con. Mot			0.191
	Step 5	4.898***	0.274***		Step 5	3.966**	0.233**	
	Condition			0.307*	Condition			0.312*
	IM			0.457**	IM			0.330*
	Aut. Sup			−0.058	Aut. Sup			−0.133
	Con. Mot			0.236*	Con. Mot			0.170
	Aut. Mot			0.266*	Aut. Mot			0.391**

the users can make mistakes while constantly monitoring progress. Such functions that exist in the application are assumed to increase students' motivation. According to SDT, support for autonomy (i.e. choice) and competence (i.e. feedback) leads to a shift from an external to internal locus of causality, which in turn leads to intrinsic motivation (Deci & Moller, 2005; Deci & Ryan, 1985). Several empirical studies have found support for this. For instance, Vallerand and Reid (1984) found in a study among physical education students, that positive feedback predicted students' intrinsic motivation, mediated by perceived competence. In a study by Zuckerman, Porac, Lathin, Smith, and Deci (1978), students who were given choices in a puzzle with respect to activity and time had significantly higher intrinsic motivation compared to students without such choices. Second, mobile applications may enhance learning for students because of the technological aspect. Specifically, ArtsApp may facilitate student learning because it is more dynamic, game-like, and interest evoking, and thus supports a student's deep psychological need for autonomy and competence (Rigby & Przybylski, 2009). Third, as a result of the construction of ArtsApp that gives immediate feedback to students on how many sedges have been excluded from the identification process, and how many are left before identifying the sedge, the students are able to exercise their capacities during the identification process (Deci & Ryan, 1985). Thus, it provides the students with feedback, it is clear in its goals, and matches each student's skills and challenge (difficulty) closely (Csikszentmihalyi, 1990; Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005; Vallerand & Reid, 1984).

A further aim of the study was to test the hypothesis that intrinsic motivation and perceived competence have an indirect effect between the study condition (mobile application vs. textbook) and achievement. Results from the path-analysis partly support this, indicating that only intrinsic motivation could be uniquely related to achievement. Specifically, the path-analysis shows that the use of ArtsApp predicts students' intrinsic motivation, which in turn predicts higher achievement. The analysis shows that the use of ArtsApp also predicts perceived competence, however perceived competence does not predict achievement. This is especially important because it explains not only the "what" association a mobile application has on achievement, but also the "how" relation. Self-Determination Theory states that when students' perceived choice and competence are facilitated, they will demonstrate higher levels of intrinsic motivation (Deci & Ryan, 1985). Intrinsically motivated students in an autonomy-supportive environment exhibit, in turn, more creative thinking, higher conceptual understanding, and more positive emotions (Benware & Deci, 1984; Koestner et al., 1984; Ryan et al., 1990), as well as a preference for challenging tasks (Deci, Schwartz, Sheinman, & Ryan, 1981). These by-products of intrinsic motivation contribute to higher achievement, but the behaviour is not performed for the external reason of achievement but for the inherent satisfaction of the behaviour (Ryan & Deci, 2000a, 2006).

The last hypothesis we tested was that intrinsic motivation, autonomous motivation, and autonomy support would independently account for interest in identifying species and the importance of knowing species. The results from the hierarchical multiple regression analysis generally support this hypothesis and are consistent with SDT reasoning. SDT suggests that when students transform an outer regulation to an inner regulation, and thus internalise the value of a behaviour, the student becomes more self-regulating (i.e. autonomous) (Deci, Ryan, & Williams, 1996). Autonomously motivated students understand the value and identify with the importance of the behaviour. Intrinsic motivation and autonomous motivation has previously been found to predict lower dropout rates (Vallerand & Bissonnette, 1992), less procrastination with schoolwork (Katz, Eilot, & Nevo, 2014; Senecal, Koestner, & Vallerand, 1995), future intentions to persist in college, and grade-point average scores (Guiffrida, Lynch, Wall, & Abel, 2013). Both interest and importance of knowing species are important aspects of biology. Therefore, having students that value vital aspects of biological knowledge and are autonomously motivated for these behaviours is expected to be beneficial at the individual-level (student learning) and the contextual-level (environmentally conscious individual able to address climate challenges). Finding ways to facilitate autonomously motivated students is hence recommended for a shift from rote-learning knowledge to higher-order cognition in species knowledge. However, based on our results, we suspect that the condition (mobile application vs. textbook) might have a suppressor effect due to its significant appearance in the last step when all predictors are included in the model (Lancaster, 1999; Smith, Jr., & Williams, 1992). That is, the condition only predicts a unique and significant proportion of importance of knowing species when controlling for intrinsic motivation, autonomy support, and autonomous and controlled motivation, indicating that the condition (using mobile application or textbook) is not important for students' perceived importance of knowing species.

In light of our results, some practical recommendations are suggested to facilitate students' learning species-identification skills. Teachers (and development of technological solutions) are thus encouraged to provide students with choices and options, optimal challenging tasks, and effectance-relevant feedback (Deci et al., 1994). Importantly, m-learning provides an informal aspect to learning, thus furthering students' learning outside of a classroom context (Sandberg, Maris, & Geus, 2011), and could also enhance learning and intrinsic motivation, as our results indicate. Some scholars argue against technological implementations in higher education, highlighting paradoxes and consequences of having technology in education (Guri-Rosenblit, 2005). Critiques suggest that m-learning may pose some challenges, for example, there might be technological difficulties, frustration with the device, time consumption, and antipathetic teachers (Gikas & Grant, 2013). Specifically, challenges such as small keypads, network issues, and using smartphones for other purposes than educational, are important concerns that could interfere with learning. However, using a smartphone in the field has several advantages for the student. Studies by Gikas and Grant (2013) and Mouza and Barrett-Greenly (2015) find that students reported that m-learning has the advantages of being able to access information rapidly, make communication with both peers and teachers easier, provides a different way of learning, and that learning is more situated, as smartphones allow greater possibilities to interact more dynamically with the real-world and with the teacher. Awareness concerning the use of technology and its limitations is important when integrating technology in an educational setting. Assurance of basic academic skills is a prerequisite of

technological skills (OECD, 2015), a notion that is also supported meta-analytically (Archer et al., 2014). Although not tested explicitly in the present study, the correlational results show that teachers' provision of autonomy support is positively associated with students' interest in identification of species, but is not a unique contributor of interest in identification of species or importance of knowing species. Our results suggest that self-motivation (i.e. autonomous and intrinsic motivation) is more important, independent of identification tool/teaching method, with respect to interest in identification and importance of knowing species.

Several limitations of the study are worth mentioning while interpreting the results. One limitation is the students' short amount of time to learn species identification. Students were introduced to sedges, ArtsApp, and Lids Flora on the first day and the experiment was conducted on the second day, which may explain the low mean scores on the achievement test. However, the results do show a difference between the mobile application and the textbook as expected. Thus, the experimental manipulation was successful. Moreover, the present study has a homogeneous sample (i.e. undergraduate students). Future studies should assess more advanced and heterogeneous students, including both undergraduate and graduate students. Motivational problems, in terms of species identification might be more prominent at the undergraduate level since the students may not have internalised the value of the behaviour (Williams & Deci, 1996). Thus the preliminary study on undergraduates is adequate for the purpose of this study. A last limitation identified is the lack of adequately assessing the novelty effect a mobile application tool might have on students' intrinsic motivation and interest in identification of species. New technologies might have a novelty effect on students, which in turn increases the students' intrinsic motivation (Lepper, 1985). On the one hand, according to Hartnett (2016), students using e-learning tools are more intrinsically motivated compared to students using traditional methods. On the other hand, Keller and Suzuki (2004) argue that the novelty effects wanes as students become accustomed to the technology. In our study we tested for differences between students with previous experience in identifying species, experience with sedges, and preference for identification tool (i.e. mobile application or textbook): we find no significant difference for intrinsic motivation, perceived competence or achievement. Although the experimental intervention (using the mobile application or textbook) was only done shortly after learning the different identification tools, these non-significant results provide initial support for a lack of novelty effect, suggesting instead the main effect of the mobile application has on intrinsic motivation, competence and achievement.

This paper presents the results of a new mobile application tool for biologists. We generally find support for our hypotheses and the basic tenets of Self-Determination Theory in the m-learning realm. Importantly, the present study adds to the m-learning literature in several important ways. First, the mobile application tool increased students' motivation and learning. Compared to the textbook, the mobile application tool facilitated students' perception of the importance of learning about identification and sedges. Furthermore, the present study has found important indirect results in line with SDT. Future studies should expand upon the design and include autonomy supportive and controlling conditions to further assess the validity of SDT in relation to m-learning. Lastly, few studies have investigated the effect of m-learning in a SDT-approach; this study narrows this gap. Future studies are needed to further understand how SDT-concepts relate to e-learning in higher education, and why students are more intrinsically motivated when employing mobile applications.

References

bioCEED. (2015). *ArtsApp Carex Norge*. Retrieved from https://play.google.com/store/apps/details?id%3Dcom.bioceed.artsapp.artsapp1%26hl%3Dfr.

Archer, K., Savage, R., Sanghera-Sidhu, S., Wood, E., Gottardo, A., & Chen, V. (2014). Examining the effectiveness of technology use in classrooms: A tertiary meta-analysis. *Computers & Education, 78*, 140−149. http://dx.doi.org/10.1016/j.compedu.2014.06.001.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238−246.

Benware, C. A., & Deci, E. L. (1984). Quality of learning with an active vesus passive motivational set. *American Educational Research Journal, 21*(4), 755−765.

Bloom, B. S. (1956). *Taxonomy of educational objectives. Handbook 1: Cognitive domain*. London: David McKay Company, Inc.

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21*(2), 230−258.

Byrne, B. M. (2016). *Structural equation modeling with Amos. Basic concepts, applications and programming* (3 ed.). New York: Routledge.

Chen, K.-C., & Jang, S.-J. (2010). Motivation in online learning: Testing a model of self-determination theory. *Computers in Human Behavior, 26*, 741−752. http://dx.doi.org/10.1016/j.chb.2010.01.011.

Chen, Y. S., Kao, T. C., & Sheu, J. P. (2003). A mobile learning system for scaffolding bird watching learning. *Journal of Computer Assisted Learning, 19*(3), 347−359.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297−334.

Csikszentmihalyi, M. (1990). *Flow. The psychology of optimal experience*. New York: Harper & Row.

Csikszentmihalyi, M., Abuhamdeh, S., & Nakamura, J. (2005). Flow. In A. J. Elliot, & C. S. Dweck (Eds.), *Hanbook of competence motivation* (pp. 598−608). New York: The Guilford Press.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Fasilitating Internalization: The Self-Determination Theory Perspective. *Journal of Personality, 62*(1), 119−142.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*(6), 627−668.

Deci, E. L., & Moller, A. C. (2005). The concept of competence: A starting place for understanding intrinsic motivation and self-determined extrinsic motivation. In A. J. Elliot, & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 579−597). New York: The Guilford Press.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Deci, E. L., & Ryan, R. M. (2008). Self-Determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology, 49*(3), 182−185. http://dx.doi.org/10.1037/a0012801.

Deci, E. L., Ryan, R. M., & Williams, G. C. (1996). Need satisfaction and the self-regulation of learning. *Learning and Individual Differences, 8*(3), 165−183.

Deci, E. L., Schwartz, A. J., Sheinman, L., & Ryan, R. M. (1981). An instrument to assess adults' orientations toward control versus autonomy with Children: Reflection on intrinsic motivation and perceived competence. *Journal of Educational Psychology, 73*(5), 642−650.

Diseth, Å., Danielsen, A. G., & Samdal, O. (2012). A path analysis of basic need support, self-efficacy, achievement goals, life satisfaction and academic achievement level among secondary school students. *Educational Psychology*, 1−20. http://dx.doi.org/10.1080/01443410.2012.657159.

Erstad, O., Amdam, S., Arnseth, H. C., & Silseth, K. (2014). *Om fremtidens kompetansebehov. En systematisk gjennomgang av internasjonale og nasjonale initiativ.* Oslo: Universitetet i Oslo.

Fortier, M. S., Vallerand, R. J., & Guay, F. (1995). Academic motivation and school Performance: Toward a structural model. *Contemporary Educational Psychology, 20,* 257–274.

Gikas, J., & Grant, M. M. (2013). Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media. *Internet and Higher Education, 19,* 18–26. http://dx.doi.org/10.1016/j.iheduc.2013.06.002.

Guiffrida, D. A., Lynch, M. F., Wall, A. F., & Abel, D. S. (2013). Do reasons for attending college affect academic Outcomes? A test of a motivational model from a self-determination theory perspective. *Journal of College Student Development, 54*(2), 121–139.

Guri-Rosenblit, S. (2005). Eight paradoxes in the implementation process of e-learning in higher education. *Higher Education Policy, 18,* 5–29.

Hartnett, M. (2016). *Motivation in online education.* Singapore: Springer.

Hartnett, M., George, A. S., & Dron, J. (2011). Examining motivation in online distance learning Environments: Complex, multifaceted, and situation-dependent. *International Review of in Open and Distance Learning, 12*(6), 20–38.

Hashemi, M., Azizinezhad, M., Najafi, V., & Nesari, A. J. (2011). What is mobile Learning? Challenges and capabilities. *Procedia - Social and Behavioral Sciences, 30,* 2477–2481.

Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives, Structural Equation Modeling. *A Multidisciplinary Journal, 6*(1), 1–55.

Huang, Y.-M., Lin, Y.-T., & Cheng, S.-C. (2010). Effectiveness of a mobile plant learning system in a science curriculum in Taiwanese elementary education. *Computers & Education, 54,* 47–58. http://dx.doi.org/10.1016/j.compedu.2009.07.006.

Hwang, G.-J., & Chang, H.-F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education, 56,* 1023–1031. http://dx.doi.org/10.1016/j.compedu.2010.12.0 02.

Jeno, L. M. (2015). Encouraging active learning in higher education: A self-determination theory perspective. *International Journal of Technology and Inclusive Education, 5*(1), 716–721.

Jeno, L. M., & Diseth, Å. (2014). A self-determination theory perspective on autonomy support, autonomous self-regulation, and perceived school performance. *Reflecting Education, 9*(1), 1–20.

Jones, A., & Issroff, K. (2007). Motivation and mobile devices: Exploring the role of appropriation and coping strategies. *Research in Learning Technology, 15*(3), 247–258. http://dx.doi.org/10.1080/09687760701673675.

Katz, I., Eilot, K., & Nevo, N. (2014). "I'll do it later": Type of motivation, self-efficacy and homework procrastination. *Motivation and Emotion, 38,* 111–119. http://dx.doi.org/10.1007/s11031-013-9366-1.

Keller, J. M., & Suzuki, K. (2004). Learner motivation and e-learning design: A multinationally validated process. *Journal of Educational Media, 29*(3), 229–239.

Kline, R. B. (2011). *Principles and practice of structural equation modeling.* New York: The Guilford Press.

Koestner, R., Ryan, R. M., Bernieri, F., & Holt, K. (1984). Setting limits on children's behavior: The differential effects of controlling vs. informational styles on intrinsic motivation and creativity. *Journal of Personality, 52*(3), 233–248.

Koh, C., Tan, H. S., Tan, K. C., Fang, L., Fong, F. M., Kan, D., et al. (2010). Investigating the effect of 3D simulation- based learning on the motivation and performance of engineering students. *Journal of Engineering Education, 99*(3), 237–251.

Lancaster, B. P. (1999). *Defining and interpreting suppressor Effects: Advantages and limitations. Paper presented at the annual meeting of the southwest educational research associations.* San Antonio: Texas.

Law, K. M. Y., Lee, V. C. S., & Yu, Y. T. (2010). Learning motivation in e-learning facilitated computer programming courses. *Computers & Education, 55,* 218–228.

Lawler, S. (2016, February 26). Identification of animals and plants is an essential skill set. *The Conversation.* Retrieved from http://theconversation.com/identification-of-animals-and-plants-is-an-essential-skill-set-55450 (website).

Legrain, P., Gillet, N., Gernigon, C., & Lafreniere, M.-A. K. (2015). Integration of information and communication technology and pupils' motivation in a physical education setting. *Journal of Teaching in Physical Education, 34,* 384–401. http://dx.doi.org/10.1123/jtpe.2014-0013.

Lepper, M. R. (1985). Microcomputers in education. *American Psychologist, 40*(1), 1–18.

Lid, J., & Lid, D. (2005). *Norsk flora* (7 ed.). Oslo: Det Norske Samlaget.

Ling, C., Harnish, D., & Shehab, R. (2014). Educational Apps: Using mobile applications to enhance student learning of statistical concepts. *Human Factors and Ergonomics in Manufacturing & Service Industries, 24*(5), 532–543.

Maltese, A. V., & Tai, R. H. (2011). Pipeline Persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. Students. *Science Education, 95*(5), 877–907.

Martens, R. L., Gulikers, J., & Bastiaens, T. (2004). The impact of intrinsic motivation on e-learning in authentic computer tasks. *Journal of Computer Assisted Learning, 20,* 368–376.

McAurley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: A confirmatory faactor analysis. *Research Quarterly for Exercise and Sport, 60*(1), 48–58.

Ministry of Education and Research. (2015a). *Langtidsplan for forskning og høyere utdanning 2015-2024. St.meld. 7 (2014-2015).* Oslo: Ministry.

Ministry of Education and Research. (2015b). *NOU 2015:8 Fremtidens skole. Fornyelse av fag og kompetanser.* Oslo.

Mouza, C., & Barrett-Greenly, T. (2015). Bridging the app gap: An examination of a professional development initiative on mobile learning in urban schools. *Computers & Education, 88,* 1–14. http://dx.doi.org/10.1016/j.compedu.2015.04.009.

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence and relatedness in the classroom. Applying self-determination theory to education practice. *Theory and Research in Education, 7*(2), 133–144. http://dx.doi.org/10.1177/1477878509104318.

Noguera, J. M., Jiménez, J. J., & Osuna-Pérez, M. C. (2013). Development and evaluation of a 3D mobile application for learning manual therapy in the physiotherapy laboratory. *Computers & Education, 69,* 96–108. http://dx.doi.org/10.1016/j.compedu.2013.07.007.

OECD. (2014). *OECD skills strategy diagnostic report: Norway.* Paris: OECD Publications.

OECD. (2015). *Students, computers and learning. Making the connection.* PISA: OECD Publishing.

Olaussen, B. S. (2009). Arbeidsplaner i skolen: En kontekst for utvikling av selv-regulert læring? - Refleksjoner etter en studie på småskoletrinnet. *Norsk Pedagogisk Tidsskrift, 93*(3), 189–201.

Parkin, M. (2016, February 26). Save field biology skills from extinction risk. *Times Higher Education.* Retrieved from https://www.timeshighereducation.com/comment/opinion/save-field-biology-skills-from-extinction-risk/2018721.article (website).

Pitts, K., Pudney, K., Zachos, K., Maiden, N., Krogstie, B., Jones, S., et al. (2015). Using mobile devices and apps to support reflective learning about older people with dementia. *Behaviour & Information Technology, 34*(6), 613–631. http://dx.doi.org/10.1080/0144929X.2015.1015165.

Plant, R. W., & Ryan, R. M. (1985). Intrinsic motivation and the effects of self-consciousness, self-awareness, and ego-involvement: An investigation of internally controlling styles. *Journal of Personality, 53*(3), 435–449.

Rigby, C. S., & Przybylski, A. K. (2009). Virtual worlds and the learner hero. How today's video games can inform tomorrow's digital learning environments. *Theory and Research in Education, 7*(2), 214–223. http://dx.doi.org/10.1177/1477878509104326.

Roca, J. C., & Gagne, M. (2008). Understanding e-learning continuance intention in the workplace: A self-determination theory perspective. *Computers in Human Behavior, 24,* 1585–1604. http://dx.doi.org/10.1016/j.chb.2007.06.001.

Rockström, J., Steffen, W., Noone, K., Persson, A. s., F. Stuart Chapin, I., Lambin, E. F., et al. (2009). A safe operating space for humanity. *Nature, 461*(24), 472–475.

Ryan, R. M., & Deci, E. L. (2000b). Self-Determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. http://dx.doi.org/10.1037110003-066X.55.1.68.

Ryan, R. M., Connell, J. P., & Plant, R. W. (1990). Emotions in nondirected text learning. *Learning and Individual Differences, 2*(1), 1–17.

Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67. http://dx.doi.org/10.1006/ceps.1999.1020.

Ryan, R. M., & Deci, E. L. (2002). An overview of self-determination Theory: An organismic-dialectical perspective. In E. L. Deci, & R. M. Ryan (Eds.), *Handbook of self-determination research* (pp. 3–36). New York: The University of Rochester Press.

Ryan, R. M., & Deci, E. L. (2006). Self-regulation and the problem of human autonomy: Does psychology need choice, self-determination, and will? *Journal of Personality, 74*(6), 1557–1585. http://dx.doi.org/10.1111/j.1467-6494.2006.00420.x.

Ryan, R. M., & Deci, E. L. (2009). Promoting self-determined school engagement. Motivation, learning, and well-being. In K. R. Wentzel, & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 171–195). New York: Routledge.

Ryan, R. M., Mims, V., & Koestner, R. (1983). Relation of reward contingency and interpersonal context to intrinsic motivation: A review and test using cognitive evaluation theory. *Journal of Personality and Social Psychology, 45*(4), 736–750.

Ryan, R. M., Rigby, C. S., & Przybylski, A. K. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30*, 347–363. http://dx.doi.org/10.1007/s11031-006-9051-8.

Sandberg, J., Maris, M., & Geus, K. d (2011). Mobile English learning: An evidence-based study with fifth graders. *Computers & Education, 57*, 1334–1347. http://dx.doi.org/10.1016/j.compedu.2011.01.015.

Schafer, J. L. (1999). Multiple imputation: A primer. *Statistical Methods in Medical Research, 8*, 3–15.

Schafer, J. L., & Graham, J. W. (2002). Missing Data: Our view of the state of the art. *Psychological Methods, 7*(2), 147–177. http://dx.doi.org/10.1037//1082-989X.7.2.147.

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Surkes, M. A., et al. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education, 72*, 271–291. http://dx.doi.org/10.1016/j.compedu.2013.11.002.

Senecal, C., Koestner, R., & Vallerand, R. J. (1995). Self-regulation and academic procrastination. *The Journal of Social Psychology, 135*(5), 607–619.

Sha, L., Looi, C.-K., Chen, W., & Zhang, B. H. (2012). Understanding mobile learning from the perspective of self-regulated learning. *Journal of Computer Assisted Learning, 28*, 366–378. http://dx.doi.org/10.1111/j.1365-2729.2011.00461.

Slettemeås, D. (2014). *Bruk av smarttelefon og nettbrett i den norske befolkningen. SIFO-survey hurtigstatistikk 2013. (Prosjektnotat 2*. Oslo: SIFO.

Smith, R. L., J. W. A., Jr., & Williams, D. L. (1992). Suppressor variables in multiple regression/correlation. *Educational and Psychological Measurement, 52*, 17–29.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equations models. In S. Leinhart (Ed.), *Sociological methodology 1982* (pp. 290–312). San Francisco, CA: Jossey-Bass.

Sørebø, Ø., Hallgeir Halvari, Gulli, V. F., & Kristiansen, R. (2009). The role of self-determination theory in explaining teachers' motivation to continue to use e-learning technology. *Computers & Education, 53*(4), 1177–1187.

Tamborini, R., Bowman, N. D., Eden, A., Grizzard, M., & Organ, A. (2010). Defining media enjoyment as the satisfaction of intrinsic needs. *Journal of Communication, 80*, 758–777.

Tham, C. M., & Werner, J. M. (2005). Designing and evaluating e-learning in higher education: A review and recommendations. *Journal of Leadership and Organizational Studies, 11*(2), 15–25.

Tømte, C., & Olsen, D. S. (2013). *IKT og læring i høyere utdanning. Kvalitativ undersøkelse om hvordan IKT påvirker læring i høyere utdanning. (Report 32)*. Oslo: NIFU STEP.

Vallerand, R. J., & Bissonnette, R. (1992). Intrinsic, extrinsic, and amotivational styles as predictors of behavior: A prospective study. *Journal of Personality, 60*(3), 599–620.

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-Determination and persistence in a real-life Setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*(5), 1161–1176.

Vallerand, R. J., & Reid, G. (1984). On the causal effects of perceived competence on intrinsic motivation: A test of cognitive evaluation theory. *Journal of Sport Psychology, 6*, 94–102.

Wang, L., Tao, T., Fan, C., & Gao, W. (2015). Does psychological need satisfaction perceived online enhance well-being? *PsyCh Journal*, 1–9. http://dx.doi.org/10.1002/pchj.98.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology, 70*(4), 767–779.

Williams, G. C., Niemiec, C. P., Elliot, A. J., LaGuardia, J. G., Gorin, A. A., & Rigby, C. S. (2014). Virtual look ahead Program: Initial support for a partly virtualized intensive lifestyle intervention in type 2 diabetes. *Diabetes Care, 37*, e169–e170. http://dx.doi.org/10.2337/dc14-0831.

Wu, W.-H., Wu, Y.-C. J., Chen, C.-Y., Kao, H.-Y., Lin, C.-H., & Huang, S.-H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59*(2), 817–827.

Zuckerman, M., Porac, J., Lathin, D., Smith, R., & Deci, E. L. (1978). On the importance of self-determination for intrinisically-motivated behavior. *Personality and Social Psychology Bulletin, 4*(3).

III

The Relative Effect of Team-Based Learning on Motivation and Learning: A Self-Determination Theory Perspective

Lucas M. Jeno,[†]* Arild Raaheim,[‡] Sara Madeleine Kristensen,[§] Kjell Daniel Kristensen,[§] Torstein Nielsen Hole,[†] Mildrid J. Haugland,[∥] and Silje Mæland[∥]

[†]bioCEED—Centre of Excellence in Biology Education, Department of Biology, University of Bergen, 5006 Bergen, Norway; [‡]bioCEED—Centre of Excellence in Biology Education, Department of Biology, University of Bergen, Norway, 5020 Bergen, Norway; [§]Department of Education, University of Bergen, 5020 Bergen, Norway; [∥]Faculty of Health and Social Sciences, Western Norway University of Applied Sciences, 5036 Bergen, Norway

ABSTRACT

We investigate the effects of team-based learning (TBL) on motivation and learning in a quasi-experimental study. The study employs a self-determination theory perspective to investigate the motivational effects of implementing TBL in a physiotherapy course in higher education. We adopted a one-group pretest–posttest design. The results show that the students' intrinsic motivation, identified regulation, perceived competence, and perceived autonomy support significantly increased going from lectures to TBL. The results further show that students' engagement and perceived learning significantly increased. Finally, students' amotivation decreased from pretest to posttest; however, students reported higher external regulation as a function of TBL. Path analysis shows that increases in intrinsic motivation, perceived competence, and external regulation positively predict increases in engagement, which in turn predict increases in perceived learning. We argue that the characteristics of TBL, as opposed to lectures, are likely to engage students and facilitate feelings of competence. TBL is an active-learning approach, as opposed to more passive learning in lectures, which might explain the increase in students' perception of teachers as autonomy supportive. In contrast, the greater demands TBL puts on students might account for the increase in external regulation. Limitations and practical implications of the results are discussed.

INTRODUCTION

In their most traditional application, lectures impose on students a role as passive recipients, with lecturers being transmitters of information. In contrast, active learning requires students to actively interact with the learning material and has been shown to have a positive effect on retention, as well as reducing dropout and failure rates (Freeman *et al.*, 2014; Wieman, 2014). Similar results have been documented by Ryan and Reid (2015) using flipped-classroom techniques. Further, Singer *et al.* (2013) showed that interactive lecture demonstrations, in which students discuss, watch, and compare their predictions with actual results, improve students' conceptual understanding. Finally, Cavanagh and colleagues (2016) implemented active learning among higher education students and found that it was positively associated with students' self-regulated motivation, engagement, and achievement. There is, in other words, much to be gained by exchanging traditional lectures for more active-learning alternatives.

The purpose of the present research is twofold. First, we investigate how the empirically supported motivation theory of self-determination theory (SDT; Deci and Ryan, 1985; Ryan and Deci, 2017) explains the underlying psychological processes of different learning methods; that is, which psychological factors accounts for passive- and

active-learning methods. Second, we investigate whether the implementation of a specific active-learning method, namely team-based learning (TBL; Michaelsen *et al*., 1982; Michaelsen, 1992), contributes to an increase in students' engagement and learning. In line with previous studies, active-learning methods are associated with increases in engagement and retention. To our knowledge, no studies have investigated TBL in a theoretical framework to understand its motivational mechanisms (Tucker and Brewster, 2015). The majority of the research on TBL has been atheoretical. The research has, in other words, lacked a meta-theoretical assumption when proposing hypotheses and interpreting the results. Thus, it is important to investigate what the motivational consequences of implementing TBL are in order to make changes in courses in higher education and motivate and engage students to participate in class.

TBL

TBL is characterized as a four-step process that facilitates student learning and participation before and during class. The four TBL stages are 1) student preparation, 2) readiness assurance, 3) application, and 4) peer assessment (Michaelsen and Sweet, 2008; McMahon, 2010). The first stage of TBL requires students, who have been allocated to specific teams, to prepare by reading specific parts of the literature or by watching a short lecture on the Internet. The readiness assurance process starts as all members of class meet to undertake a multiple-choice test—the individual readiness assurance test (iRAT). Second, the multiple-choice test is performed in teams (tRAT) applying the immediate-feedback assessment technique (IFAT). The teams must agree on their answers and are given immediate feedback. This stage is followed by a procedure in which the teams are set to work on specific cases, their task being to apply the knowledge and information they have obtained during the whole process. All teams are asked to work on the same significant cases, and they are asked to provide specific answers simultaneously.

Previous research has found support for TBL in different educational domains. For instance, Shankar and Roopa (2009) found that students who participate in TBL sessions are better at fulfilling learning objectives and that the TBL sessions enable better understanding and are more interesting compared with traditional teaching sessions. Vasan *et al*. (2011) found that medical students who took part in TBL-based preclinical anatomy courses achieved higher examination scores than students who took part in lecture-based courses. Further, Carmichael (2009) found that TBL students in a large-enrollment biology class performed better on tests and exams throughout the semester compared with students who took part in traditional lectures. Similar results have been found for students in undergraduate clinical neurology education (Tan *et al.*, 2011), architectural students (Epsey, 2008), and medical students (Koles *et al.*, 2010). In a systematic review of 17 studies, Sisk (2011) found that TBL students overall are more satisfied and more engaged and perform better in exams than students who participate in traditional lecture-based courses.

In sum, the above-mentioned research suggests positive outcomes for student motivation, engagement, and learning when employing active-learning methods such as TBL. To further investigate this, we employ SDT, which is particularly useful for understanding how student outcomes in education occur due to its conceptualization of sociocontextual factors that promote student motivation and wellness (Figure 1). Furthermore, SDT has explicit assumptions of which type of motivation is hypothesized to promote learning and beneficial outcomes, providing an interesting framework to further understand the benefits of TBL.

SDT

SDT is a macro-theory of human motivation and personality. SDT views students as active organisms acting on the environment, as opposed to being passive recipients (Deci and Ryan, 1985). According to SDT, students have three universal psychological needs: the needs for autonomy, competence, and relatedness (Deci and Ryan, 1985; Ryan and Deci, 2000). Autonomy refers to being the causal agent and perceiving volition in one's behaviors. Competence is defined as feeling efficacious in the
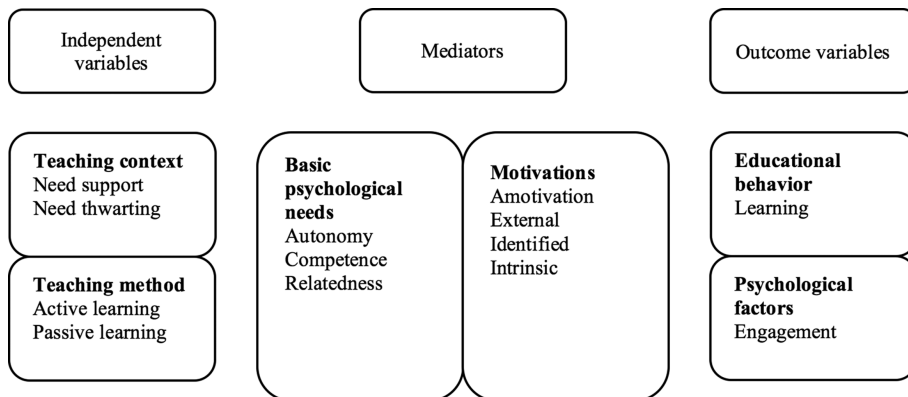

FIGURE 1. Basic model of SDT adapted from Deci *et al.* (2017). The model depicts antecedents of students' basic psychological needs and motivation. The motivations are ranged from least autonomous (amotivation) to fully autonomous (intrinsic motivation).

interaction with one's environment. Relatedness refers to feeling connected to, cared for, and belonging to a significant other or one's community. Further, according to SDT, there are two broad classes of motivation, intrinsic and extrinsic motivation. Intrinsic motivation are behaviors done out of interest and enjoyment, whereas extrinsic motivation are behaviors done because they lead to some separable outcome (Ryan and Deci, 2000).

Motivations

As opposed to other motivational theories, SDT differentiates between different types of extrinsic motivations, depending on their relative autonomy (Ryan and Deci, 2000, 2002). Amotivation is characterized by a state of lacking intentions to act. Students who are amotivated believe that they are unable to achieve an outcome, lack perceived competence, or do not value the activity. External regulation is the least autonomous type of motivation. Students who are externally regulated perform an activity to obtain a reward or avoid punishment. Identified regulation is the most autonomous type of motivation and is associated with valuing an activity. The students perform the activity volitionally, because it is personally important or relevant for them. Within SDT, it is postulated that satisfaction of the basic psychological needs for autonomy, competence, and relatedness promote autonomous types of motivation (i.e., identified regulation and intrinsic motivation), whereas thwarting these needs yields controlled types of motivation (i.e., amotivation and external regulation; Ryan and Deci, 2017). Studies have shown that autonomous types of motivation are associated with higher creativity (Liu *et al.*, 2013), more homework (Otis *et al.*, 2005), and higher persistence in school (Hardre and Reeve, 2003). Conversely, controlled types of motivation have been shown to be associated with less perceived learning (Jeno and Diseth, 2014; Taylor *et al.*, 2014), more negative coping strategies and anxiety (Ryan and Connell, 1989), and more surface-learning strategies (Yamauchi and Tanaka, 1998).

Social Context

SDT argues for the importance of a supportive interpersonal context. That is, students' social context within a learning situation could either support or impede students' psychological needs. For instance, teachers who take the students' perspective and try to understand the students' internal frame of reference, provide choices and opportunities, and nurture the students' inner motivational resources are assumed to support students' needs for autonomy, competence, and relatedness, which in turn promotes autonomous motivations (Reeve, 2009). In contrast, controlling teachers take their own perspective and pressure students to think, feel, and behave in a specific way. Controlling teachers are more likely to thwart the students' basic psychological needs and thus promote controlled motivations. Previous research shows that when teachers are autonomy supportive, the students have higher self-esteem (Deci *et al.*, 1981), higher engagement (Jang *et al.*, 2010), and perceive themselves as more competent (Diseth *et al.*, 2012).

A relatively unexplored research area within SDT has been on how different active-learning methods relate to students' autonomous motivation, perceived autonomy support, and needs satisfaction. However, Jeno (2015) argues that SDT could be employed to understand, test, and implement active-learning methods. Accordingly, Chang *et al.* (2017) argues that passive-learning environments are more susceptible to controlling teaching practices due to lack of responsibility on the part of students, lower interpersonal relations, and fewer possibilities for offering optimal challenges. Furthermore, Kusurkar *et al.* (2011) suggests that active-learning can enhance students' autonomous motivation because it provides opportunities for feedback (competence support), collaboration (relatedness support), and greater responsibility (autonomy support).

THE PRESENT STUDY

Research on TBL using a well-established motivational theory is still in its infancy, thus providing a novel and important research area. To address the lack of theoretical basis in TBL studies, we investigate the effects of TBL in an SDT perspective. Furthermore, Vallerand (1997) argues for the importance of investigating motivation not only at the global (individual) level and contextual level, but also at the situational (state) level. That is, the level of generality in the measurement of motivation can be differentiated on three levels (Vallerand and Ratelle, 2002). For instance, students' motivation could be considered to be an individual difference that applies across contexts (global level). Further, students' motivation could vary between contexts as well; for example, students can be more intrinsically motivated for sports and exhibit greater identified regulation for biology education (contextual level). Importantly, within a specific context, students' motivation can vary from situation to situation. That is, students could find a learning situation or subject within a course to be more autonomously motivating than others (situational context). Thus, we investigate the situational reasons students have for attending lectures or tutorials. This is especially important when differentiating between teaching methods within the same course, as we are doing in the present research.

In the present research, we adopt a quasi-experimental design (Shadish *et al.*, 2002) to investigate why students attend classes and to test whether active learning (i.e., TBL) promotes engagement and learning compared with passive learning (i.e., traditional lectures). See Figure 2 for the general flow of the present study. Quasi-experimental studies are especially useful when randomization is not feasible due to natural criteria, such as administrative selection of which class the students attend or students' self-selection (Shadish *et al.*, 2002; Crano *et al.*, 2015). We employed a one-group pretest–posttest design. This was chosen due to difficulties of finding equivalent control groups in quasi-experimental designs.

Owing to the explorative nature of the present investigation, and the lack of previous studies assessing TBL in a motivational perspective, we center our assumptions around the theoretical propositions of SDT. Specifically, we assume that the students will be more active in the TBL condition (intervention), as opposed to the lecture condition (baseline), and thus will experience more interest and engagement in tasks. This is due to the learner-centered framework of TBL, in which the student is engaged in meaningful learning tasks (Lambert and McCombs, 1998; Parmelee *et al.*, 2012). Thus, we assume that students will experience more autonomous motivations (i.e., intrinsic motivation and identified regulation). Some studies within the SDT framework support our line of reasoning. For example, Benware and Deci (1984) performed a study among university students and found that students in the active condition,
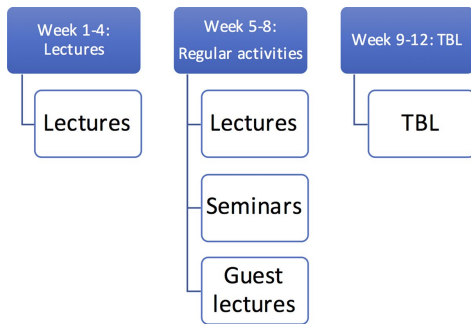
FIGURE 2. Flow and duration of the learning activities during the quasi-experiment. The pretest period (weeks 1–4) consisted of traditional lectures. A period followed during which the students had regular teaching activities (weeks 5–8). The posttest period (weeks 9–12) was the experimental intervention and consisted of TBL. The pre- and posttest measurements were done at the end of the lecture/TBL session, on the last day of the respective experimental week.

relative to students in the passive condition, were more intrinsically motivated and performed better at a heuristic task. Furthermore, Ryan *et al.* (1990) found that students with learning that is active and with a positive emotional set scored better on an unexpected test, compared with students with learning that is passive and with a negative emotional set. Conversely, because TBL requires more of the students (i.e., it provides students with structure) and affords students fewer choices, and therefore reduced autonomy around their learning, we suggest that a possible outcome of the intervention is an increase in external regulation for the students in the transition from the lecture condition to the TBL condition. A study by Jang *et al.* (2010) suggests the necessity of autonomy along with structure for an intervention to be autonomy supportive.

Furthermore, TBL classrooms are facilitated by both the teacher, who provides rationales for the learning assignments and offers structure and challenging tasks through the iRAT and tRAT, and the collaboration with peers. We thus expect TBL to afford students with competence support, autonomy support, and relatedness support. Specifically, with teacher-facilitated learning, as opposed to direct learning, students can internalize the value of the learning behavior and perform the activity volitionally and out of choice (Deci *et al.*, 1996). TBL teachers provide students with clear and meaningful learning goals, optimal challenges that are solved both individually and in teams, thus affording both competence and relatedness satisfaction, which in turn facilitate autonomous types of motivation, perceived competence, and engagement (Skinner and Belmont, 1993; Jang *et al.*, 2010; Chang *et al.*, 2017). A previous study has found that individual situational interest is accounted for by teachers' autonomy and competence support (Tsai *et al.*, 2008). In a study with biology students, Jeno *et al.*, (2017) found that active-learning methods enhanced intrinsic motivation and perceived competence, which in turn, predicted student learning. Finally, as TBL expects students to come to class prepared and work on both rote (iRAT/tRAT) and conceptual (application of

significant case) learning, we assume that students will have higher learning gains as a function of the TBL intervention.

METHODS
Pilot Study
Pilot-Study Methods. Owing to the lack of previous studies employing TBL in a SDT perspective and the explorative nature of the present study, we conducted a pilot study. The participants in the study comprised a convenience sample consisting of biology students from a large university in Norway. Participants were enrolled in a biology course on evolution and ecology. The students in this study were second- and third-year bachelor's students and first-year master's students. The sample included 24 students; 11 were male (45.8%), and 13 were female (54.2%). The participants used a seven-point scale to respond on a range of items measuring intrinsic motivation, identified regulation, external regulation, amotivation, competence, needs satisfaction, autonomy support, engagement, and perceived learning. The participants were recruited at the end of a teaching session. The study was designed as a one-group pretest–posttest design (Shadish *et al.*, 2002). We collected the data 1 month after the semester had started in mid-January 2016. After a 2-week period of traditional lectures, at the end of the last lecture session, we provided the students with the pretest questionnaire. A 4-week period followed, during which the students attended regular teaching activities, after which a 2-week period with TBL teaching commenced. At the end of these 2 weeks, we asked the students to complete the same questionnaire.

Pilot-Study Results. The number of missing values was large, ranging from 8.3% to 41.7% on some of the items. There were 19 students at the pretest measurement and 15 students at the second, posttest measurement. Little's missing completely at random test revealed that the values missing from the data set were missing at random, $\chi^2(434) = 20.85$, $p = 1.00$. In other words, missing by design. Thus, we augmented the data by means of expectation-maximization imputation techniques, to increase the power of the data. We found five significant effects from pretest to posttest: intrinsic motivation, $t(23) = -2.42$, $p = 0.02$; amotivation, $t(21) = -2.59$, $p = 0.01$; perceived competence, $t(23) = -3.12$, $p = 0.005$; autonomy support, $t(23) = -2.40$, $p = 0.02$; and engagement, $t(23) = -1.82$, $p = 0.08$. Results from the pilot study indicated three main concerns; first, that missing by design could largely influence final sample size; second, that between-topic differences in intrinsic motivation and engagement could affect the mean differences between pretest and posttest; and third, that 2 weeks of TBL may be too short for the students to understand the benefits of TBL and get accustomed to the teams. Thus, as suggested by van Teijingen *et al.* (2001) and van Teijingen and Hundley (2001), modifications on the main study were done based on the results from the pilot study. Specifically, we conducted the main study in a course in which attendance was mandatory, thus removing missing by design; the topic was similar across the experimentation period, thus removing any between-interest effect; and the experimentation time could be extended.

Participants
The participants were a convenience sample consisting of second-year physiotherapy students at a large university college in

Norway. The participants ($n = 64$) consisted of 23 males and 41 females. Participant ages were sorted into 4-year intervals: below 20 (6.3%), 21–24 (82.8%), 25–29 (9.4%), and 30–34 (1.6%).

Procedure

Students were recruited from a mandatory course in physiological neurology. The pretest questionnaire was distributed to the students in late August 2016, after 4 weeks of traditional lecturing. This was done so that students would have received relevant information about the semester workload and would have become accustomed to the course syllabus and the teaching environment. The students filled out the questionnaire on the last day of traditional lecture. The students were told that we were interested in their general attitudes toward the previous 4 weeks of *lectures*. Furthermore, the students were told that we would collect data at several time points. This was done so the students would believe that we were interested in the development of their attitudes toward teaching activities and not the difference between two teaching activities. A 4-week period followed, during which the students attended regular teaching activities, after which a 4-week period with TBL followed (Figure 2). On the last day of the TBL session, the students responded to the posttest questionnaire. We asked the students to complete the same questionnaire, but this time with specific reference to *tutorials* for the previous 4 weeks. During both the traditional-lecture period and the TBL period, the students learned about physiology (e.g., neurophysiology, exercise physiology, pain, and how physiology influences rehabilitation). This was done to control for between-topic differences in students' engagement and intrinsic motivation.

The present study received ethical approval from the Norwegian Centre for Research Data to conduct the study. The participants were informed that participation was voluntary and that they could withdraw from the study at any time. Furthermore, the students were informed that any personal identifiable data would be treated confidentially and deleted after the completion of the study.

Measures

All scales were translated from English to Norwegian by L.M.J. and A.R. The scales were then back-translated from Norwegian to English by an English-speaking editor. In instances of discrepancy between the translations, a discussion was invoked to achieve correct, grammatical wording and capture the psychological meaning of the item. This procedure has previously been used in other Norwegian (Hole *et al.*, 2016) and international studies (Deci *et al.*, 2001) and is recommended when working with scales in other languages (Harkness and Schoua-Glusberg, 1998).

Motivation. To measure the students' situational motivation during a learning session, we employed the Situational Motivation Scale (SIMS; Guay *et al.*, 2000). The SIMS measures the students' state of motivation during a learning task or situation. The SIMS consists of a general stem asking "Why are you currently engaged in this activity?," and four subscales measuring intrinsic motivation ("Because I think that this activity is interesting"), identified regulation ("Because I am doing it for my own good"), external regulation ("Because I am supposed to do

it"), and amotivation ("There may be good reasons to do this activity, but personally I don't see any"). The students were asked to respond on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). A previous study in the science education domain has documented the validity of the scale (Ntoumanis, 2003).

The scale has been validated and found reliable across three studies, with alphas ranging from 0.75 to 0.93 (Guay *et al.*, 2000). In the present study, the following Cronbach's alphas were obtained for the scales for intrinsic motivation (pretest: $\alpha = 0.78$; posttest: $\alpha = 0.81$), identified regulation (pretest: $\alpha = 0.88$; posttest: $\alpha = 0.79$), external regulation (pretest: $\alpha = 0.58$; posttest: $\alpha = 0.69$), and amotivation (pretest: $\alpha = 0.80$; posttest: $\alpha = 0.78$),

Perceived Competence. To measure the students' perceived competence, we employed the four-item Perceived Competence scale (PC; Williams and Deci, 1996). PC measures feelings of competence with respect to an activity ("I am competent enough to achieve the goals I have for the course"). The participants were asked to respond on a seven-point scale ranging from 1 (not at all true) to 7 (very true). Jeno and Diseth (2014) and Williams and Deci (1996) have previously reported satisfactory reliability scores of $\alpha = 0.86$ and $\alpha = 0.80$, respectively. The scale has been used in similar context with biology students (Jeno *et al.*, 2017). Reliability analysis showed high alpha levels for perceived competence (pretest: $\alpha = 0.93$; posttest: $\alpha = 0.93$).

Autonomy Support. To measure the students' perception of the teacher's autonomy support, we employed the short six-item Learning Climate Questionnaire (LCQ). The LCQ is answered on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). An item example is "I feel understood by my teacher." The scale has proven to be highly reliable in previous studies. For instance, Black and Deci (2000) reported an alpha level of 0.93, while Williams and Deci (1996) reported an alpha level of 0.96. The scale has been proven valid among biology students in Norway (Jeno *et al.*, 2017). For the present study, autonomy support produced the following alpha levels: pretest, $\alpha = 0.75$; posttest, $\alpha = 0.90$.

Needs Satisfaction in General. The 21-item Basic Psychological Needs Scale (BPNS; Deci and Ryan, 2000; Gagné, 2003) was used to measure the students' needs satisfaction at the university. The BPNS has three subscales: seven items measuring autonomy ("At university I feel free to make my own decisions"); six items measuring competence ("Often I do not feel very competent" [reversed item]); and eight items measuring relatedness ("I really like the people I associate with at university"). Two items were omitted due to low reliability scores, measuring autonomy ("At university, I have little opportunity to decide how to do things" [reversed item]), and competence ("When I am at university I do not get the chance to show how competent I am" [reversed item]). The three subscales were combined to measure a general needs satisfaction scale. The students were asked to respond on a seven-point scale ranging from 1 (not at all true) to 7 (very true). Previous studies have found adequate Cronbach's alphas ranging from 0.66 to 0.86 for this scale (Ntoumanis, 2005; Jeno and Diseth, 2014). Previous validation has been done with a student sample learning

biopsychological values (Williams and Deci, 1996). Reliability analysis produced good alpha levels for needs satisfaction (pretest: α = 0.83; posttest: α = 0.78).

Engagement. The multidimensional 22-item scale measuring four aspects of engagement was employed to measure the students' in-class engagement (Reeve and Tseng, 2011). The engagement scale comprises four subscales: agentic engagement ("I ask questions during lectures"), behavioral engagement ("I listen carefully in class"), emotional engagement ("Lectures are fun"), and cognitive engagement ("When I study, I try to relate what I am learning with what I already know"). The students were asked to respond on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The subscales can be used separately or combined into a general engagement scale (Reeve and Tseng, 2011; Jang *et al.*, 2016b). Previous studies by Jang *et al.* (2016b) and Reeve and Tseng (2011) have reported satisfactory Cronbach's alphas ranging from α = 0.87 to α = 0.97. The engagement scale has previously been shown to predict achievement among science, technology, engineering, and mathematics (STEM) students (Reeve, 2013). In the present study, the subscales were combined and produced good Cronbach's alphas (pretest: α = 0.88; posttest: α = 0.92).

Perceived Learning. To measure the students' learning in class, we employed a four-item scale measuring perceived learning gains. The students were asked to respond on a seven-point Likert scale ranging from 1 (not at all true) to 7 (very true). An item example is "These last four weeks I have learned a lot." A previous study found validity support for a measure of perceived learning among a Norwegian sample, correlating positively with autonomous types of motivation, and unrelated with controlled types of motivation (Jeno and Diseth, 2014). The following Cronbach's alphas were obtained for perceived learning: pretest, α = 0.82; posttest, α = 0.88.

Analytical Strategy

All analyses were conducted using IBM SPSS version 23 and IBM AMOS version 23. To analyze the differences between the students' scores on pretest (lecture) and posttest (TBL), we conducted paired-sample *t* tests. Cohen's *d* was calculated to measure effect sizes for mean differences, which are considered small, medium, and large, at 0.2, 0.5, and 0.8 (Cohen, 1988), respectively. To test how well the theoretical model of SDT accounts for the changes in students' engagement and perceived learning, we conducted a path-analytical model. Specifically, to analyze change scores from pretest to posttest, we calculated the standardized residuals used in the model by regressing the posttest scores on the pretest score for all variables (Zimmerman and Williams, 1982; Allison, 1990). We employed conventional cutoff criteria for goodness of fit to assess model fit, as suggested by Hu and Bentler (1999). Accordingly, comparative fit index (CFI) values above 0.90, root mean square estimate of approximation (RMSEA) below 0.08, and a χ^2/df ratio below 2 are considered a good model fit. Path analysis was chosen due to the theory-driven and multivariate nature (Byrne, 2016) of the present study. That is, path analysis allowed us to test both how well the SDT constructs predict student engagement and perceived learning,

TABLE 1. Descriptive statistics of the study variables for pretest and posttest along with means, SDs, skewness, and kurtosis

	M	SD	Skewness	Kurtosis
Intrinsic motivation: pretest	4.40	1.04	−0.11	−0.33
Intrinsic motivation: post	5.25	1.06	−0.08	−0.80
Identified regulation: pretest	5.24	1.30	−1.15	1.35
Identified regulation: posttest	5.87	0.96	−0.84	0.23
External regulation: pretest	4.96	1.19	−0.52	0.70
External regulation: posttest	5.49	1.09	−0.43	−0.70
Amotivation: pretest	2.72	1.21	1.42	2.43
Amotivation: posttest	2.01	0.97	1.10	1.09
Perceived competence: pretest	5.47	1.22	−0.92	0.26
Perceived competence: posttest	5.85	1.08	−0.81	−0.13
Engagement: pretest	4.36	0.74	−0.04	0.01
Engagement: posttest	5.04	0.89	0.44	−0.80
Autonomy support: pretest	4.22	0.87	−0.21	0.28
Autonomy support: posttest	6.09	1.04	−1.30	1.50
Needs satisfaction: pretest	5.03	0.57	−0.85	2.31
Needs satisfaction: posttest	5.55	0.50	0.04	0.05
Perceived learning: pretest	3.10	1.44	0.35	−0.61
Perceived learning: posttest	6.24	1.09	−1.89	2.93

directly and indirectly, and the interrelationship between the predictors. In our model, we specified that all motivational variables would predict engagement, which in turn would predict perceived learning, as suggested by the engagement model within SDT (Reeve, 2012).

RESULTS

Descriptive analyses of the study variables are presented in Table 1. All variables show signs of normal distribution at both the pretest and posttest measurements.

Main Effects

To test for changes in scores between the pretest and posttest, we conducted a range of repeated-sample *t* tests for the study variables. The results are presented in Figure 3. The results show that, on average, the students' intrinsic motivation, identified regulation, external regulation, perceived competence, engagement, autonomy support, needs satisfaction, and perceived learning, significantly increased from pretest to posttest. Further, students' amotivation significantly decreased from pretest to posttest. The effect sizes for the mean differences in change scores are all large in magnitude.

Indirect Effects

To test how well the SDT constructs fit together and to test for indirect effects, we conducted a path analysis. Model fit was excellent ($\chi^2(7) = 4.198$, $p = 0.757$, CFI = 1.0, χ^2/df ratio = 0.60, RMSEA = 0.000 [confidence interval, CI: 0.00 – 0.108]; see Figure 4). Specifically, increases in perceived competence predict increases in engagement. Increases in intrinsic motivation positively predict increases in engagement. Further, increases in external regulation positively predict increases in engagement. Finally, increases in engagement predict increases in perceived learning. The model as a whole accounts for 70% of the variance in engagement and 17% of the variance in perceived learning. Given our four
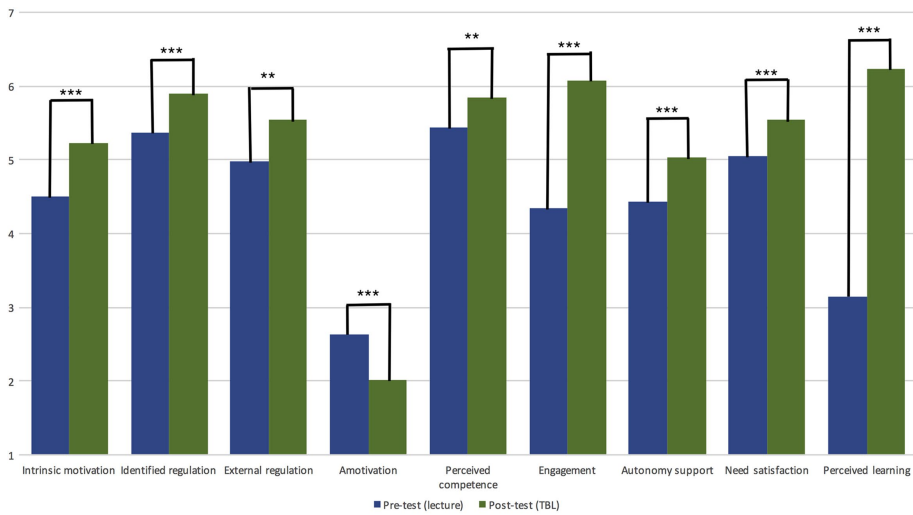
FIGURE 3. Changes in scores between the pretest and posttest. Pretest (lecture) reflects the baseline; posttest (TBL) reflects the intervention. Significance: **, $p < 0.01$; ***, $p < 0.001$. Effect sizes (Cohen's d) for differences between pretest and posttest: intrinsic motivation, $d = -0.66$; identified regulation, $d = -0.53$; external regulation, $d = -0.42$; amotivation, $d = 0.64$; perceived competence, $d = -0.35$; engagement, $d = -0.78$; autonomy support, $d = -1.56$; needs satisfaction, $d = -1.09$; and perceived learning, $d = -1.97$.
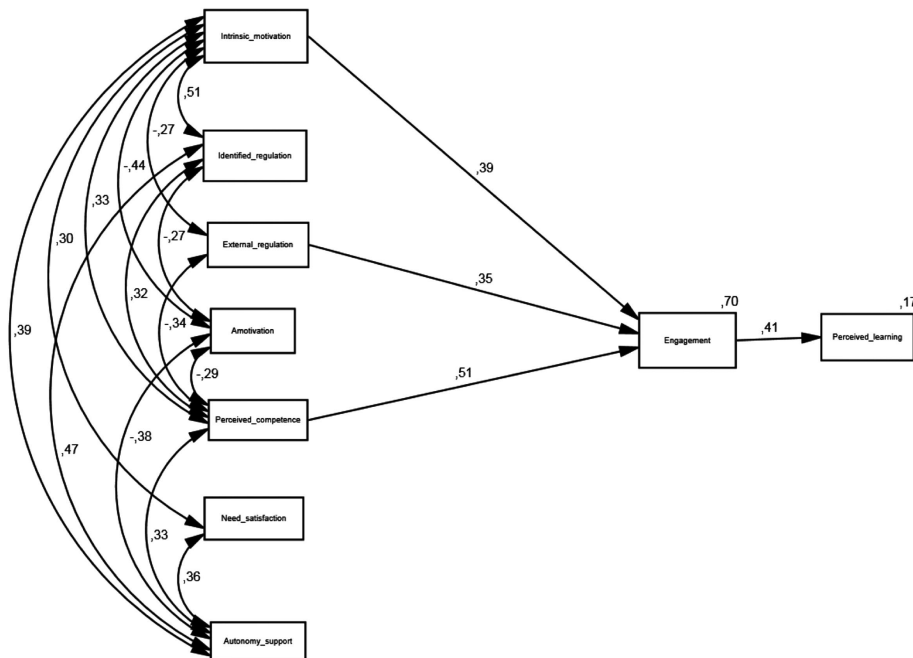

FIGURE 4. The model shows all the study variables predicting students' perceived learning indirectly through engagement. All variables are significant at $p < 0.05$, except amotivation ↔ identified regulation, amotivation ↔ perceived competence, external regulation ↔ intrinsic motivation, needs satisfaction ↔ intrinsic motivation, which are significant at $p < 0.10$. For clarity, only significant paths are shown.

significant paths, we conducted several Sobel tests (Sobel, 1982) to test for indirect effects. Specifically, we calculated the significant regression coefficients and SEs between predictor and mediator and between mediator and dependent variable (Baron and Kenny, 1986). Results showed that perceived competence predicted engagement, which in turn predicted perceived learning ($\beta = 0.209$, $z = 2.73$, $p < 0.01$). Further, external regulation significantly predicted engagement, which in turn predicted perceived learning ($\beta = 0.14$, $z = 2.48$, $p < 0.05$). Finally, intrinsic motivation predicted perceived learning, through the effect of engagement ($\beta = 0.16$, $z = 2.36$, $p < 0.05$).

DISCUSSION

The goal of the present research was to address the psychological processes attached to two teaching methods: traditional lectures and TBL. Through the lenses of SDT, we investigated whether the implementation of TBL, compared with lectures, influenced the students' different types of motivation, perceived competence, perception of the teacher as autonomy supportive, needs satisfaction, engagement, and perceived learning. In general, our assumptions were supported, although some interesting patterns emerged.

TBL, Autonomy, and Autonomous and Controlled Motivations

Results largely support our reasoning on the interest-enhancing effects of TBL. Specifically, we expected that students' intrinsic motivation and identified regulation would increase from pretest to posttest. There might be aspects within the TBL session that promote intrinsically motivated behaviors (Deci and Ryan, 2000). For instance, novelty has previously been associated with intrinsic motivation (Lepper, 1985; Hartnett, 2016). Scratching the immediate feedback cards during the team readiness assurance test to find out whether one's team has the correct answer adds novelty and curiosity to learning, and may, consequently, increase intrinsic motivation. A previous study has found similar results. A study by Gomez *et al.* (2010) assessed the impact of computer-supported TBL in a classroom. Using structural equation modeling, they found that the students' perception of teamwork uniquely predicted students' motivation and enjoyment, which in turn predicted students' perceived learning. Further, the increase in students' identified regulation are in line with theoretical assumptions of SDT. When a teaching method provides support for students' basic psychological needs for autonomy and competence, autonomous motivation is facilitated. Furthermore, in an autonomy-supportive context that provides students with meaningful rationales, affords engaging learning tasks, and communicate respect and warmth in a noncontrolling language (Reeve, 2006), students internalize the importance of the activity and thus promotes identified regulation.

It was hypothesized based on previous research and the controlling requirements of TBL that students' external regulation would increase form pretest to posttest. Results from the repeated *t* test supported our assumptions. Students reported higher mean levels of external regulation in the TBL-condition compared with the lecture-condition. This may be due to few choices in the learning process (i.e., learning activity, choosing teams, few choices in working with signifi-

cant cases), whereby thwarting the basic need for autonomy (Ryan and Deci, 2002). Finally, results show that the students' amotivation decreased from pretest to posttest. This in line with assumptions of active learning. Active learning encompasses activity and engagement while conducting meaningful learning activities (Prince, 2004). Thus, lectures, due to its more passive nature are more likely to enhance feelings of amotivation, than TBL which require active students in the learning process. This is in accordance with SDT which suggests that feelings of amotivation emanate from a lack of perceived control, lack of intentionality and lack of value (Abramson *et al.*, 1978; Deci and Ryan, 1985).

TBL and Perceived Competence

According to SDT (Deci and Ryan, 1985), positive feedback and optimal challenges tend to facilitate a student's perception of competence. Thus, a learning environment that provides structure is highly associated with a student's increase in perceived competence (Guay *et al.*, 2008). Results from the present research support this line of reasoning. Specifically, perceived competence increased from pretest to posttest as a function of TBL. The result of the students' increase in competence after the introduction of TBL could be explained by small discussion groups, significant cases, immediate feedback from the readiness assurance tests, and the teachers' increased provision of structure and competence support in TBL (Michaelsen and Sweet, 2008).

TBL, Autonomy Support, and Relatedness

According to SDT, when students are in learning environments that provide choice, optimal challenges, and a sense of caring, the students' learning is characterized by autonomous motivation. That is, if the sociocontextual climate is nurturing and provides students with effectance relevant feedback in an autonomy-supportive context, the students' intrinsic motivation and autonomous motivation will increase (Niemiec and Ryan, 2009). Thus, to the extent that the teacher is sensitive to supporting the students' basic psychological needs for autonomy, competence, and relatedness, irrespective of the teaching environment, the students thrive.

Our results indicate that the students perceived the teacher to be more autonomy supportive during the TBL phase. This is important, because in traditional lecture-based courses, students are less active and are more prone to accept the role of passive recipient of information. Research has shown that students' attention tends to wander 15–20 minutes into a lecture (Wilson and Korn, 2007; Risko *et al.*, 2012). Because of this, and because there is little demand for personal involvement, the learning output for traditional lectures may be rather poor (Freeman *et al.*, 2014; Wieman, 2014). In contrast, TBL is a more active-learning approach, and the teacher takes on the role of facilitator, as opposed to being the provider of information or taken-for-granted facts. Teachers in TBL courses have to provide students with guidance, encourage them, and facilitate their growth potential and critical thinking (Lane, 2008). Results from the path analysis show support for the basic tenets of SDT. Specifically, the covariance of the predictors shows that autonomy support was highly related to needs satisfaction, perceived competence, identified regulation, and intrinsic motivation, whereas it was unrelated or negatively related to amotivation and external

regulation. This is in line with the SDT's proposition of autonomy support. For instance, Black and Deci (2000) found in a study among chemistry students that learning contexts that were more active and student centered increased the students' autonomous motivation over the semester. Grolnick *et al.* (2007) conducted an intervention study wherein students were divided into either an after-school program or a control group. Students in the after-school group were more active in their learning, and results revealed that the students in this group increased their intrinsic motivation and learning goals from pretest to posttest relative to the control group. Additionally, previous research shows that when teachers are autonomy supportive, the students have a better conceptual understanding of the learning material (Benware and Deci, 1984), higher perceived learning (Jeno and Diseth, 2014), and higher self-esteem (Deci *et al.*, 1981) and are more autonomously motivated (Vallerand *et al.*, 1997).

TBL, Engagement, and Perceived Learning

We found a significant increase in the students' engagement from pretest to posttest. Finding ways to engage students is important, because engagement is related to the quality of the students' learning and their involvement during the teaching session (Reeve, 2012). Previous studies have found engagement to be associated with learning (Archambault *et al.*, 2009; Reeve and Tseng, 2011) and positive emotions (Mageau and Vallerand, 2007), thus supporting the notion that engagement is important. Finally, we found a significant increase in students' perceived learning. Similar results were reported by Vasan *et al.* (2011) among students in a human anatomy course. In a comparison of class averages and results from a National Board of Medical Examiners subject exam, students who attended TBL classes achieved significantly better results on the exam than students who attended a traditional lecture-based course. Results from the path analysis show that increases in perceived competence, intrinsic motivation, and external regulation from pretest to posttest predicted increases in engagement, which in turn predicted increases in perceived learning. The model predicted a substantial amount of variance in engagement, but also a significant amount in perceived learning. An interesting finding was that external regulation indirectly predicted perceived learning. A possible interpretation might be that the controlling functions within TBL enable the students to participate in TBL activities, providing needs satisfaction and autonomy support, thus supporting control and structure within the context of autonomy. This line of reasoning has previously been found in laboratory studies and meta-analytically (Ryan *et al.*, 1983; Deci *et al.*, 1999).

Limitations and Practical Implications

Several limitations are worth mentioning when interpreting the results. First, the study was quasi-experimental, and thus no causal inferences could be made. Including a control group could have limited the confounding effects of maturity and history in the current one-group pretest–posttest design. Randomization of the participants to either of the conditions could have strengthened the conclusions of the study. However, according to Shadish *et al.* (2002), different constraints inhibit the possibility of randomization in quasi-experimental studies for ethical, funding, and/or administrative reasons. Furthermore, quasi-experiments also allow for a more context-sensitive investigation. Owing to the students' enrollment in courses, randomization was not possible. Although ruling out factors that could threaten the internal validity of the study increases the strength of the results (Baldwin and Berkeljon, 2012), we recommend future studies employ true experimental designs to further strengthen the validity of the results.

Second, the present study employs perceived learning, as opposed to actual achievement such as grades or achievement from a test. On the one hand, assessment of grades could have accounted for more variability. On the other hand, previous studies have shown that perceived learning is an adequate measure of actual learning (Kuncel *et al.*, 2005; Cole and Gonyea, 2010; Felder-Puig *et al.*, 2012) and related to needs satisfaction (Jang *et al.*, 2016a). Thus, the strategy employed for our design was adequate for the aims of our investigation.

Third, some of the scales employed had Cronbach's alphas that were below the recommended cutoff point of 0.70. Specifically, external regulation had low alphas at pretest and posttest. Some might argue that this is a concern. However, according to Cronbach (1951), scales with few items yield lower alpha levels, and the same scale with more items would have increased the alpha level proportionally with the increasing amount of items. Also, due to the explorative nature of the present investigation, we accepted a higher degree of measurement error (Crano *et al.*, 2015). Furthermore, smaller sample size has more variation, which may cause larger measurement error in the scales.

A final limitation was the short amount of time the students in the TBL condition had to become accustomed to the learning method. According to Michaelsen and Sweet (2011), TBL sessions require students to get to know their team members and stay together as a team throughout the semester. Thus, if the experimental period had lasted longer, the students could have gained more of the benefits that TBL provides (Slavin, 1991). Despite increasing the test period from the pilot test to the present study, the relative time the students had to get accustomed to the groups and the learning method was short. However, due to a shorter lecture semester in Fall (August–November) and the criteria of having a similar topic in both teaching methods, we were not able to extend the test period any further. On the one hand, continuous measurement of participants throughout the experimentation could have eliminated the engagement or autonomous motivation effect of the topic. On the other hand, several measurements could have produced pretest sensitization effect (Crano *et al.*, 2015), thereby either enhancing or reducing the effect of the intervention (i.e., TBL). Furthermore, a last follow-up measurement after the implementation of TBL, when students returned to traditional lectures, could have impacted their answers and their ability to detect the study hypotheses, especially when the experimentation time was as short as 4 weeks.

Several practical implications are put forth based on the results. We recommend teachers incorporate active-learning approaches, specifically TBL, into their teaching. Our results show that students perceive the teachers as more autonomy supportive under TBL conditions. Furthermore, TBL as a teaching method facilitates rote learning and conceptual learning, both of which are important for the future workforce to master (Ministry of Education and Research, 2015). In line with the

theoretical assumptions of SDT, we recommend teachers evaluate any teaching activities in light of motivational consequences and autonomy-supportive contexts. A strength of this study is the ability to investigate what the various motivational effects of TBL are, and why this might be the case. There might be some controlling aspects of TBL that enhance feelings of external regulation. We recommend teachers nurture students' psychological needs for autonomy, competence, and relatedness in an autonomy-supportive way to reduce feelings of external regulation (Cheon and Reeve, 2015) by providing choice, structure, and caring. Finally, based on our findings, we recommend teachers incorporate TBL in higher education due to the positive motivational effects of increased intrinsic motivation, perceived competence, and engagement.

CONCLUSION

In conclusion, our investigation has been a first step toward assessing the motivational implications of TBL in a higher education context, an area of investigation that has been understudied. Despite the limitations in our study, we have found some initial support for the motivational benefits that TBL can have on higher education students in physiotherapy. Specifically, implementing active-learning approaches, such as TBL, compared with passive-learning approaches, such traditional lectures, could improve students' autonomous motivation, competence, engagement, and learning over time.

Future studies should conduct randomized controlled trials of the effects of TBL and lectures from an SDT perspective. By conducting randomization, it is possible to remove within-group differences, a risk associated with quasi-experiments. Furthermore, more complex longitudinal designs over several semesters, in which the experimental treatments are counterbalanced with control groups, are recommended to rule out any training or novelty effects. Finally, we recommend future studies to assess students' psychological well-being in order to test how teaching methods (active vs. passive) interact with students' motivation (autonomous vs. controlled) in explaining psychological health and affect.

REFERENCES

Abramson, L. Y., Seligman, M. E. P., & Teasdale, J. D. (1978). Learned helplessness in humans: Critique and reformulation. *Journal of Abnormal Psychology*, *87*(1), 49–74.

Allison, P. D. (1990). Change scores as dependent variables in regression analysis. *Sociological Methodology*, *20*, 93–114.

Archambault, I., Janosz, M., Morizot, J., & Pagani, L. (2009). Adolescent behavioral, affective, and cognitive engagement in school: Relationship to dropout. *Journal of School Health*, *79*(9), 408–415.

Baldwin, S., & Berkeljon, A. (2012). Quasi-experimental design. In Salkind, N. J. (Ed.), *The encyclopedia of research design* (pp. 1172–1176). Thousand Oaks, CA: Sage.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173–1182.

Benware, C. A., & Deci, E. L. (1984). Quality of learning with an active versus passive motivational set. *American Educational Research Journal*, *21*(4), 755–765.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*, 740–756.

Byrne, B. M. (2016). *Structural equation modeling with AMOS: Basic concepts, applications and programming* (3rd ed.). New York: Routledge.

Carmichael, J. (2009). Team-based learning enhances performance in introductory biology. *Journal of College Science Teaching*, *38*(4), 54–61.

Cavanagh, A. J., Aragón, O. R., Chen, X., Couch, B. A., Durham, M. F., Bobrownicki, A., … Graham, M. J. (2016). Student buy-in to active learning in a college science course. *CBE—Life Sciences Education*, *15*(4), ar76. doi: 10.1187/cbe.16-07-0212

Chang, R., Fukuda, E., Durham, J., & Little, T. D. (2017). Enhancing students' motivation with autonomy-supportive classrooms. In Wehmeyer, M. L., Shogren, K. A., Little, T. D., & Lopez, S. J. (Eds.), *Development of self-determination through the life-course* (pp. 99–110). Dordrecht, Netherlands: Springer.

Cheon, S. H., & Reeve, J. (2015). A classroom-based intervention to help teachers decrease students' amotivation. *Contemporary Educational Psychology*, *40*, 99–111.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cole, J. S., & Gonyea, R. M. (2010). Accuracy of self-reported SAT and ACT test scores: Implication for research. *Research in Higher Education*, *51*(4), 305–319.

Crano, W. D., Brewer, M. B., & Lac, A. (2015). *Principles and methods of social research* (3rd ed.). New York: Routledge.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668.

Deci, E. L., Nezlek, J., & Sheinman, L. (1981). Characteristics of the rewarder and intrinsic motivation of the rewardee. *Journal of Personality and Social Psychology*, *40*(1), 1–10.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-determination theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior*, *4*(10), 1–25. doi: 10.1146/annurev-orgpsych-032516-113108

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*, New York: Plenum.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*(4), 227–268.

Deci, E. L., Ryan, R. M., Gagné, M., Leone, D. R., Usanov, J., & Kornazheva, B. P. (2001). Need satisfaction, motivation, and well-being in the work organization of a former eastern bloc country: A cross-cultural study of self-determination. *Personality and Social Psychology Bulletin*, *27*(8), 930–942.

Deci, E. L., Ryan, R. M., & Williams, G. C. (1996). Need satisfaction and the self-regulation of learning. *Learning and Individual Differences*, *8*(3), 165–183.

Deci, E. L., Schwartz, A. J., Sheinman, L., & Ryan, R. M. (1981). An instrument to assess adults' orientations toward control versus autonomy with children: Reflection on intrinsic motivation and perceived competence. *Journal of Educational Psychology*, *73*(5), 642–650.

Diseth, Å., Danielsen, A. G., & Samdal, O. (2012). A path analysis of basic need support, self-efficacy, achievement goals, life satisfaction and academic achievement level among secondary school students. *Educational Psychology*, *32*(3), 335–354. doi: 10.1080/01443410.2012.657159

Epsey, M. (2008). Does space matter? Classroom design and team-based learning. *Review of Agricultural Economics*, *30*(4), 764–775. doi: 10.1111/j.1467-9353.2008.00445.x

Felder-Puig, R., Griebler, R., Samdal, O., King, M. A., Freeman, J., & Duer, W. (2012). Does the school performance variable used in the International Health Behavior in School-Aged Children (HBSC) study reflect students' school grades?. *Journal of School Health*, *82*(9), 404–409.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences USA*, *111*(23), 8410–8415. doi: 10.1073/pnas.1319030111

Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and Emotion*, *27*(3), 199–221.

Gomez, E. A., Wu, D., & Passerini, K. (2010). Computer-supported team-based learning: The impact of motivation, enjoyment and team contributions on learning outcomes. *Computers and Education, 55,* 378–390. doi: 10.1016/j.compedu.2010.02.003

Grolnick, W. S., Farkas, M. S., Sohmer, R., Michaels, S., & Valsiner, J. (2007). Facilitating motivation in young adolescents: Effects of an after-school program. *Journal of Applied Developmental Psychology, 28,* 332–344. doi: 10.1016/j.appdev.2007.04.004

Guay, F., Ratelle, C. F., & Chanal, J. (2008). Optimal learning in optimal contexts: The role of self-determination in education. *Canadian Psychology*, *49*(3), 233–240. doi: 10.1037/a0012758

Guay, F., Vallerand, R. J., & Blanchard, C. (2000). On the assessment of situational intrinsic and extrinsic motivation: The Situational Motivation Scale (SIMS). *Motivation and Emotion*, *24*(3), 175–213.

Hardre, P. L., & Reeve, J. (2003). A motivational model of rural students' intentions to persist in, versus drop out of high school. *Journal of Education Psychology*, *95*(2), 347–356. doi: 10.1037/0022-0663.95.2.347

Harkness, J. A., & Schoua-Glusberg, A. (1998). Questionnaire in translation. *ZUMA-Nachrichten Spezial*, *3*(1), 87–127.

Hartnett, M. (2016). *Motivation in online education*. Singapore: Springer.

Hole, T. N., Jeno, L. M., Holtermann, K., Raaheim, A., Velle, G., Simonelli, A. L., & Vandvik, V. (2016). *bioCEED survey 2015*, Retrieved May 1, 2016, from https://hdl.handle.net/1956/11952

Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55.

Jang, H., Kim, E. J., & Reeve, J. (2016a). Why students become more engaged or more disengaged during the semester: A self-determination theory dual-process model. *Learning and Instruction, 43,* 27–38. doi: 10.1016/j.learninstruc.2016.01.002

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology*, *102*(3), 588–600. doi: 10.1037/a0019682

Jang, H., Reeve, J., & Halusic, M. (2016b). A new autonomy-supportive way of teaching that increases conceptual learning: Teaching in students' preferred ways. *Journal of Experimental Education*, *84*(4), 686–701. doi: 10.1080/00220973.2015.1083522

Jeno, L. M. (2015). Encouraging active learning in higher education: a self-determination theory perspective. *International Journal of Technology and Inclusive Education*, *5*(1), 716–721.

Jeno, L. M., & Diseth, Å. (2014). A self-determination theory perspective on autonomy support, autonomous self-regulation, and perceived school performance. *Reflecting Education*, *9*(1), 1–20.

Jeno, L. M., Grytnes, J.-A., & Vandvik, V. (2017). The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A self-determination theory perspective. *Computers and Education*, *107*, 1–12. doi: 10.1016/j.compedu.2016.12.011

Koles, P. G., Stolfi, A., Borges, N. J., Nelson, S., & Parmelee, D. X. (2010). The impact of team-based learning on medical students' academic performance. *Academic Medicine*, *85*(11), 1739–1745.

Kuncel, N. R., Credé, M., & Thomas, L. L. (2005). The validity of self-reported grade point averages, class ranks and test scores: A meta-analysis and review of the literature. *Review of Educational Research*, *75*(1), 63–82.

Kusurkar, R. A., Croiset, G., Olle, T. J., & Cate, T. (2011). Twelve tips to stimulate intrinsic motivation in students through autonomy-supportive classroom teaching derived from self-determination theory. *Medical Teacher*, *33*(12), 978–982.

Lambert, N. M., & McCombs, B. L. (1998). Introduction: Learner-centered schools and classrooms as a direction for school reform. In Lambert, N. M., & McCombs, B. L. (Eds.), *How students learn: Reforming schools through learner-centered education* (pp. 1–22). Washington, DC: American Psychological Association.

Lane, D. R. (2008). Teaching skills for facilitating team-based learning. In Michaelsen, L. K., Sweet, M., & Parmelee, D. X. (Eds.), *Team-based learning: Small group learning's new big step* (pp. 55–68). San Francisco: Wiley.

Lepper, M. R. (1985). Microcomputers in education. *American Psychologist*, *40*(1), 1–18.

Liu, G., Zhang, S., Zhang, J., Lee, C., Wang, Y., & Brownell, M. (2013). Autonomous motivation and Chinese adolescents' creative thinking: The moderating role of parental involvement. *Creativity Research Journal*, *25*(4), 446–456. doi: 10.1080/10400419.2013.843401

Mageau, G. A., & Vallerand, R. J. (2007). The moderating effect of passion on the relation between activity engagement and positive affect. *Motivation and Emotion*, *31*, 312–321. doi: 10.1007/s11031-007-9071-z

McMahon, K. K. (2010). Team-based learning. In Jeffries, W. B., & Huggett, K. N. (Eds.), *An introduction to medical teaching* (pp. 55–64). New York: Springer.

Michaelsen, L. K. (1992). Team learning: A comprehensive approach for harnessing the power of small groups in higher education. *To Improve the Academy*, *11*, 107–122.

Michaelsen, L. K., & Sweet, M. (2008). The essential elements of team-based learning. In Michaelsen, L. K., Sweet, M., & Parmelee, D. X. (Eds.), *Team-based learning: Small group learning's new big step* (pp. 7–28). San Francisco: Wiley.

Michaelsen, L. K., & Sweet, M. (2011). Team-based learning. *New Directions for Teaching and Learning*, *128*, 41–51. doi: 10.1002/tl.467

Michaelsen, L. K., Watson, W., Cragin, J. P., & Dee Fink, L. (1982). Team learning: A potential solution to the problems of large classes. *Exchange: The Organization Behavior Teaching Journal*, *7*(1), 13–22.

Ministry of Education and Research. (2015). *NOU 2015:8 Fremtidens skole. Fornyelse av fag og kompetanser*. Oslo, Norway.

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence and relatedness in the classroom. Applying self-determination theory to education practice. *Theory and Research in Education*, *7*(2), 133–144. doi: 10.1177/1477878509104318

Ntoumanis, N. (2003). Contextual and situational motivation in education: A test of the specificity hypothesis. *European Physical Educational Review*, *9*(1), 5–21.

Ntoumanis, N. (2005). A prospective study of participation in optional school physical education using a self-determination theory framework. *Journal of Educational Psychology*, *97*(3), 444–453. doi: 10.1037/0022-0663.97.3.444

Otis, N., Grouzet, F. M. E., & Pelletier, L. G. (2005). Latent motivational change in an academic setting: A 3-year longitudinal study. *Journal of Educational Psychology*, *97*(2), 170–183. doi: 10.1037/0022-0663.97.2.170

Parmelee, D. X., Michaelsen, L. K., Cook, S., & Hudes, P. D. (2012). Team-based learning: A practical guide: AMEE Guide No. 65. *Medical Teacher*, *34*(5), e275–e287.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231.

Reeve, J. (2006). Teachers as facilitators: What autonomy-supportive teachers do and why their students benefit. *Elementary School Journal*, *106*(3), 225–236.

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist*, *44*(3), 159–175. doi: 10.1080/00461520903028990

Reeve, J. (2012). A self-determination theory perspective on student engagement. In Christenson, S. L., Reschly, A. L., & Wylie, C. (Eds.), *Handbook of research on student engagement* (pp. 149–172). New York: Springer.

Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. *Journal of Educational Psychology*, *105*(3), 579–595. doi: 10.1037/a0032690

Reeve, J., & Tseng, C.-M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology*, *36*, 257–267. doi: 10.1016/j.cedpsych.2011.05.002

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology*, *26*(2), 234–242. doi: 10.1002/acp.1814

Ryan, R. M., & Reid, S. A. (2015). Impact of the flipped classroom on student performance and retention: A parallel controlled study in general chemistry. *Journal of Chemical Education*, *93*, 13–23. doi: 10.1021/acs.jchemed.5b00717

Ryan, R. M., & Connell, J. P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *Journal of Personality and Social Psychology*, *57*(5), 749–761.

Ryan, R. M., Connell, J. P., & Plant, R. W. (1990). Emotions in nondirected text learning. *Learning and Individual Differences*, *2*(1), 1–17.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. doi: 10.1006/ceps.1999.1020

Ryan, R. M., & Deci, E. L. (2002). An overview of self-determination theory: An organismic-dialectical perspective. In Deci, E. L., & Ryan, R. M. (Eds.), *Handbook of self-determination research* (pp. 3–36). Rochester, NY: University of Rochester Press.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory. Basic psychological needs in motivation, development, and wellness.* New York: Guilford.

Ryan, R. M., Mims, V., & Koestner, R. (1983). Relation of reward contingency and interpersonal context to intrinsic motivation: A review and test using cognitive evaluation theory. *Journal of Personality and Social Psychology*, *45*(4), 736–750.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Belmont, CA: Wadsworth, Cengage Learning.

Shankar, N., & Roopa, R. (2009). Evaluation of a modified team based learning method for teaching general embryology to 1st year medical graduate students. *Indian Journal of Medical Science*, *63*(1), 4–12.

Singer, S. R., Nielsen, N. R., & Schweingruber, H. A. (2013). Biology education research: Lessons and future directions. *CBE—Life Sciences Education*, *12*(2), 129–132.

Sisk, R. J. (2011). Team-based learning: Systematic research review. *Journal of Nursing Education*, *50*(2), 665–669. doi: 10.3928/01484834-20111017-01

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, *85*(4), 571–581.

Slavin, R. E. (1991). Synthesis of research on cooperative learning. *Educational Leadership*, *48*(5), 71–82.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological Methodology*, *13,* 290–312.

Tan, N. C., Kandiah, N., Chan, Y. H., Umapathi, T., Lee, S. H., & Tan, K. (2011). A controlled study of team-based learning for undergraduate clinical neurology education. *BMC Medical Education*, *11*(91), 1–8.

Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., & Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemporary Educational Psychology*, *39,* 342–358. doi: 10.1016/j.cedpsych.2014.08.002

Tsai, Y.-M., Kunter, M., Lüdtke, O., Trautwein, U., & Ryan, R. M. (2008). What makes lessons interesting? The role of situational and individual factors in three school subjects. *Journal of Educational Psychology*, *100*(2), 460–472. doi: 10.1037/0022-0663.100.2.460

Tucker, J. M., & Brewster, M. P. (2015). Evaluating the effectiveness of team-based learning in undergraduate criminal justice courses. *Journal of Criminal Justice Education*, *26*(4), 446–470. doi: 10.1080/10511253.2015.1052000

Vallerand, R. J. (1997). Toward a hierarchical model of intrinsic and extrinsic motivation. In Zanna, M. P. (Ed.), *Advances in experimental social psychology*. Vol. 29, (pp. 271–360). San Diego: Academic.

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology*, *72*(5), 1161–1176.

Vallerand, R. J., & Ratelle, C. F. (2002). Intrinsic and extrinsic motivation: A hierarchical model. In Deci, E. L., & Ryan, R. M. (Eds.), *Handbook of self-determination research* (pp. 37–63). Rochester, NY: University of Rochester Press.

van Teijingen, E., & Hundley, V. (2001). The importance of pilot studies. *Social Research Update* 35, 1–4.

van Teijingen, E., Rennie, A.-M., Hundley, V., & Graham, W. (2001). The importance of conducting and reporting pilot studies: The example of the Scottish Births Survey. *Journal of Advanced Nursing*, *34*(3), 289–295.

Vasan, N. S., DeFouw, D. O., & Compton, S. (2011). Team based learning in anatomy: An efficient, effective and economical strategy. *Anatomical Science Education*, *4*(6), 333–339.

Wieman, C. E. (2014). Large-scale comparison of science teaching methods sends clear message. *Proceedings of the National Academy of Sciences USA*, *111*(23), 8319–8320. doi: 10.1073/pnas.1407304111

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology*, *70*(4), 767–779.

Wilson, K., & Korn, J. H. (2007). Attention during lectures: Beyond ten minutes. *Teaching of Psychology*, *34*(2), 85–89.

Yamauchi, H., & Tanaka, K. (1998). Relations of autonomy, self-referenced beliefs, and self-regulated learning among Japanese children. *Psychology Reports*, *82,* 803–816.

Zimmerman, D. W., & Williams, R. H. (1982). Gain scores in research can be highly reliable. *Journal of Educational Measurement*, *19*(2), 149–154.