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Jani Hartikainen

Sedentary Behaviour, Physical Activity and Engagement in Open Learning Spaces and Conventional Classrooms in Primary School Settings

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND HEALTH SCIENCES

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Päivi Vuorio
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ABSTRACT

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The high amount of school-based sedentary time in children is a persistent issue of concern. The aims of this dissertation were to investigate associations of (1) different classroom designs on students' classroom-based sedentary behaviour and physical activity (CPA), (2) observed teacher instructions with respect to students' CPA, and (3) classroom design and CPA with students' emotional and behavioural school engagement. In a cross-sectional design, Study I was conducted during two separate academic years among 130 Finnish third- and fifth-grade students (9 or 11 years old) in a school undergoing renovation from conventional classrooms (CC) to open learning spaces (OLS). Studies II, III and IV used CPA measures, systematic observation and a school engagement questionnaire that were collected from 204 students in third and fifth grades attending three different schools, one with OLS. CPA was assessed using accelerometery. Statistical analyses included three-way ANOVA and structural equation modelling. The main finding was that OLS were associated with more breaks from sedentary time, more 1-to-4–minute sedentary bouts, fewer sedentary bouts of more than 10 minutes, and more sit-to-stand transitions. Contradictorily, OLS were associated with more total sedentary time in fifth-grade students compared to CC. Both gender and grade of participants influenced CPA as girls tended to accumulate less CPA than boys, while third graders accumulated more CPA than fifth graders. Fifth-grade teachers in OLS were more restrictive towards students' movement in the classroom compared to other schools with CC. Teachers in schools with CC seemed to promote CPA with teacher-organized breaks more than in OLS. OLS were associated with students' emotional engagement. In conclusion, schools with OLS facilitate shorter sedentary bout durations, breaks from sedentary time and postural transitions, which may translate into potential health benefits over the longer term. Teachers' actions to incorporate CPA into general education classroom time may be crucial for promoting CPA. OLS may facilitate emotional aspects of school engagement, which may also have beneficial effects on other dimensions school engagement. Increased engagement may have potential benefits on academic achievement during primary school years.

Keywords: open learning spaces, conventional classrooms, physical activity, sedentary behaviour, movement integration, school engagement

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Hartikainen, Jani
Paikallaanolo, fyysinen aktiivisuus ja kouluun kiinnittyminen avoimissa ja perinteisissä luokkatiloissa.
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Tutkimuksen tavoitteena oli selvittää luokkatilaratkaisujen yhteyksiä oppilaiden oppituntien aikaiseen fyysiseen aktiivisuuteen, kouluun kiinnittymiseen sekä opettajien liikkumista tukevaan tai rajoittavaan toimintaan. Osatutkimuksessa I selvitettiin yhteensä 130 vuosiluokkien 3 ja 5 oppilaiden kiihtyvyysmittarilla mitatun oppituntien aikaisen fyysisen aktiivisuuden määriä ennen ja jälkeen kouluremontin, jossa perinteiset luokkahuoneet muutettiin avoimiksi oppimistiloiksi. Osatutkimukset II-IV perustuivat 204 3. ja 5. luokkalaiselta kiihtyvyysmittarilla mitattuun fyysiseen aktiivisuuteen, kouluun kiinnittymistä selvittävään kyselyyn sekä opettajien liikkumista tukevan ja rajoittavan toiminnan systemaattiseen havainnointiin kolmessa eri koulussa, joissa yhdessä oli käytössä avoimet oppimistilat. Tilastollisissa vertailuissa hyödynnettiin kolmisuuntaista varianssianalyysiä ja rakenneyhtälömallinnusta. Avoimet tilat olivat yhteydessä suurempaan määrään passiivisen ajan tauottamista, suurempaan määrään 1–4-minuutin mittaisia passiivisia jaksoja, vähäisempään määrään yli 10-minuutin passiivisuusjaksoja ja suurempaan määrään seisomaan nousuja. Viidesluokkalaiset olivat fyysisesti passiivisempia avoimissa tiloissa. Tyttöjen havaittiin olevan fyysisesti passiivisempia kuin pojat, kun taas kolmasluokkalaiset olivat aktiivisempia kuin viidesluokkalaiset. Systemaattisen havainnoinnin perusteella viidesluokkalaisten oppilaiden liikkumista rajoitettiin enemmän avoimissa tiloissa kuin perinteissä luokkahuoneissa. Avoimissa tiloissa organisoitiin fyysisesti aktiivisia siirtymiä, kun taas perinteisissä tiloissa toteutettiin enemmän opettajajohtoista fyysistä aktiivisuutta. Kyselyjen tulokset osoittivat positiivisen yhteyden avoimien tilojen ja oppilaiden emotionaalisen kiinnittymisen välillä. Avoimet tilat olivat yhteydessä paikallaanolon tauottamiseen, joka voi edistää terveyttä pitkällä aikavälillä. Opettajien liikkumista tukeva toiminta on tärkeää oppilaiden liiallisen paikallaanolon välttämiseksi. Avoimet tilat vaikuttaisivat olevan myönteisesti yhteydessä emotionaaliseen kouluun kiinnittymiseen. Tämä voi tukea myös muita kouluun kiinnittymisen ulottuvuuksia, jotka voivat olla yhteydessä koulumenestykseen pidemmällä aikavälillä.

Asiasanat: Avoimet tilaratkaisut, luokkatilat, fyysinen aktiivisuus, paikallaanolo, liikkuminen oppitunneilla, kouluun kiinnittyminen

Author Jani Hartikainen, MSc
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland
jani.p.hartikainen@jyu.fi
ORCID: 0000-0003-2315-4486

Supervisors Professor Taija Finni, PhD
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland

Eero A. Haapala, PhD, Title of Docent
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland

Associate Professor Arja Sääkslahti, PhD
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland

Professor, Anna-Maija Poikkeus
Department of Teacher Education
University of Jyväskylä
Finland

Reviewers Professor Lorraine Cale
School of Sport, Exercise and Health Sciences
Loughborough University
United Kingdom

Professor Erica Hinckson
Department of Physical Activity and Nutrition
School of Sport and Recreation
Faculty of Health and Environmental Sciences
Auckland University of Technology
New Zealand

Opponent Professor Gareth Stratton
Department of Engineering
Swansea University
United Kingdom

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In the final moments of this journey
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LIST OF ORIGINAL PUBLICATIONS

The current dissertation is based on the following original publications, which will be referred to as studies I–IV.

I. Hartikainen, J., Haapala, E. A., Poikkeus, A. M., Lapinkero, E., Pesola, A. J., Rantalainen, T., Sääkslahti A., Gao, Y., & Finni, T. (2021). Comparison of classroom-based sedentary time and physical activity in conventional classrooms and open learning spaces among elementary school students. *Frontiers in Sports and Active Living*, 3, 168, https://doi.org/10.3389/fspor.2021.626282

II. Hartikainen, J., Haapala, E.A., Poikkeus, A. M., Sääkslahti, A., Laukkanen, A., Gao, Y., & Finni, T. (2023). Classroom-based physical activity and teachers' instructions on students' movement in conventional classrooms and open learning spaces. *Learning Environments Research*, 26, 177-198. https://doi.org/10.1007/s10984-022-09411-3

III. Hartikainen, J., Poikkeus, A-M., Haapala, E.A., Sääkslahti, A., & Finni, T. (2021). Associations of classroom design and classroom-based physical activity with behavioral and emotional engagement among primary school students. *Sustainability*, 13(14), 8116, https://doi.org/10.3390/su13148116

IV. Hartikainen, J., Haapala E.A., Sääkslahti, A., Poikkeus, A-M., & Finni, T. (2022). Sedentary patterns and sit-to-stand transitions in open learning spaces and conventional classrooms among primary school students. *International Journal of Environmental Research and Public Health*. 19(13):8185. https://doi.org/10.3390/ijerph19138185

As the first author of the original publications, the author responsible for drafting the original manuscripts, considering the comments of co-authors, taking main responsibility in data preparation for statistical analysis, and conducting the statistical analysis. Study I was originally planned by Anna-Maija Poikkeus, Eero Lapinkero, and Taija Finni. Data for Study I were collected by Eero Lapinkero and Arto Pesola. Studies II, III and IV were originally planned by Taija Finni, Arja Sääkslahti, Anna-Maija Poikkeus, Arto Laukkanen, Arto Pesola, Ying Gao, Timo Rantalainen, and Eero Haapala. The author was responsible for data collection for studies II, III and IV with assistance of Eero Haapala, Ying Gao and Taija Finni.

FIGURES

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1 INTRODUCTION

During childhood, foundations are laid for health behaviours which further facilitate development and maintenance of a healthy body and mind (Craigie et al., 2011). Because considerable time in childhood is spent at school, it is an important goal for the educational institutions to provide both quality learning opportunities and facilitate the physical, social, and emotional development of students (World Health Organisation [WHO] & the United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021). The aims of the Finnish basic education curriculum (Finnish National Core Curriculum for Basic Education, 2014) include supporting students' learning of habits and skills to develop overall well-being, that is, physical literacy (Keegan et al., 2019). Thus, schools are seen as important resources for influencing the health and well-being of students, as well as that of their families and communities (WHO & UNESCO, 2021). It is further recognized by governments and school communities that health, wellbeing, and educational outcomes, such as academic achievement, are closely associated (WHO & UNESCO, 2021). The United Nations Convention on the Rights of the Child (1989) states that all children should have the right to a healthy life and development towards reaching their own potential. Behaviours or habits which are unhealthy may influence children's functioning over a longer term and limit their future capacities to in life.

The high amount of overall and especially school-based sedentary time of children and adolescents (Grao-Cruces et al., 2020; van Stralen et al., 2014) is considered as a major issue of concern, because of the documented adverse effects of both total and prolonged bouts of sedentary time on health (V. Carson et al., 2016; Saunders et al., 2013). Decreasing sedentary behaviour and breaking up prolonged sedentary bouts may confer health benefits in children and youth (V. Carson et al., 2016; Saunders et al., 2013), while higher levels of physical activity are concurrently associated with better cardiometabolic, vascular, bone and mental health in children (Biddle et al., 2019; I. Janssen & LeBlanc, 2010; Poitras et al., 2016). In addition to physical and mental health benefits, physical activity has been shown to be positively associated with children's cognitive functions (Verburgh et al., 2014) and learning outcomes (Bedard et al., 2019).

Classroom-based physical activity has been suggested to have a positive impact on other academic-related outcomes, such as school engagement and students' on-task behaviour (Goh et al., 2016; Mavilidi et al., 2020; Watson et al., 2017). Increased engagement is considered as a possible mechanism by which physical activity could have a positive influence on academic achievement over the years (Mavilidi et al., 2020; Owen et al., 2018; Watson et al., 2017).

Current frameworks, such as comprehensive school physical activity programmes aiming to reduce sedentary behaviour and increase the physical activity of students, have emphasized multicomponent approaches to physical activity interventions which include physical activity during the school day, before and after school programmes, staff involvement and family and community engagement (R. Carson & Webster, 2020). As part of current frameworks, general education classrooms have received increasing attention as possible settings to influence children's daily physical activity in addition to physical education classes and recess (Webster et al., 2015). Studies have sought to reduce school-based sedentary behaviour of children and adolescents with interventions focusing on the physical environment or furnishings of the school (Aminian et al., 2015; Clemes et al., 2016), the curriculum (Fairclough et al., 2013), in-class activities (Breslin et al., 2012), home-work activities (Kääpä et al., 2019, 2021; Kipping et al., 2014), or a mixture of these (V. Carson, Salmon et al., 2013; Yıldırım et al., 2014).Teachers have aimed to integrate physical activity into general education by utilizing physical activity breaks with or without curriculum content during and between lessons (Ma et al., 2015; Mahar et al., 2006), physical activity enabling learning methods (Riley et al., 2016), and transitions requiring students to change place from one part of the classroom to another (Kohl III & Cook, 2013; Russ et al., 2017).

Interventions utilizing teacher-focused approaches, such as the utilization of active breaks, rely on the motivation, skills, and time allocation and engagement of individual teachers (Michael et al., 2019; Rossi et al., 2016). Teachers often experience barriers to movement integration, including both institutional and personal factors (Michael et al., 2019). Thus, limitations due to space and resources as well as school interior design may be critical factors influencing teachers' possibilities for movement integration (Michael et al., 2019). The possibilities of the indoor built environment of schools are currently poorly understood, though studies have suggested that major changes in the architecture and furniture of classrooms may increase physical activity and reduce sedentary behaviour (Ucci et al., 2015). Interventions aiming to increase physical activity and reduce sedentary behaviour in school-settings that have used stand-biased desks (Hegarty et al., 2016), flexible furniture (Kariippanon, Cliff, Okely et al., 2019) and activity permissive school physical environments (Brittin et al., 2017; Lanningham-Foster et al., 2008), have shown promising results. The challenge with physical environmental change interventions is that they are likely to be limited as the renovation of spaces and acquisition of new furniture are expensive to implement.

Alongside with general education classrooms being pointed out as possible settings to influence children's daily physical activity (Webster et al., 2015), schools have increasingly incorporated non-partitioned, open, and flexible designs and principles that emphasize fostering student autonomy, self-regulated learning, collaboration, and digital competences (Saltmarsh et al., 2015). This trend for renewed spaces and pedagogy originates from an undergoing paradigm shift of global education systems aiming to better meet student learning needs (Land & Jonassen, 2012; Prain et al., 2015). To facilitate adaptive teaching and learning, schools have begun to replace traditional classrooms with designated desks with open and flexible spaces and furniture that allows for multiple reconfigurations, while educators adapt their educational practices and move towards a student-centred approach (Attai et al., 2021; Kariippanon, Cliff, Okely et al., 2019). Depending on the cultural and educational context, these kinds of learning spaces are referred to by several names including open learning spaces, flexible learning spaces, innovative learning spaces, deskless schools, or 21st-century learning environments (Byers, Imms & Hartnell-Young 2018; Imms & Byers, 2017; Kariippanon et al., 2021; Niemi, 2021; Reinius et al., 2021). According to Kariippanon et al., (2018), student-centred pedagogy associated with open and flexible learning spaces typically employs project-based learning (Blumenfeld et al., 1991) and differentiated instruction (Tomlinson, 2014) with a focus shifted towards development of higher-order skills and lesser time devoted to explicit instruction.

In Finland, after the most recent curriculum reform of Finnish basic education was introduced in 2014 and issued in 2016 (Finnish National Core Curriculum for Basic Education, 2014) conventional self-contained classrooms have increasingly been replaced by flexible, multipurpose, informal, and transformable open learning spaces (Niemi, 2021). Recent studies have investigated teachers' and students' views on open learning spaces, also known as deskless schools (Reinius et al., 2021), and teachers' adaptation to these spaces (Niemi, 2021). Open learning spaces may enhance opportunities to increase classroom-based physical activity among students, as the goals set for interior design of the open learning space bear close resemblance to activity permissive classrooms (Brittin et al., 2015) and flexible learning spaces (Kariippanon, Cliff, Okely et al., 2019), when supplemented with appropriate teaching methods. Students attending schools with open learning spaces are encouraged to work with peers, and engage in self-directed learning, and optimally also granted more freedom of movement (Saltmarsh et al., 2015). To the extent that classroom design successfully aligns with adaptive pedagogical practices, open physical spaces and flexible furniture are presumed to promote student-centred learning (Kariippanon et al., 2018). Students' attending open flexible learning spaces have been observed to engage more in collaborative learning activities, and they may incorporate mobility into their own learning activities and develop agency by choosing how and where they would work (Reinius et al., 2021).

Currently, increasing interest has been focused on the link between the indoor school environment, pedagogical approaches, sedentary behaviour, physical activity, school engagement, academic achievement and how these factors and behaviours may influence each other (Kariippanon et al., 2021; Ucci et al., 2015). Productive interplay between the physical and pedagogical elements, coupled with the teacher's ability to capitalize the affordances of the space, is seen to enable effective learning and may additionally provide possibilities to break up sedentary behaviours in flexible learning spaces (Kariippanon et al., 2021). Interdisciplinary approaches are warranted to examine novel learning environments from a physical, pedagogical, and social perspectives to understand the complex interaction among these elements and the potential effect they have on both educational outcomes and physical activity (Kariippanon et al., 2021). Prior studies on flexible or physical activity enabling learning spaces have reported the use of physically active or student-centred teaching methods or combined effects of improved indoor and outdoor facilities (Brittin et al., 2017; Kariippanon, Cliff & Okely et al., 2019; Lanningham - Foster et al., 2008), but direct evidence of actual effects of classroom-design on physical activity and sedentary behaviour during lessons is still lacking.

The aim of this dissertation was to investigate the associations of school indoor environment on classroom-based physical activity using a design where teaching methods were not experimentally altered. It is acknowledged that physical aspects of learning spaces do not influence physical activity in the classroom alone, but they exert their influence together with factors related to the school culture and pedagogical solutions (Michael et al., 2019; Russ et al., 2017). In the present study, an observational approach was applied to gain a novel understanding and information on the extent to which indoor learning spaces are associated with students' classroom-based sedentary behaviour and physical activity without an intervention. The associations of teachers' instructions with students' classroom-based sedentary behaviour and physical activity were investigated with respect to the extent of classroom-based physical activity, based on the expectation that teachers' pedagogical solutions may influence the forms, intensities, and overall amounts of students' accumulated classroom-based physical activity (Russ et al., 2017; Watson et al., 2017). Finally, associations of classroom-based physical activity and classroom-type (conventional vs. open learning spaces) were investigated with respect to their effects on students' emotional and behavioural engagement. This research questions were based on a proposition suggesting that both classroom-based physical activity and classroom spaces themselves may influence school engagement (Kariippanon, Cliff, Lancaster et al., 2019; Mavilidi et al., 2020; Vazou et al., 2012; Watson et al., 2017), which in turn may influence academic outcomes over the longer term. To our knowledge, this dissertation is the first one to investigate associations of classroom physical design with classroom-based sedentary behaviour, physical activity, as well as teachers' instructions on student movement and school engagement.

2 LITERATURE REVIEW

The following section reviews the relevant scientific research literature of the topic of this dissertation. While the dissertation investigates Finnish primary school aged children (7- to 12-year-olds), some studies included in this literature review have been conducted among adolescents or adults due to limited evidence in younger age groups. This review includes discussion on definitions of sedentary behaviour and physical activity as well as description of current methodology of accelerometery-based methods of the assessment of sedentary behaviour and physical activity. Current knowledge on associations of school-based, and classroom-based physical activity and sedentary behaviour on overall health and academic related outcomes are reviewed. Furthermore, current international and Finnish national physical activity recommendations are presented. International and Finnish national educational frameworks for utilizing open and flexible classroom designs are described with a special focus on the proposed or documented benefits of open classroom design on classroom-based physical activity. The theoretical construct of school engagement is examined with views on how physical activity may facilitate engagement towards school. The review provides a theoretical background for this dissertation, which will help in evaluating the importance of supporting classroom-based physical activity and the ways in which open learning spaces may facilitate classroom-based physical activity and school engagement.

2.1 Sedentary behaviour and physical activity

Sedentary behaviour is generally defined as any waking behaviour characterized by an energy expenditure of ≤1.5 metabolic equivalents of task, while in a sitting, reclining, or lying posture (Tremblay et al., 2017). As a distinction, stationary behaviour refers to any waking behaviour done while lying, reclining, sitting, or standing, with no ambulation, irrespective of energy expenditure (Tremblay et al., 2017). Despite this distinction, the term "stationary time" has not been used widely and many current studies conducting accelerometer-based measures still appear to use the term sedentary behaviour also for stationary activities. As standing does not significantly increase energy expenditure, sedentary behaviour was defined in this dissertation to include all stationary and sedentary behaviours without bodily movement based on accelerometery measures (Sedentary Behavior Research Network [SBRN], 2012).

Breaks from sedentary time are defined as a non-sedentary period in between two sedentary bouts (Altenburg & Chinapaw, 2015). It has been recommended that a sedentary bout should be defined as a minimum period of uninterrupted sedentary time, without any tolerance time spent in non-sedentary behaviours (Altenburg & Chinapaw, 2015). Additionally, it has been proposed that a threshold of 5 or 10 minutes should be used to define prolonged sedentary bouts based on the associations between accelerometer-derived sedentary bout length and cardiovascular disease risk factors both in child (Saunders et al., 2013) and adult populations (Kim et al., 2015). Studies aiming to reduce and break up continuous bouts of sitting have also investigated postural transitions, for example transitions from sitting to standing (Kariippanon, Cliff, Okely et al., 2019).

Physical activity has been defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985). Physical activity is typically classified as light, moderate and vigorous intensity physical activity according to intensity of movement (Aittasalo et al., 2015; Evenson et al., 2008; Gao et al., 2019; Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015).

2.1.1 Accelerometery-based measurement of sedentary behaviour and physical activity

Accelerometery is a device-based method used to assess the volume and intensity of habitual physical activity (Ekelund et al., 2011; I. Janssen & LeBlanc, 2010). These intensity classifications are typically based on different calibration activities, such as standing, walking, and running, with or without measurement of oxygen uptake during tasks (Aittasalo et al., 2015; Evenson et al., 2008; Gao et al., 2019; Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015). The next section describes issues related to the validity, reliability, and accuracy of accelerometer-based measurement of sedentary behaviour and physical activity.

The most frequently used accelerometer locations in children are the waist, thigh, or wrist (Arvidsson et al., 2019; Migueles et al., 2017). Waist-worn accelerometers are positioned near centre of mass of the human body and therefore are thought to best reflect the movement of the whole body (Arvidsson et al., 2019). Accelerometers are used to measure changes in velocity (i.e., acceleration) that typically occur during ambulatory activities such as walking. Waist-worn accelerometers may underestimate the intensity of activities that are conducted without ambulatory movement of the whole body, such as cycling (Arvidsson et al., 2019; van Loo et al., 2017). The thigh-worn accelerometers can be used to assess posture and activities like cycling more reliably than waist-worn accelerometers as they also separate sitting or lying down from standing and physical activity (Arvidsson et al., 2019; X. Janssen & Cliff, 2015). Posture can be estimated with a single accelerometer placed on a thigh or waist with validated angle for posture estimation method (Löppönen et al., 2021; Vähä-Ypyä et al., 2018). Breaks from sitting can be measured as postural transition from sitting to standing (Kariippanon, Cliff, Okely et al., 2019; Löppönen et al., 2021). Waist- and thigh- worn accelerometers can, thus, be used to reliably capture and quantify whole-body movement around the classroom as well as to assess time spent in different postures or postural transitions, but they are likely to underestimate the intensity of activities conducted mainly with arms, for example during crafts or arts lessons.

Different accelerometer data quantification methods have been developed to provide meaningful information on sedentary behaviour and physical activity. The most common data quantification method is to estimate the time spent sedentary and at different physical activity intensities using different cut-points for the acceleration signal magnitude (Migueles et al., 2022). Statistical interpretation of estimates of time spent in different physical activity intensities can, be challenging for both conducting and interpreting statistical tests (Migueles et al., 2022). Mean acceleration or step counts can be used as a single estimate for overall movement, which can be used both for simple statistical interpretations, but also for more complex statistical approaches such as structural equation modelling (Lindberg et al., 2018; Migueles et al., 2022).

The most notable limitation of cut-point-based methods assessing time spent at different physical activity intensities is that the agreement between different quantification methods may be poor and, therefore, the results from different methods may not be comparable (Migueles et al., 2022). The intensity of physical activity is commonly summarized using proprietary algorithms with different transducers, amplifiers, sampling frequencies and signal filters to indicate a unit of measure called "Counts" (Crouter et al., 2006; Marschollek, 2013; Rothney et al., 2008). However, as a wide range of processing methods are used, different methods may produce different count values even when measuring the same input acceleration signal (Marschollek, 2013). Therefore, direct comparison of results from different studies and cross-validation of different devices are not possible (Vähä - Ypyä, Vasankari, Husu, Suni et al., 2015). To provide a more transparent approach to accelerometer-based measures, analysis methods utilizing raw data of accelerometers are being developed (Vähä - Ypyä, Vasankari, Husu, Mänttäri et al., 2015). For example, the mean amplitude deviation method can be used as a single algorithm irrespective of the device that was used in the data collection, and it has been shown to be accurate across different accelerometer brands (Aittasalo et al., 2015; Vähä - Ypyä, Vasankari, Husu, Suni et al., 2015).

Instead of collecting data over pre-defined intervals (i.e., epochs), it is preferred that accelerometers are used to collect second-by-second activity count data (Altenburg et al., 2021). After data collection, data are aggregated with specified epoch lengths, after which cut-points are used to classify accelerometer data into sedentary behaviour and physical activity of different intensities (Altenburg et al., 2021). The length of epoch influences the results obtained from the accelerometer data. When longer epochs are used, especially children's total time in sedentary behaviour and moderate-to-vigorous intensity physical activity decreases while time accumulated in bouts of sedentary behaviour and moderate-to-vigorous physical activity accumulated in bouts increases (Altenburg et al., 2021).

Development of intensity cut-points for accelerometery have been criticized for using subjective criteria based on certain calibration activities rather than using physiologically meaningful criteria (Boddy et al., 2018; Haapala, Gao, Rantalainen et al., 2021). Utilizing metabolic equivalents of task-based cut- points for physical activity intensities have been suggested to improve the comparability between studies (Sievänen & Kujala, 2017), but these fixed metabolic equivalents of task-based cut-points have been found to misclassify physical activity intensity in children and adult populations (Haapala et al., 2020; Tompuri, 2015). Furthermore, absolute and fixed measures of physical activity underestimate the intensity of physical activity in children with lower peak oxygen uptake, oxygen uptake at ventilatory threshold and lower motor competence (Haapala, Gao, Hartikainen et al., 2021). It has been suggested that fixed accelerometery cut-points used to define physical activity intensities should be adjusted for age, sex, body size, and body composition (Haapala, Gao, Rantalainen et al., 2021). Additionally, the use of self-paced running may provide a novel and practical method for determining individualized vigorous intensity physical activity cut-points in children (Haapala et al., 2020). Despite these novel suggestions, there is currently no established methodology to produce individualised cut-points without laboratory measurements in field studies. Researchers must be aware of the challenges described above regarding fixed cut-points for different physical activity intensities.

2.1.2 Associations of sedentary behaviour and physical activity with health

A sedentary lifestyle among children and adolescents may increase their risk for chronic non-communicable diseases later in life (V. Carson et al., 2016), but the evidence on the independent role of sedentary behaviour is still unclear (Barnett et al., 2018). Accordingly, experimental studies have suggested that both short bouts of physical activity and frequent interruptions in sitting have beneficial effects on cardiometabolic biomarkers, which may reduce the risk for type 2 diabetes and metabolic syndrome in children (Belcher et al., 2015; Saunders et al., 2013), adolescents (V. Carson, Ridgers, et al., 2013; Fletcher et al., 2018), and adults (Howard et al., 2015). Current evidence about the benefits of breaking up sedentary time for children and adolescents is limited (V. Carson et al., 2016; Cliff et al., 2016). One of the few studies showed that, for children with a family history of obesity, breaks in sedentary time and the number of sedentary bouts lasting 1 to 4 minutes were associated with reduced cardiometabolic risk score and a lower BMI Z score in both boys and girls, whereas the number of sedentary bouts lasting 5 to 9 minutes was negatively associated with waist circumference only in girls (Saunders et al., 2013). Additionally, the number of sedentary bouts lasting 10 to 14 minutes was positively associated with fasting glucose in girls, and with BMI Z-score in boys (Saunders et al., 2013).

Physical activity has been shown to have positive association with both physical and mental health of among school aged children. (Biddle et al., 2019; I. Janssen & LeBlanc, 2010; Poitras et al., 2016). Furthermore, reduced duration of sedentary bouts and increased breaks from sedentary time are positively associated with health in school-aged children (V. Carson et al., 2016; Saunders et al., 2013). Especially moderate-to-vigorous physical activity has been associated positively with physical, psychological, social, and cognitive health indicators (Poitras et al., 2016). Also, lower levels of adiposity, cardiometabolic risk, arterial stiffness, and higher cardiorespiratory fitness have been associated with both moderate-to-vigorous and vigorous intensity physical activity in children and adolescents (Ekelund et al., 2011; Poitras et al., 2016). Particularly, light intensity physical activity may have a beneficial effect against excess adiposity among primary school aged children (Kwon et al., 2011). Studies have shown that physical activity is positively associated with children's cognitive functions (Verburgh et al., 2014) and learning outcomes (Bedard et al., 2019). In addition to the described potential benefits on physical and mental health, increased classroom-based physical activity may have a positive impact on academic outcomes and students' on-task behaviour (Goh et al., 2016; Watson et al., 2017).

2.1.3 Physical activity recommendations

Public health guidelines in different countries (Ministry of Education and Culture, 2021; Tremblay et al., 2016) and institutions, including the World Health Organization (WHO) (Bull et al., 2020), recognize both the adverse effects of sedentary behaviour and the positive associations of physical activity on overall health and wellbeing. These recommendations typically suggest both breaking up sedentary time and limiting accumulation of total sedentary time, as well as emphasize accumulation of moderate-to-vigorous intensity physical activity. Furthermore, regular muscle strengthening activity is generally recommended. For example, current guidelines in Finland for children and adolescents recommend that all children and adolescents aged 7 to 17 years should be physically active in a versatile, brisk, and strenuous manner for at least 60 minutes a day in a way that suits the individual, considering one's age, while excessive and extended sedentary activity should be avoided (Ministry of Education and Culture, 2021).

Counter to these guidelines, less than half of children and youth achieve the WHO's recommendation for an average of 60 minutes of daily moderate-to-vigorous physical activity in many Western countries, including Finland (Bull et al., 2020). It has been estimated that children spend 40% to 60% of their time sedentary, which equals five to eight hours a day (Colley et al., 2013; Konstabel et al., 2014; Ortega et al., 2013). Finnish 7-to 15-year-old children spend over half of their waking hours in a sitting or reclining posture, while less than 10% of their time was spent standing (Husu et al., 2019). Light intensity physical activity comprises a little over 25% of time, while moderate-to-vigorous physical activity comprises about 10% of time (Husu et al., 2019). Sedentary time increases significantly by age and at the same time especially moderate-to-vigorous intensity physical activity decreases (Husu et al., 2019). Boys tend to engage in more moderate-to-vigorous intensity physical activity than girls, but conversely boys spend slightly more time sitting or lying down than girls during their waking time (Husu et al., 2019). The School Health Promotion study and LIITU study have indicated that less than half of primary school students achieve the recommended levels of physical activity in Finland (S. Kokko et al., 2019; National Institute for Health and Welfare, 2021).

2.1.4 Physical activity during school days

Schools are widely considered as feasible locations for interventions aiming to reduce total sedentary time and to increase overall physical activity among children because students spend a large proportion of their waking hours at school (Hegarty et al., 2016). School days have been observed to be primarily sedentary with long periods of uninterrupted sedentary behaviour (Bailey et al., 2012; Harrington et al., 2011; Nettlefold et al., 2011). Children tend to accumulate more sedentary bouts lasting over 20 minutes during the school day compared to time after school or weekend (Harrington et al., 2011). Current evidence suggests that both in and out of school sedentary time increases concurrently with decrease in moderate-to-vigorous physical activity already during the early primary school years (Grao-Cruces et al., 2020; Harding et al., 2015; Jago et al., 2017; Trost et al., 2002). Currently, European 10-to-12-year-old students spend 65–70% of school time being sedentary and 5% on moderate-to-vigorous intensity physical activity, boys having less sedentary time and more moderate-to-vigorous intensity physical activity than girls (Salin et al., 2019; van Stralen et al., 2014).

Finnish primary school students accumulate on average 22 minutes and secondary school students on average 17 minutes of moderate-to-vigorous intensity physical activity during a typical school day (Tammelin et al., 2015). Approximately 34% of a weekday's moderate-to-vigorous physical activity is accumulated during the school day (Tammelin et al., 2015). For those children who are most inactive, 40% of a day's moderate-to-vigorous intensity physical activity is accumulated during the school hours, indicating that school-based physical activity may be more important to especially physically inactive children (Tammelin et al., 2015). Overall, the majority of a school day is spent in sedentary behaviour as Finnish primary school students have been documented to accumulate 39 minutes of sedentary time per 60 minutes (Tammelin et al., 2015).

Current frameworks, such as the comprehensive school physical activity programmes model, have emphasized multicomponent approaches to physical activity interventions consisting of physical activity during the school day, before and after school physical activity programmes, staff involvement and family and community engagement (R. Carson & Webster, 2020). In Finland, Finnish Schools on the Move is a national action programme aiming to build a physically active culture in Finnish comprehensive schools (Blom et al., 2018). Schools and municipalities participating in the programme have high autonomy to implement their own plans to increase physical activity during the school day. In this programme students are encouraged to participate in developing physical activities for breaks, whereas teachers are encouraged to utilize physically active learning methods during academic classes (McMullen et al., 2015). In addition, active commuting to school is promoted while also developing facilities and schoolyards to foster physical activity participation (McMullen et al., 2015). More than 90% of Finnish municipalities and of comprehensive schools are involved in this national programme (Blom et al., 2018).

2.1.5 Classroom-based physical activity

Because of the concern over the current high levels of sedentary behaviour and low levels of physical activity, different approaches have been developed to reduce the sedentary behaviour of children and adolescents in school settings (Hegarty et al., 2016). In addition to physical education and recess, general education classrooms have received increased attention as possible settings to reduce sedentary behaviour and increase the physical activity of students (Hegarty et al., 2016; Webster et al., 2015). These studies have focused on the physical environment or furniture of the school (Aminian et al., 2015; Clemes et al., 2016), the curriculum (Fairclough et al., 2013), in-class activities (Breslin et al., 2012), homework activities (Kipping et al., 2014), or a mixture of them (V. Carson, Salmon, et al., 2013b; Yıldırım et al., 2014). For example, the recent Finnish Moving Math project aims to investigate the effects of both the acute and long-term the effects of physically active math lessons on learning outcomes, cognitive functions, affective school engagement, learning motivation, and motor skills (Sneck et al., 2022).

The current Finnish Government legislation (Basic Education Act 793/2018, 6§) and The Finnish National Curriculum (Finnish National Core Curriculum for Basic Education, 2014) define national boundary conditions for the distribution of weekly lesson hours for primary schools (Table 1). Local educational institutions may implement their local curriculum within these boundary conditions, which allows some freedom in how daily lessons and recess are organized (Finnish National Core Curriculum for Basic Education, 2014). For example, 9 hours of physical education in grades 3 to 6 can be divided as follows: Grade 3: 2 lesson hours per week; Grade 4: 2 lesson hours per week; Grade 5: 3 lesson hours per week; and Grade 6: 2 lesson hours per week. Most daily lessons of Finnish students in grades 3 to 6 are provided by classroom teachers. While the national curriculum provides possibilities to increase daily physical activity with extra physical education lessons and recess, it is important to explore the possibilities of promoting classroom-based physical activity.

TABLE 1 Distribution of lesson hours in grades 3–6 and 1–9 in Finland (Basic Education Act, 793/2018, 6§)

Subject	Lesson hours (Grades 3-6)	Lesson hours (Grades 1-9)
Mother tongue and literature	14	42
A1 language	9	18
B1 language[1]	2	6
Mathematics	15	32
Environmental and Nature studies[2]	10	31
Religion/Ethics	5	10
History and Social Studies[3]	5	12
Music	4	8
Visual Arts	5	9
Crafts	5	11
Physical Education	9	20
Artistic and Elective studies[4]	6	11
Optional Subjects[5]	-	9

[1] Starting from grade 6, [2] Subject integrates biology, geography, physics, chemistry, and health education, [3] Starting from grade 4, [4] In grades 1-6, [5] In grades 1-9

In primary schools, students spend the majority of the school day in academic lessons where classroom teachers are responsible for instructing students in academic subjects (Russ et al., 2017). Currently, there is limited information on how and to what extent teachers are integrating movement within their general education lessons (Webster et al., 2015). Prior research is also limited by being focused mainly on teacher self-reports (Russ et al., 2017; Webster et al., 2015). Self-reported measures may be biased by respondents consciously or unconsciously altering their responses due to push for social desirability. Furthermore, self-reported measures are affected by individuals’ ability to recall past events.

Classroom-based physical activity provides possibilities for children to ingrain habits of daily physical activity at the same time as they may increase energy expenditure, enhance physical competency and obtain chances for more diverse social interactions (Mullins et al., 2019). Studies on classroom-based physical activity have reported that physically active academic lessons increase physical activity levels, both students and teachers have enjoyed participating in them which may benefit learning and health outcomes (Barr-Anderson et al., 2011; Gibson et al., 2008; Martin & Murtagh, 2017). From the academic perspective, classroom-based physical activity has been observed to have beneficial effects on mathematics standardized test scores, but not on reading in a study among third- to fifth-grade students from United States (Fedewa et al., 2015). On the other hand physically active lessons were associated with both mathematics and writing skills among second- to third-grade students in a study carried out in the Netherlands (Mullender-Wijnsma et al., 2016). Even though some studies have not observed beneficial effects on physically active breaks on academic achievement, no adverse effects of physical activity on academic achievement have been observed in these studies (Erwin et al., 2012; Reed et al., 2010).

External assessment methods, such as systematic observation, have been developed to capture and quantify behavioural and contextual factors in order to evaluate teaching and physical activity promotion in different settings (McKenzie et al., 1992, 2006; Russ et al., 2017). Systematic observation methods are generally considered flexible methods with low interference during data collection as well as the ability to capture information about both physical and social environments at the same time (McKenzie & van der Mars, 2015). A further advantage of systematic observations is that results can often be summarized in a way that can provide practical, meaningful, and understandable information for administrators and practitioners (McKenzie & van der Mars, 2015).

Systematic observation tools, such as SOSMART, are developed to measure movement integration in academic classroom lessons (Russ et al., 2017). It has been documented that many recommended movement integration strategies focus on teacher-directed opportunities for physical activity (Webster et al., 2015), while both teacher-led transitions and non-teacher directed transitions occur most frequently (Russ et al., 2017). However, SOSMART developers have noted that this method does not fully represent the range of movement integration strategies that would be found across diverse classroom settings and therefore suggested that it should be used with a greater emphasis on documenting movement integration strategies than on determining the effects of these strategies on children (Russ et al., 2017).

Earlier mentioned aspects reveal that physical activity has multiple associations and although potential benefits of classroom-based physical activity are acknowledged and recommended in Finnish government-level guidelines, all teachers do not incorporate physical activities within their classroom lessons or seek opportunities to break up students' prolonged sedentary time. It has been reported in a comprehensive Finnish sample that 51% of primary schools, 43% of comprehensive schools and 19% of secondary schools utilize physically active teaching methods in Finland (Kämppi et al., 2018). Physically active lessons aim to increase children's physical activity while maintaining academic time by incorporating physical activity into the academic content (Norris et al., 2015). Physically active lessons are hence distinct from activity breaks, which facilitate bouts of classroom-based physical activity without direct educational emphasis or content at hand (Bartholomew & Jowers, 2011).

It has been reported that it is quite rare to have school-level policies regarding breaking up students' prolonged sitting (Kämppi et al., 2018). Approximately half of the classroom teachers reported that they utilized physically active teaching methods while 65% of teachers aimed to break up time spent sitting in all or almost every lesson (Kämppi et al., 2018). It has been suggested that teachers often experience barriers for movement integration, including both institutional (i.e., administrative support) and personal (i.e., perceptions of value of physical activity) factors (Michael et al., 2019). Limitations due to space and resources, including the school interior design, may also be a critical factor influencing teachers' possibilities for movement integration (Michael et al., 2019). Therefore, alternative approaches to reduce the sedentary behaviour of students that do not rely so heavily on teachers' personal perceptions, motivation, or employment of practices, are warranted.

2.1.6 Physical activity and classroom architecture and furniture

In addition to studies focusing on teacher-implemented physical activity during classroom time, some studies have focused on the role of built school environment in increasing physical activity and reducing sedentary time of students (Brittin et al., 2017; Kariippanon, Cliff, Okely, et al., 2019; Lanningham‐Foster et al., 2008). Even though there is limited information on the possibilities of indoor built environment of schools to reduce sedentary behaviour and increase physical activity, some studies have suggested that radical changes in architecture and furniture of classroom may increase physical activity and reduce sedentary behaviour (Ucci et al., 2015).

Different classroom design approaches aiming to reduce sitting time have managed to reduce youth sitting time up to 60 minutes per day and increase standing time by up to 55 min per day during classroom time at school (Hinckson et al., 2016). A guideline-informed school physical environment (Brittin et al., 2015) may also decrease sedentary time and length of sedentary bouts in children aged 8 to 10 years (Brittin et al., 2017). Active school design has been shown to have beneficial effects on light intensity physical activity but not on moderate to vigorous physical activity (Brittin et al., 2017). Furthermore, when supplemented with appropriate teaching methods, environments designed to encourage active learning increase physical activity levels in children compared to traditional classroom environments (Lanningham‐Foster et al., 2008). In classrooms utilizing flexible spaces including a variety of furniture and resources, adolescents were found to spend less class time in sitting and accumulate more breaks in sitting time, more bouts of intermittent (≤9 minutes) sitting, and fewer bouts of prolonged (≤30 minutes) sitting than in traditionally furnished and arranged classrooms when coupled with a greater use of student-centred pedagogies (Kariippanon, Cliff, Okely, et al., 2019).

2.2 Educational reform and open and flexible learning spaces

Educational institutions of different countries are aiming to find ways to prepare students and communities to succeed in rapidly changing and developing societies across all curriculum areas and learning stages (Kuhlthau et al., 2015; Organisation for Economic Co-operation and Development [OECD], 2017). Skills including critical thinking, problem solving, collaboration, creativity, and leadership are considered as so-called 21st-century learning skills (Binkley et al., 2012; Carvalho et al., 2020; OECD, 2017). Many countries have undertaken educational reforms where schools are seen as both innovative and flexible learning environment where reforms manifest in the use of educational technologies, utilization of informal and outdoor spaces, active surfaces, and also in classroom design with co-joining of classrooms (Deed et al., 2020; Leiringer & Cardellino, 2011).

Because the physical learning environment is considered an additional resource contributing to learning outcomes, schools have begun to replace traditional furniture with flexible furniture that allows for multiple configurations to facilitate teaching and learning (Attai et al., 2021). In some countries including Finland, the United Kingdom, Germany and Spain, schools with non-partitioned instructional spaces have re-emerged as a result of educational reforms (Mäkitalo-Siegl et al., 2010; Saltmarsh et al., 2015). Typically, these open spaces, equipped with mobile furniture, involve multiple classes, multiple teachers, and technology-enhanced common space without designated desks for students or teachers' podiums (Cardellino & Woolner, 2020; Saltmarsh et al., 2015). Mobile furniture and privacy screens are used to divide spaces for different pedagogical purposes (A. Kokko & Hirsto, 2021). Even though open learning spaces can take varied forms, some of the defining features include integration of physical and virtual space, multifunctionality, and affording students autonomy over their learning (Melhuish, 2011). Depending on both cultural and pedagogical contexts, these modern learning spaces are referred to by several names in different countries, including open learning spaces, flexible learning spaces, innovative learning spaces, deskless schools, or 21st-century learning environments (Byers, Imms, et al., 2018; Imms & Byers, 2017; Kariippanon et al., 2021; Niemi, 2021; Reinius et al., 2021).

2.2.1 Pedagogical views and challenges of open learning spaces

Whole learning environment of a school comprises not only physical design, but also the organization, educational culture, and student dynamics (Gislason, 2010, 2018). As novel physical learning environments are envisioned to have systemic effects on the operational culture of the school (Reinius et al., 2021), for teachers, working in open learning spaces typically also implies re-distribution of roles and responsibilities towards working as a team sharing space and resources (Niemi, 2021; Saltmarsh et al., 2015). These teaching practices are influenced by the physical, social, and cultural landscape of a school (Deed et al., 2020). Teachers are dependent on the school premises in their teaching practices, and therefore open, dynamic, flexible, and mobile spaces and furniture enables them to use a wider spectrum of instructional approaches (Reinius et al., 2021). The new affordances and pedagogical methods facilitated by open learning spaces encourage teachers to utilize more interactive teaching and collaborative learning (Sigurðardóttir & Hjartarson, 2016). Furthermore, teachers working in open learning spaces have emphasized professional co-planning and further experienced the facilitating effects of collaborative learning (Reinius et al., 2021)

According to Kariippanon et al. (2018), the student-centred pedagogy associated with open and flexible learning spaces typically employs project-based learning (Blumenfeld et al., 1991) and differentiated instruction

(Tomlinson, 2014), with the focus shifted towards higher-order skills while explicit instruction occurs less frequently. The framework of project-based learning includes pedagogy where students are encouraged to pursue solutions to real-world problems by asking questions, designing plans to study problems, conducting research or experiments, analysing the findings, drawing conclusions, communicating the findings to others, and finding new directions for enquiry (Blumenfeld et al., 1991). With differentiated instruction, teachers aim to proactively adjust learning methods to accommodate each child's learning needs and preferences (Tomlinson, 2014), which places further demand on teachers (Campbell et al., 2013; Saltmarsh et al., 2015). The open learning spaces are commonly designed for 40 to up to 100 students and a teacher team consisting of two to four classroom teachers and possible special education teachers (Niemi, 2021). These large student groups are meant to study in areas equipped with dynamic furniture and acoustic curtains, a set-up which allows multiple different learning activities in smaller groups to take place in the same classroom simultaneously (Niemi, 2021; Saltmarsh et al., 2015).

These open and flexible spaces do not guarantee productive learning and teaching as those are dependent on multiple issues, including adequate instructional support, resources for productive dialogue and regulation of learning (Niemi, 2021). Therefore, working in open learning spaces also poses challenges for teachers, as they need to balance between facilitating autonomous student learning while managing shared spaces and resources in their pedagogical practice (Saltmarsh et al., 2015). Especially adaptation to changes in the physical learning space is demanding for teachers as it has been observed that teachers have continued utilizing the same pedagogical practices that were used in conventional classrooms (Carvalho & Yeoman, 2018; Niemi, 2021; Saltmarsh et al., 2015; Sigurðardóttir & Hjartarson, 2016). Further negative experiences include difficulties in changing institutional routines, creating coherent pedagogy for open learning spaces, clashes between the teaching team, and deficiency in teachers' skills for manipulating the environment (Campbell et al., 2013; Deed & Lesko, 2015; Kariippanon et al., 2018). It must be acknowledged that in-depth pedagogical transformations take years because teachers must make changes in both their own pedagogical approaches, classroom practices, and school-level policies (Gislason, 2018). The student-centred approach supported by open and flexible classroom-design has to be internalized by teachers (Alterator, 2018), while chosen pedagogies should be compatible with the school's physical environment (Gislason, 2010).

2.2.2 Student perspective on open learning spaces

Individuals are motivated by being able to exert personal influence over their own behaviours and their environment through self-reflective and cognitive self-regulatory processes (Bagozzi, 1992; Bandura et al., 1999). This sense of personal control is often referred to as personal agency (Bandura, 2001). It has been suggested that development of student agency is poorly supported by traditional individualized, acquisition-oriented, and externally regulated schoolwork, and therefore there is a need to transform the overall school-based learning environment, including physical spaces (Reinius et al., 2021).

Open physical space and flexible furniture are presumed to promote student-centred learning (Kariippanon et al., 2018), as students attending schools with open learning spaces are encouraged to work with peers, and engage in self-directed learning, and optimally also granted more freedom of movement (Saltmarsh et al., 2015). The openness and flexibility of spaces may allow versatile physical activity and, enable students to choose and change a place to work in the classroom which facilitates both breaks from sedentary time and postural transitions (Kariippanon, Cliff, Lancaster et al., 2019; Kariippanon et al., 2021; Saltmarsh et al., 2015). Students' attending learning spaces with flexible furniture have reported greater satisfaction with the learning spaces than students in the classroom with traditional furniture as the former provide more opportunities for student autonomy (Attai et al., 2021).

There is some evidence that academic results may benefit from the utilization of flexible learning spaces (Kariippanon et al., 2021). There is some evidence that academic results in English, mathematics and humanities may benefit from the utilization of flexible learning spaces among Australian children and adolescents (Kariippanon et al., 2021). The associations of open learning spaces and academic results have not been studied in a Finnish educational setting. However, there seems to be limited evidence on associations of open learning spaces with academic outcomes in children aged 7 to 8 (Byers, Mahat et al., 2018).

Generally, in open learning spaces students have more opportunities for personalized learning and making their own decisions concerning one's learning as well as monitoring ones' own work (Yeoman & Wilson, 2019). Redesigning spaces can influence general social relationships by facilitating spontaneous interactions among pupils and teachers (Reinius et al., 2021). Students attending open flexible learning spaces have been observed to engage more in collaborative learning activities, such as working in pairs or small groups, while they incorporated mobility into their own learning activities and developed agency by choosing how and where they would work (Reinius et al., 2021). Therefore, open learning spaces may broaden students' possibilities by enabling types of agencies other than those provided by traditional learning environments (Charteris & Smardon, 2018). Open and flexible school designs may support students' self-regulation and self-determination skills (Charteris & Smardon, 2018; Gislason, 2018), while also enhancing motivation and learning as enlarged reference groups may reduce social comparison within class (Prain et al., 2015). There is some research indicating that health behaviours (i.e., physical activity and nutrition) may be promoted by interventions developing personal agency (Contento et al., 2007).

2.2.3 The Finnish context

The most recent curriculum reform of Finnish basic education, issued in 2016, emphasizes fostering student autonomy, self-regulated learning, collaboration, and digital competencies (Finnish National Core Curriculum for Basic Education, 2014). The pedagogical approach of the current curriculum emphasizes phenomenon-based learning, which aims to cross subject boundaries by approaching the real-world issues from different perspectives (Finnish National Core Curriculum for Basic Education, 2014; Niemi, 2021). This current approach is utilized to enable the investigation of areas of personal interest alongside what the whole class is learning (Arvaja et al., 2020; Finnish National Core Curriculum for Basic Education, 2014)

Alongside the curriculum reform, new or renovated comprehensive schools in Finland have increasingly incorporated open and flexible designs and principles, where conventional self-contained classrooms are being replaced by more flexible, multipurpose, informal, and transformative open learning spaces (Finnish National Core Curriculum for Basic Education, 2014; Niemi, 2021). This context involves the radical transformation of both the pedagogical and also the operational culture of schools to be aligned with the new school designs and changes in the national curriculum towards a phenomenon-based approach (Niemi, 2021). One aim of the utilization of open and flexible classroom designs is to facilitate a change in the traditional roles of teachers and students towards more collaborative forms of teaching and learning (Reinius et al., 2021).

In the Finnish curriculum, these student-centred approaches consider students as active agents of their own learning, capable of solving problems both independently and along with others (Finnish National Core Curriculum for Basic Education, 2014). The curriculum strongly advises the use of a phenomenon-based approach to learning across different subjects, where learner-centred and inquiry-based approaches are emphasized along with technology-enhanced learning and student autonomy (Finnish National Core Curriculum for Basic Education, 2014) The high autonomy Finnish teachers have in planning and implementing their teaching derives from the specific features of Finnish education that differ from many other countries. Schools in Finland draw up their own curriculum based on the national curriculum and there are no nationwide standardized tests except the matriculation exam at the end of high school (Niemi 2016, Biesta, 2015). Characteristics of Finnish basic education includes the high-level of autonomy to choose pedagogy and low-level direct control or test-based accountability of teachers (Campbell et al., 2013) and trust and informality (Niemi, 2016; Sahlberg, 2021). As teachers in Finland have high professional autonomy, they cannot be mandated to change their practices or be expected to appropriate activities they cannot influence (Hargreaves & Shirley, 2009; Senge et al., 2012).

2.3 School engagement

Engagement in the school context refers to the extent of a student's active participation or involvement in learning activities (Christenson et al., 2012). School engagement is typically conceptualized as a multidimensional construct having multiple interrelated components, and multiple taxonomies have been proposed to define different aspects of school engagement (Appleton et al., 2008; Fredricks et al., 2004). Multidimensionality of school engagement is manifested when a student's active involvement in learning activities is assessed. Optimally, a comprehensive assessment would need to capture factors such as students' concentration and effort, the presence of emotions related to a task, the use of different learning strategies, and the extent to which a student aims to enrich the learning experience (Christenson et al., 2012).

The school engagement represents a countermeasure for the declining academic motivation and achievement which has been observed among a notable proportion of students which may disengage them from the academic and social dimensions of school (Appleton et al., 2008; Fredricks et al., 2004). Distinguishing motivation from engagement is not clear cut, but the construct of motivation is seen as a more unobservable psychological, neural, and biological process that serves as an antecedent for observable actions defined as engagement (Christenson et al., 2012). Although school engagement is considered to be also responsive to contextual features, including environmental changes, a student's own perspectives and experiences substantially influence academic and social outcomes (Appleton et al., 2008; Fredricks et al., 2004). Parental support and educational aspirations have been observed to be important for the overall perceived health of the students (Markkanen et al., 2019). In adolescence both the teacher's and classmates' roles are critical in maintaining students' satisfaction with school and education which are likely to contribute positively to their development (Horanicova et al., 2020). School engagement, school strain, and teacher-student relations have been found to serve as the most influential predictors in the psychosocial school environment (Haapasalo et al., 2010). Therefore, work must be done to promote students' school engagement and their satisfaction with school.

2.3.1 Different taxonomies for school engagement

School engagement is typically described to include two (Willms, 2003), three (Fredricks et al., 2004) or four (Appleton et al., 2006; Reschly & Christenson, 2006) interrelated components and despite the relative agreement of the overall multifactorial nature of the construct there are some inconsistencies with terminologies used in different taxonomies (Appleton et al., 2008). Two-component taxonomies typically include *behavioural* (e.g., positive conduct) and *emotional, or affective* (e.g., positive attitude about learning) components that are both considered critical foundational to understand school engagement (Finn, 1989; Willms, 2003).

The most typical three component taxonomy conceptualizes school engagement as a multidimensional construct including behaviour, emotions, and cognitions, which are considered interrelated (Archambault et al., 2009; Fredricks et al., 2004; Jimerson et al., 2003). Students' *behavioural* engagement refers to the range of actions that reflect involvement in school activities and it is commonly assessed via indicators of students' classroom behaviour, time on-task, and concentration (Fredricks et al., 2004). *Emotional* engagement and disengagement encompass positive and negative affective reactions to school, such as enjoyment and experience of belonging, and *cognitive* engagement refers to investment in learning, which involves learning motivation, strategic learning skills, and problem solving (Fredricks et al., 2004). Behavioural and emotional engagement have been suggested to be related bidirectionally and behavioural engagement has been seen to contribute to cognitive engagement (Li & Lerner, 2013). This three-component taxonomy can be further extended to four components by adding the dimension of agentic engagement, which refers to learners' active participation aiming to enrich their learning experience (e.g., through seeking challenges and deepening one's understanding) rather than being passive recipients of learning tasks and stimuli (Christenson et al., 2012).

An alternate four-component engagement taxonomy have been proposed comprising academic, behavioural, cognitive, and psychological engagement (Appleton et al., 2008; Reschly & Christenson, 2006). Academic engagement includes indicators such as time on task, credits earned toward graduation, and homework completion, while indicators of behavioural engagement include attendance, suspensions, voluntary classroom participation, and extracurricular participation (Appleton et al., 2008). Less observable internal indicators of cognitive engagement include aspects of self-regulation, perceived value of learning, personal goals and autonomy, and indicators of psychological engagement include feelings of belonging, and relationships with teachers and peers (Appleton et al., 2006).

In this dissertation, school engagement is conceptualized according to the three-component taxonomy as a multidimensional construct including behavioural, emotional, and cognitive experiences in school which are considered interrelated (Archambault et al., 2009; Fredricks et al., 2004; Jimerson et al., 2003). Behavioural and emotional engagement are considered to be related bidirectionally, while behavioural engagement is seen to have an effect on cognitive engagement (Li & Lerner, 2013). In subsequent sections, behavioural emotional components are reviewed more thoroughly with respect to propositions and documentation on how open learning spaces and physical activity may improve school engagement.

2.3.1.1 Behavioural engagement

Behavioural school engagement can be defined multiple ways (Fredricks et al., 2004). First conceptualization includes positive conduct and absence of disruptive behaviours (Finn, 1993; Finn et al., 1995). The second comprises involvement in academic tasks and behaviours employing effort, concentration, and attention (Birch & Ladd, 1997; Finn et al., 1995). Finally, the third conceptualization includes overall participation in school-related activities such as athletics, school governance or other extracurricular activity (Finn, 1993; Finn et al., 1995). From the perspective of classroom participation most typical indicators of interest include cooperative participation, adhering to classroom rules, and self-directed academic behaviours (Birch & Ladd, 1997).

Teacher ratings and students' self-reports are the main methods for assessing behavioural engagement, but observation techniques also are used to assess behavioural engagement (Fredricks et al., 2004; Stipek, 2002; Watson et al., 2017). Scales capture either separate aspects of behaviour or combine several aspects, including conduct, persistence, and participation, into a single scale (Fredricks et al., 2004). To assess task-related behaviours some scales include effort, attention, and persistence (Fredricks et al., 2004).

Past learning experiences evoke expectations in new learning situations, and therefore lay a foundation for students' behavioural approaches towards new academic tasks (Wang & Eccles, 2012). Good academic performance may facilitate activation of mastery orientation and task-focused behaviour, whereas task-avoidant behaviour may result from previous poor learning outcomes (Onatsu-Arvilommi & Nurmi, 2000). Task-focused behaviour indicates a willingness to invest effort in learning and therefore increase the possibilities to succeed in academic tasks (Hughes et al., 2008).

In the present dissertation, student-reported task-focused behaviour was operationalized as behavioural approaches towards learning (Kiuru et al., 2014), capturing motivational incentives for investment and energy in a task, rather than purely measures of on-task behaviour such as school attendance (Kiuru et al., 2014). The current operationalization has similarities with concepts such as mastery orientation (Aunola et al., 2013) and some aspects of emotional engagement (Wang & Eccles, 2012).

2.3.1.2 Emotional engagement

Students' affective reactions in the classroom and school are referred to as emotional engagement (Fredricks et al., 2004). This construct comprises emotional reactions, including interest, boredom, happiness, sadness, and anxiety towards school-related activities, peers, teachers and parents (Fredricks et al., 2004; Kiuru et al., 2014; Skinner & Belmont, 1993; Stipek, 2002). Self-report items about students' emotions related to school, schoolwork and the people at school are typically used to assess emotional school engagement (Fredricks et al., 2004). Measures of emotional engagement tend to be more general than related motivational constructs such as interest and task value (Eccles, 1983; Fredricks et al., 2004). As indicators of behavioural and emotional engagement are often included in the same scale, it may be difficult to identify the precursors and consequences of each type of engagement (Fredricks et al., 2004).

A student's general affect toward and interest in the school one attends is referred as attitude towards school (Suldo et al., 2008). This construct is captured by survey questions about liking or disliking the school, the teacher, or the schoolwork itself (Stipek, 2002; Suldo et al., 2008). General feelings of happiness at school are often included in this construct (Fredricks et al., 2004). Attitudes towards school and beliefs about one's personal achievements are considered to influence motivation and have an effect on the extent to which one invests effort on academic tasks (Suldo et al., 2008).

2.3.2 School engagement and open learning spaces

Self-determination theory (Ryan & Deci, 2000) suggests that people may become self-determined when their needs for competence, connection, and autonomy are fulfilled. Since all students have their own interests, needs, values and goals, these motivational aspects manifest in and out of school time (Christenson et al., 2012). In the school context, teachers and learning environments, including their physical, psychological, and emotional domains, facilitate student motivation and engagement (Christenson et al., 2012; Finnish National Core Curriculum for Basic Education, 2014). Varied, adaptable and flexible learning spaces, coupled with the use of student-centred pedagogies, are expected to facilitate a higher proportion of class time with students interacting, collaborating, and engaging with the lesson content, which may, in turn, translate into beneficial long-term learning outcomes (Kariippanon, Cliff, Lancaster et al., 2019). Behavioural engagement has been reported to be higher among students studying in flexible learning spaces than among students in traditional classrooms (Byers, Imms et al., 2018; Imms & Byers, 2017; Kariippanon, Cliff, Lancaster, et al., 2019; Kariippanon et al., 2018). Some studies document that student self-reports also indicate higher cognitive and emotional engagement in flexible classroom designs compared to conventional classrooms (Byers, Imms, et al., 2018).

Classroom design is posited to foster engagement through low-cost learning tools, and a flexible, open, student-centred space which affords a variety of active learning strategies (Rands & Gansemer-Topf, 2017). It has been shown that the difference in spatial layouts between innovative leaning environment (similar to that of open and flexible classroom-designs) and traditional classrooms has effects on student attitudes to their learning experiences and engagement (Byers, Imms et al 2018). Students have identified a wider array of active learning experiences and more collaborative learning in innovative learning spaces compared to settings with a traditional lay-out (Byers et al., 2018a). Successful utilization of novel learning spaces may rely to a large extent on the teachers' ability and willingness to align to affordances of the physical learning environment (Byers, Imms et al., 2018).

Dynamic and adaptive spaces with affordances of technology have been suggested to have a positive effect on students' perceptions concerning their learning especially in relation to the importance of technology as a valuable learning tool (Imms & Byers, 2017). Furthermore, dynamic and adaptive spaces have been documented to be associated with the teacher's pedagogical approach and therefore students' level of engagement (Imms & Byers, 2017).

2.3.3 School engagement and physical activity

There is some evidence that classroom-based physical activity has a positive impact on academic-related outcomes and students' on-task behaviour (Goh et al., 2016; Watson et al., 2017). Current evidence suggests that students who are physically more active are also more engaged in their classroom lessons and, thus, increased engagement is considered a potential mediating mechanism through which physical activity could have a positive influence on academic achievement (Mavilidi et al., 2020; Owen et al., 2018; Watson et al., 2017).

Physical activity integrated with instruction of academic subjects can positively impact children's academic motivation, however, it is not possible to draw definitive conclusions about this link due to the level of heterogeneity in the assessment of various components of classroom-based physical activity and academic-related outcomes (Watson et al., 2017). Thus, objective (i.e., device-assessed) measures of physical activity are warranted (Vazou et al., 2012; Watson et al., 2017).

There seems to be only a few studies examining associations of physical activity on emotional and cognitive engagement (Owen et al., 2016), and to our knowledge only a single study has examined associations between physical activity and behavioural, emotional, and cognitive engagement (Owen et al., 2018). There is some evidence that emotional engagement can be improved by integrating physical activity into classroom lessons (Vazou et al., 2012), and that moderate-intensity activity prior to mathematics lessons could improve students' cognitive engagement (Owen et al., 2018). It has been reported that classroom-based physical activity with curriculum content may be more beneficial for emotional and cognitive engagement of students compared to active breaks without curriculum content (Sneck et al., 2022). Current information is limited on the extent to which open learning spaces exert direct and indirect effects via classroom-based physical activity on students' school engagement.

3 THE AIMS OF THE STUDY

There is currently scant information on whether open learning spaces increase classroom-based physical activity or reduce sedentary behaviour of students. Therefore, the main aim of this dissertation was to investigate whether open learning spaces are associated with amounts of classroom-based physical activity, sedentary time, different sedentary bout durations, number of breaks from sedentary time, and postural transitions in classrooms where teaching methods are not experimentally altered.

As physical aspects of learning spaces do not influence classroom-based physical activity alone but exert their influence together with factors related to the school culture and pedagogical solutions (Michael et al., 2019; Russ et al., 2017), associations were investigated between observed teacher instructions with respect to students' movement and accelerometer assessed classroom-based physical activity. Current information is limited on the extent to which open learning spaces exert direct and indirect effects via classroom-based physical activity on students' school engagement. Because classroom-based physical activity seems to be associated with behavioural and emotional engagement (Vazou et al., 2012; Watson et al., 2017), the associations between accelerometer-assessed classroom-based physical activity and student ratings of task-focused behaviour and attitude towards school as indicators for behavioural and emotional engagement were investigated.

The key constructs are presented in Figure 1. Our tentative expectation was that classroom architecture is likely to enable classroom-based physical activity in the long run by concurrently reducing sedentary behaviour as proximal outcome. Classroom architecture was also expected to influence teachers' instructions towards students' movement, which in turn could influence accumulation of physical activity and sedentary time during lessons. Higher classroom based physical activity was expected to facilitate both emotional and behavioural engagement. Classroom-based physical activity and school engagement were assumed to improve students' health, wellbeing, school belonging, and academic achievement in the long term as distal outcomes, which were not assessed in this dissertation.

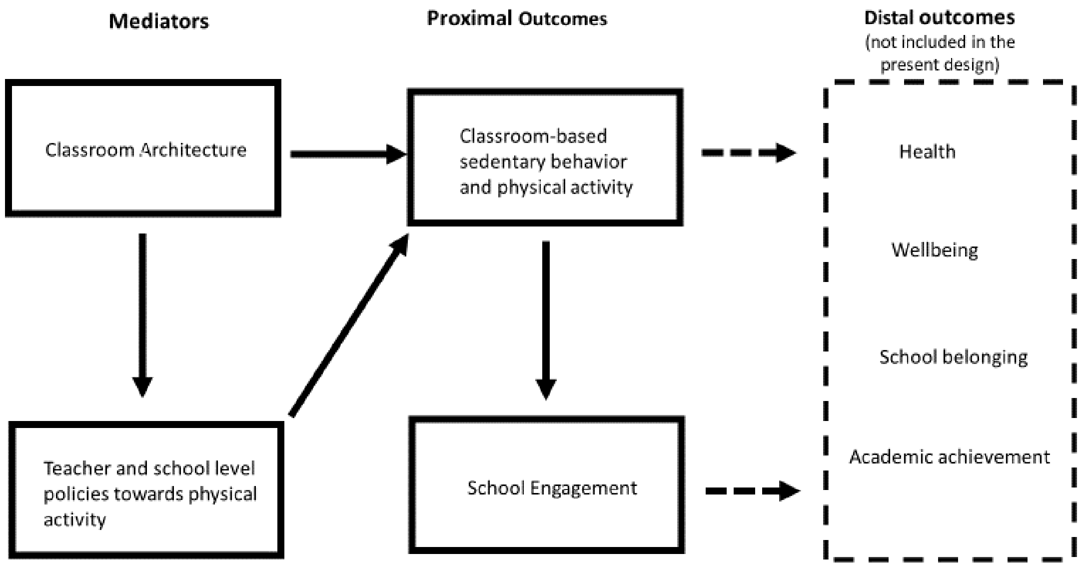

FIGURE 1 Key constructs, the expected mechanisms, and outcomes of change.

4 METHODS

4.1 Study design

The current dissertation is based on cross-sectional data collected in two different research projects investigating physical activity, sedentary behaviour, school engagement, and teacher instructions on student movement in schools with open learning spaces and conventional classrooms. The first project was the EnAct – project – *Engaging and Physically Active School as a Collaborative Learning Environment.* The EnAct project aimed to gain understanding of the changes that may follow from a redesigning of school's physical environment. The aim of the EnAct-project was to assess teacher practices, and physical activity, and their association to changes in student engagement, and physical activity and experiences of school belonging and wellbeing and collaborative problem solving.

As a part of the EnAct project, Study I was conducted based on accelerometer measures drawn from two separate academic years using cross-sectional design among Finnish third- and fifth-grade students in a school undergoing renovation from conventional classrooms to open learning spaces. In the 2015–2016 school year the students were studying in temporary modular school buildings which were like conventional classrooms with individual desks. The students began the 2016–2017 school year in the newly renovated building with mobile and flexible furniture enabling multiple classroom configurations. In this study, waist-worn accelerometery was used to measure physical activity in the renovated open flexible learning spaces.

Studies II, III and IV were based on the project "Children's physical activity spectrum: daily variations in physical activity and sedentary patterns related to school indoor physical environment" (CHIPASE). In this project, accelerometery-drawn physical activity measures, systematic observation and a school engagement questionnaire were collected from 15 classrooms of third- and fifth-grade students from three different schools and two different provinces in Finland from 2018 to 2019.

4.2 Ethical considerations

On 25 September 2015, the Ethics Committee of the University of Jyväskylä, Finland, granted approval for the EnAct subproject "Students' physical activity, school engagement, motivation and academic achievement in modern and traditional school environments". For the CHIPASE project, ethics approval was granted on 29 May 2018. Before the data collection, the children and their guardians were informed about all study procedures and their right to opt out of participation at any time without consequences. Students provided written assent and legal guardians gave their written informed consent for the students' participation in the study.

4.3 Recruitment

The recruitment for the EnACT project took place after the Ethics Committee of the University of Jyväskylä had approved the research protocol. The school recruited for this study was chosen based on appropriate timing of the complete indoor renovation of that school in relation to the project's data collection. In the CHIPASE-project, schools were chosen first based on permission provided by principals, teachers, and if required also by city-level administrators. The sample, thus, consisted of one school with open learning spaces (A) and two schools (B and C) with conventional classrooms. The school A with open learning spaces was chosen based on the relatively long adjustment time after complete indoor renovation towards open learning spaces. During the time of the data collection in school A, the third academic year had started after the renovation and therefore both teachers and students had had time to adjust to the renovated spaces.

The school staff was informed about the study. Arrangements of each measurement week (i.e., time for conducting surveys) were planned together with the classroom-teachers. A few weeks before data collection, the research team visited the participating schools to inform students and legal guardians about the study. Written consent forms and questionnaires were distributed to all students and their legal guardians in participating classes. The consent forms were collected by the classroom-teachers, and researchers retrieved them before data collection. Altogether, 220 students gave assent for participation in EnAct and a total of 206 students in CHIPASE.

4.4 Participants

The final cross-sectional sample of third- and fifth-grade students used for Study I consisted of a total of 130 students. Before renovation, complete accelerometer data were obtained from 41 third- and 42 fifth-grade students. After renovation, data were obtained from 19 third- and 28 fifth-grade students. Anthropometric assessments were not conducted in this study.

A total of 204 third- and fifth-grade students participated in assessments conducted for CHIPASE. Accelerometer data was obtained from 204 students using waist-worn accelerometery, and from 203 using thigh-worn accelerometers. After excluding accelerometer data which contained malfunctions, checking participant diaries and graphical investigation of wear-time, valid accelerometer data were obtained from 197 students of waist worn-accelerometers and 191 of both waist- and thigh-worn accelerometers. All 204 participants returned the school engagement questionnaire. Characteristics of participants in the CHIPASE project are described in Table 2.

TABLE 2 Participant characteristics of CHIPASE project.

School Classroom Type	Missing N (%)	All	School A Open		School B Conventional		School C Conventional	
Grade			3rd	5th	3rd	5th	3rd	5th
N		204	40	26	52	34	25	27
Girls (%)			40.0	50.0	59.6	52.9	44.0	44.4
Age (y)	10	10.3	9.3	11.2	9.5	11.5	9.7	11.2
	(4.9)	± 1.0	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3
Stature (cm)	3	142.4	136.5	148.0	137.0	150.2	139.0	149.2
	(1.5)	± 8.2	± 4.5	± 5.2	± 4.6	± 6.9	± 6.8	± 6.0
Weight (kg)	3	36	31.8	39.5	31.6	41.0	34.8	41.7
	(1.5)	± 8.6	± 5.6	± 6.7	± 4.2	± 9.7	± 9.8	± 10.0
ISO-BMI (kg/m^2)	10	21.5	21.7	21.4	21.0	21.3	21.7	22.2
	(4.9)	± 3.1	± 3.5	± 2.5	± 2.4	± 3.4	± 3.5	± 3.7

Values represented are means and standard deviations. Girls (%) is the percentage of females in subsample. Age and sex adjusted body mass index (ISO-BMI), which adjusts children's and adolescents BMI to correspond with adults, was calculated using Finnish references on BMI standard deviation score (Saari et al., 2011). Missing indicates the number of participants and percentage of missing values from the total samples size.

4.5 Data collection

Cross-sectional measurements for Study I were conducted during two separate academic years in a school undergoing renovation from conventional classrooms to open learning spaces. The first phase of data collection took place in autumn 2015 in conventional, self-contained classrooms with designated desks. The second phase of data collection took place in autumn 2016 when the next cohort of children was studying in the new open learning spaces in the same school after the renovation. Timetable for Study I is described in Table 3. The data for Studies II-IV were collected during years 2018–2019 and each participating class was assessed once during the data collection. Assessments were conducted for each class during one school week and timetable of the study is described in Table 4.

TABLE 3 Timetable of data collection for Study I.

Date (dd.mm.yyyy)	**Description**
Autumn 2015	***Before renovation in conventional classrooms***
25.9.2015	Ethical Approval
28.9.2015	Study info and recruitment of participants
5.10.201–9.10.2015	Measurements: 3rd grade, Class A
19.10.2015–23.10.2015	Measurements: 5th grade, Class A
26.10.2015–30.10.2015	Measurements: 5th grade, Class B
2.11.2015–6.11.2015	Measurements: 5th grade, Class C
9.11.2015–13.11.2015	Measurements: 3rd grade, Class B
Autumn 2016	***After renovation in open learning spaces***
7.11.2016–11.11.2016	Measurements: 5th grade, Class A
14.11.2016–18.11.2016	Measurements: 5th grade, Class B
21.11.2016–25.11.2016	Measurements: 3rd graders

TABLE 4 Timetable of data collection for the CHIPASE project.

Date (dd.mm.yyyy)	**Description**
29.4.2018	Ethical approval
17.9.2018–21.9.2018	Measurements: School A, 3rd graders
8.10.2018–12.10.2018	Measurements: School A, 5th graders
12.11.2018–16.11.2018	Measurements: School B, 5th grade, Class D
19.11.2018–23.11.2018	Measurements: School B, 5th grade, Classes A, B, and C
26.11.2018–30.11.2018	Measurements: School B, 3rd grade, Classes B and D
28.1.2019–1.2.2019	Measurements: School B, 3rd grade, Classes A and C
4.3.2019–8.3.2019	Measurements: School C, 3rd graders
28.10.2019–1.11.2019	Measurements: School C, 5th graders

The school A with open learning spaces was same school in both EnAct and CHIPASE projects. In school A, 70 to 80 students attended most of their lessons in large open learning spaces (Figure 2, A) with dynamic furniture, which afforded multiple options for classroom layout, as well as a smaller separate room for quiet work. Both third- and fifth-grade students had their own open learning spaces and both grades had three teachers responsible for teaching the entire grade as a collective teacher team. Students did not have an assigned place, such as a designated desk, in the open learning space. In the other two schools participating in the CHIPASE project, students attended most of their lessons in conventional classrooms with designated desks for each student and one teacher was responsible for teaching a classroom of 20 to 25 students (Figure 2, B and C).

FIGURE 2 Pictures from the classroom spaces. The pictures from the open learning space (A) show several areas for work in allowing division of the class of about 70 to 80 students into smaller groups with mobile and dynamic furniture. The pictures conventional classrooms (B and C) represent the typical self-contained rooms for around 20 students with a designated desk for each student.

The data collection in both EnAct and CHIPASE were conducted according to the following procedures. On Monday, upon students' arrival to school, accelerometers were distributed for students to be used continuously during the measurement week. In CHIPASE, body weight and stature were assessed using standard procedures described later (see section 4.6.4). During the measurement week, students filled in the school engagement rating scale. Students and their parents or legal guardians kept a diary during the school week of measurement. Participants were instructed to fill up daily wear time of accelerometer as well as to report possible absences from school. Classroom teachers were asked to provide a curriculum of the activities for the week to analyse the accelerometer data from time spent at the assigned classroom only. Accelerometers and diaries were collected from the participants at end of the measurement week on Friday.

During the measurement weeks, the content of the instruction followed the curriculum of the grades, and the instruction was not in any way altered by the researchers. During this school week, teachers' instructions on student movement were systematically observed in lessons held in the students' own learning space or classroom. These lessons included all general education lessons in mother tongue and literature, mathematics, English, arts, environmental and nature studies, religion/ethics, history and social studies, and visual arts, if the lesson was held in the student groups' own classroom.

4.6 Measurements

4.6.1 Accelerometery outcomes (Studies I–IV)

In all studies, classroom-based physical activity was measured during school hours of one school week from Monday to Friday. In Study I a waist-mounted triaxial accelerometer (Gulf Coast Data Concepts X16-1, Waveland, USA) with a measurement range of ±16 g and sample rate 40 or 50 Hz with a 16-bit A/D conversion were used. In the CHIPASE (Studies II–IV), classroom-based physical activity was measured by both waist- and thigh-mounted triaxial accelerometers (RM42, UKK Terveyspalvelut Oy, Tampere, Finland). The measurement range of the RM42 accelerometer was ±16g and the sample rate was 100 Hz with a 13-bit A/D conversion.

Only the time students spent inside the classroom during general education were included in the analysis, based on the teacher-reported weekly schedule of classroom time. Possible absences of individual students, for example, due to illness or, for example, visits to the dentist during school hours, were identified from student diaries and excluded from analysis. The data was first visually inspected lesson by lesson to ensure that accelerometers had been worn as reported by the participants.

Waist-mounted accelerometery was used to identify the time spent at different physical activity intensities, to extract breaks from sedentary time and length of active and sedentary bouts. The resultant acceleration of the triaxial accelerometer signal was calculated as $\sqrt{x^2 + y^2 + z^2}$, where x, y and z are the measurement sample of the raw acceleration signal in x-, y-, and z-directions. Mean amplitude deviation (MAD) (Vähä-Ypyä et al., 2015b) was calculated from the resultant acceleration over non-overlapping one-second epochs on the supercomputer of CSC, the Finnish IT Center for Science. MAD is described as the mean distance of data points about the mean of the given epoch,

$$\text{MAD} = \frac{1}{n}\sum_{i=1}^{n} |r_i - \bar{r}|$$

where n is the number of samples in the epoch, r_i is the i^{th} resultant sample within the epoch and $\bar{r}$ is the mean resultant value of the epoch. The MAD method used for assessing PA has been shown to be an accurate method across different accelerometer brands (Aittasalo et al., 2015; Vähä-Ypyä, Vasankari, Husu, Suni et al., 2015). MAD values were averaged over 15-second intervals, and averaged values were used to examine time spent at different physical activity intensities on MATLAB R2018a (The MathWorks Inc., Natick, MA, USA).

Cut-points for different intensities were determined as follows: light intensity PA (LPA) 16.7 mg and MVPA 91 mg (Vähä - Ypyä, Vasankari, Husu, Mänttäri et al., 2015; Vähä-Ypyä, Vasankari, Husu, Suni et al., 2015). All 15-second intervals that did not meet a light-intensity threshold contributed to sedentary time. Time spent at different physical activity intensities was first calculated as total minutes of measurement week and then proportioned to the total classroom time (i.e., time in general lessons). Breaks from sedentary time determined as any interruption in sedentary time lasting at least one minute and were further operationalized as the number of breaks per 60 minutes of classroom time (Altenburg & Chinapaw, 2015; Saunders et al., 2013). Average active and sedentary bout durations were determined as continuous bouts of 15-second epochs spent sedentary or active and were expressed as the average duration of bouts in seconds. To quantify sedentary patterns, the number of sedentary bouts were calculated for the following categories: 1-to-4 minutes, 5-to-9 minutes, 10-to-19 minutes, 20-to-29 minutes and ≥30 minutes (V. Carson et al., 2014). Sedentary bouts less than one minute were excluded from analysis as those bouts were considered as short bouts of sedentary time between physically active periods.

In Study III, total physical activity level was expressed as accumulated G per 60 minutes spent in the classroom to be used as a single parameter for structural equation modelling. The method captured the overall intensity of movement throughout the entire school week. As students tend to be sedentary for most of their time during school days (van Stralen et al., 2014), this method provides a finer granularity of physical activity, and has been used in a study investigating associations of office workstation type on physical activity and stress (Lindberg et al., 2018).

In Study IV, thigh-mounted accelerometery was used to identify sit-to-stand transitions. The accelerometer was attached on the anterior aspect of the right thigh. Sit-to-stand transitions were identified using an algorithm (Löppönen et al., 2021) with MATLAB (R2019a, The MathWorks Inc., Natick, MA, USA). The volume of the sit-to-stand transitions was determined as the number of transitions per 60 minutes spend in classroom.

4.6.2 Systematic observation of teacher instruction for movement (Study II)

Modified observational system based on SOSMART (Russ et al., 2017) was utilized for capturing a student's movement in academic routines and transitions. The observation system used in the present study was modified to capture teachers' instructions in the classroom with respect to allowing or facilitating student movement. One of the presumed key strengths or promises of open learning spaces over conventional classrooms is the facilitation of, and support for student-centred approaches to learning, where greater freedom of students' movement is one component of this type of pedagogy (Kariippanon et al., 2018; Saltmarsh et al., 2015). Therefore, observational categories developed to capture teacher management of a student's movement were developed based on prior suggestions in the literature on movement integration strategies used for transitions and teacher-led physical activity (Russ et al., 2017). Teacher-led physical activity included all common classroom-based strategies such as active breaks with (Ma et al., 2015) and without (Mahar et al., 2006) curriculum content, and physically active teaching methods (Riley et al., 2016). Observation of teacher instructions regarding a student's movement was considered a relevant measure because these impact students' physical activity independently or have an interactive effect with the type of classroom space. It is acknowledged that a change of physical environment alone does not guarantee a change in pedagogical practices (Carvalho & Yeoman, 2018; Niemi, 2021; Saltmarsh et al., 2015; Sigurðardóttir & Hjartarson, 2016).

The final teacher instructions for movement (TI) categories used in this study were selected based on several phases of preliminary testing in which inter-observer reliability was assured. TIs regarding movement integration were divided into four categories as follows:

- *T1. Teacher does not allow movement:* The teacher does not allow movement that is not necessary for the task at hand. Example: The teacher does not allow movement, except for students' being allowed to go and check the accuracy of their answers from an answer book situated on the other side of the classroom without a need to separately ask for permission to do so.

- *T2. Teacher allows free movement in the classroom:* The teacher does not limit students' movement in the classroom. Examples: Students may move around and change places at their own will. The teacher does not instruct students to pick a place or stop movement.

- *T3. Teacher organizes transition*: The teacher organizes a transition that serves an educational purpose, such as students changing working stations or picking up books from lockers.

- *T4. Teacher organizes physical activity:* The teacher organizes PA that is not categorised as T2 or T3. PA can be directed by a teacher, a student, or via video.

Three observers were carefully trained to use the observation coding manual, and they needed to pass a rater-reliability check before participating in data collection. To meet the criteria for adherence to the coding manual, they had to pass a written exam with at least 80% right answers. Teachers' instructions were observed in a total of 156 lessons, which contained lessons held in the student group's own learning space assigned for that class.

During a lesson, the teachers' instructions for one student (i.e., a chosen student assigned for coding of the specific lesson) were observed using continuous 20-second observation intervals (i.e., three observations in a minute). Within a 20-second interval, researchers coded the current teacher instruction for the observed student using web-based observation software (Moveatis, University of Jyväskylä, Finland). In addition to using the observation software, observers filled in manual forms to describe the events during lessons. To analyse the observational data, percentages of prevalence of the four observation categories for each classroom were calculated. Lessons held by special education, subject or substitute teachers were included in the analyses to better reflect overall school practices regarding classroom-based physical activity.

4.6.3 School engagement (Study III)

Children's engagement was assessed using two scales. Task-focused behaviour as an indicator of behavioural engagement was assessed with a scale based on the Achievement Beliefs Scale for Children, which has been used to assess primary school students in Finland (Aunola et al., 2013; Aunola & Nurmi, 2006; Kiuru et al., 2014). Children were presented with seven statements regarding their typical task motivation with respect to approaching or avoiding challenging academic tasks (e.g., "I enjoy working with challenging school tasks"; "Difficult tasks make me try hard"). Attitude towards school as an indicator of emotional engagement was assessed using three statements regarding their typical thoughts about school (e.g., "It is nice to come to school"). Answers were coded on a Likert scale of 1–5 with a higher value presenting higher task-focused behaviour or a more positive attitude towards school. Negatively worded statements were reverse coded. The internal consistency of items as assessed with Cronbach's alpha was 0.799 for task-focused behaviour and 0.677 for attitude towards school.

4.6.4 Anthropometric assessments (Studies II, III and IV)

Anthropometric assessments were obtained as accelerometery-assessed physical activity is susceptible to age, sex, body size, and body composition (Haapala, Gao, Rantalainen et al., 2021b). Body stature and weight were assessed in a separate and private space during distribution of accelerometers. Stature was measured to the nearest 0.1 cm using a custom and portable stadiometer (University of Jyväskylä, Finland), with average of two measurements. Weight was assessed with an average of two measurements using a digital scale (Soehle Digital, Germany). Age and sex adjusted body mass index (ISO-BMI), which adjusts children's and adolescents BMI to correspond to that of adults, was calculated using Finnish reference values (Saari et al., 2011).

4.7 Data analysis

Descriptive statistics were calculated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Statistical analyses were carried out using either IBM SPSS Statistics 26 software (IBM corp. Armonk, NY, USA) or R (R Core Team, Vienna, Austria). The normality of data distribution was assessed using normal

QQ plots, histograms, and the Shapiro-Wilk test ($p < .05$). Homogeneity of variances were assessed using residuals vs. fitted values plot and Levene's test $p<.05$).

In Study I, independent samples t-test or Mann-Whitney U-test were used to compare accelerometery assessed classroom-based sedentary time, light intensity physical activity, moderate-to-vigorous physical activity and breaks from sedentary time between cohorts assessed before and after renovation. Two-tailed significances below 0.05 were considered statistically significant. Statistical analyses were made separately for third- and fifth-grade students. Because of the small sample size, further comparisons between boys and girls were not conducted.

In studies II and IV, three-way factorial ANOVA (2x2x2) with Type III Sum of Squares was used to examine the associations type of classroom (open vs. conventional), grade (3rd vs. 5th grade) and gender (boys vs. girls) on classroom-based sedentary time, light intensity physical activity, moderate-to-vigorous physical activity, breaks from sedentary time, average active bout durations, average sedentary bout durations, sit-to-stand transitions, and the number of sedentary bouts belonging to different categories based on duration of the bout. For variables violating homogeneity of variance, heteroskedasticity-consistent HC3 version of Huber-White's robust standard errors were used using R-package "car" (Fox & Weisberg, 2019). In Study IV, variables violating the normality assumption were treated with a log(x+1) transformation to meet the requirements of normality distribution. In Study II, to report effect sizes, partial omega squared (ωp2) was utilized. To control Type I error for multiple testing, accepted p-value was adjusted by dividing 0.05 by the number of tests conducted for both simple two-way interactions and simple main effects using independent samples t-test.

In Study II, possible differences between students in the three schools separately for third and fifth graders were assessed using either one-way ANOVAs with Tukey's HSD post hoc procedures, Welch's ANOVA with the Games Howell post hoc-test, or the Kruskal-Wallis test with the Mann-Whitney post hoc test using Bonferroni adjustment, with a 0.05 level of significance. The applied statistical test was determined for each assessed variable based on normality and homogeneity of variance. To report effect size, omega squared (ω^2) for one-way ANOVA, adjusted omega squared (est. ω^2) for Welch's ANOVA and epsilon squared (ε^2) for the Kruskal-Wallis H-test were given. In Study IV, differences between schools were examined for both grade levels separately with one-way ANCOVA, with gender set as a covariate. Statistical significance was set at $p<.05$ with 95% confidence intervals. Tukey's honest significance test was utilized for multiple comparisons.

In Study II, descriptive statistics from systematic teachers' instruction observation were calculated to determine relative amounts of each teacher instruction category for each participating class and across the two grade-levels in each school. A Chi-square test was utilized to examine grade-matched differences between schools in the prevalence of teacher instructions. A

Spearman’s rank-order correlation was run to assess the relationship between teacher instructions and classroom-based physical activity.

In Study III, structural equation modelling was applied as it can be used to study the relationships among latent constructs that are indicated by multiple measures (Lei & Wu, 2007). This multivariate statistical analysis technique allowed for the exploration of complex relationships between types of classrooms, individual characteristics, physical activity, task-focused behaviour, and attitude towards school with a single model (Lei & Wu, 2007). Task-focused behaviour (seven items) and attitude towards school (three items) were each modelled as a latent construct, and all the other constructs in the structural model were directly assessed. The hypothesized model is illustrated in Figure 3.

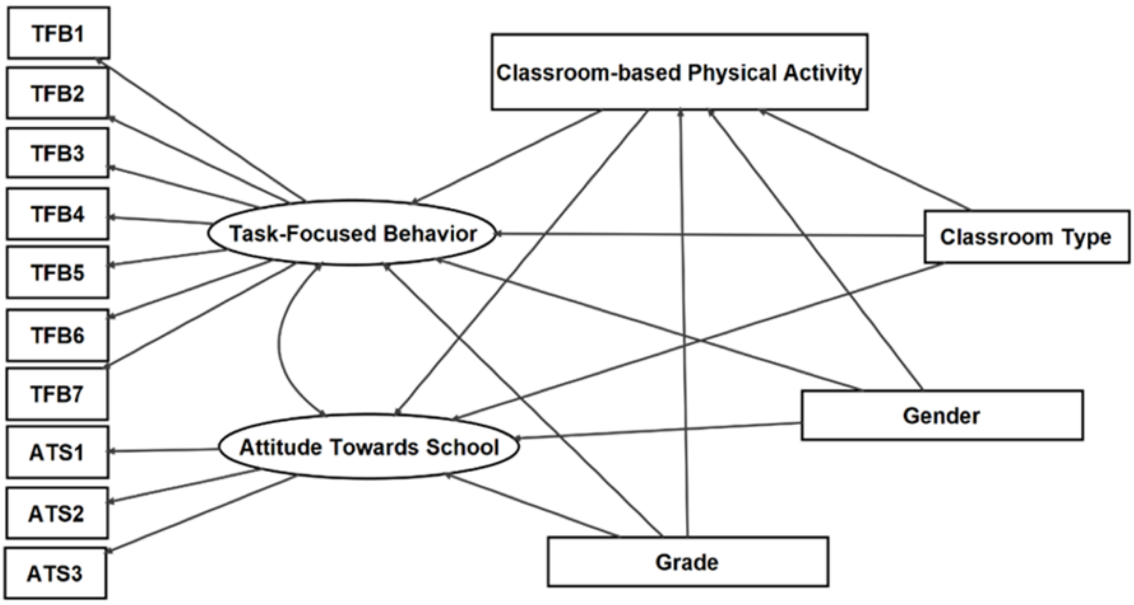

FIGURE 3 The hypothesized structural equation model. Latent factors are represented as ovals and observed variables as rectangles. Straight lines indicate hypothesized paths and curved lines indicate covariance between variables. TFB = task-focused behaviour, ATS = attitude towards school. Grade: 5th vs. 3rd grade, gender: girls vs. boys, and classroom type: open learning space vs. conventional classroom. Comparative fit index: 0.764; standardized root mean square residual: 0.130.

The lavaan package in R was used for model fit and validation. Full information maximum likelihood estimation was used to estimate the significant path coefficients in the model. Missing values were not replaced or imputed but handled within the analysis model. The comparative fit index and standardized root mean square residual were used to estimate model fit. The hypothesized model exhibited poor model fit as the comparative fit index was 0.764 and standardized root mean square residual was 0.130. To reach the recommended levels on the comparative fit index (>0.95) and standardized root mean square residual (<0.08), covariances between items representing latent constructs were added by estimating modification indices and adding covariances with highest modification indices one at a time.

5 RESULTS

The main findings of the dissertation are presented in the Results section. The original papers (I–IV) should be consulted for additional details. Participant characteristics of the CHIPASE project are provided in Table 2 describing average age, stature, weight, and ISO-BMI of participants.

5.1 Accelerometery outcomes (Studies I, II and IV)

This section describes the findings of accelerometery-based assessment of classroom-based physical activity in studies I, II, and IV. First, raw means and standard deviations are described with cross-sectional comparisons before and after renovation in Study I and between three schools in studies II and IV. Then interaction and main effects of classroom type, gender and grade are reported for studies II and IV. Tables 5 and 6 describe means and standard deviations of third- and fifth-grade students before and after renovation (EnACT, Study I) and between three schools that participated in CHIPASE (studies II and IV).

Based on results from studies I, II and IV, Finnish third- and fifth-grade students are sedentary 56% to 68% of general education classroom time. Light intensity physical activity comprises 24% to 32% and moderate-to-vigorous physical activity 8% to 15% of classroom time. Breaks from sedentary time occurred 8 to 10 times per 60 minutes spent in the classroom (Tables 5 and 6). Based on Study II, the average active bout length ranged from 62 to 99 seconds, while average sedentary bout length ranged from 114 to 125 seconds across the three schools (Table 6). Based on Study IV, there were four to seven sedentary bouts lasting 1 to 4 minutes. Sedentary bouts lasting 5 to 9 minutes were observed 1.4 to 1.5 times per hour, while there were 0.2 to 0.6 sedentary bouts per hour lasting over 10 minutes (Table 7). Sit-to-stand transitions occurred 4 to 6 times per 60 minutes spent in the classroom (Table 7).

TABLE 5 Cross-sectional cohorts and results for sedentary time and different physical activity intensities before and after renovation from conventional classrooms to open learning spaces (Study I).

Measurement	Grade	Boys/Girls	Duration(min)	ST (%)	LPA (%)	MVPA (%)	BST (breaks/h)
Before	3rd	19/22	792±153	55.9±14.0	31.6±11.0	11.2±4.6	8.5±2.0
	5th	16/26	760±180	57.0±12.2	28.7±10.0	12.9±7.1	7.4±1.2
After	3rd	11/8	609±125	58.0±10.6	30.0±10.6	14.9±6.4	9.3±1.9
	5th	19/21	776±201	67.7±5.6	22.7±4.6	10.5±3.0	9.2±1.6

Values represented are means and standard deviations. Total analysed classroom time in minutes (Duration), percentage of sedentary time (ST), light (LPA), and moderate-to-vigorous (MVPA) intensity physical activity. Breaks from sedentary time (BST) expressed as breaks per 60 minutes of classroom time (breaks/h)

TABLE 6 Characteristics of participants and results of physical activity assessments by School and Grade level (Study II).

School *Classroom type*	**A** *Open*	**B** *Conventional*	**C** *Conventional*
3rd Graders			
Participants (n)	36	50	20
Girls (%)	38.9	58.0	55.0
ST (%)	57.0 ± 7.6	57.4 ± 9.1	58.0 ± 8.8
LPA (%)	30.9 ± 6.9	29.5 ± 5.4	30.7 ± 7.1
MVPA (%)	12.1 ± 2.2	13.1 ± 5.0	11.4 ± 4.7
BST (breaks/h)	9.5 ± 1.2$^{\dagger\dagger/\dagger\dagger\dagger}$	8.1 ± 1.8†††	8.1 ± 1.6††
ActiveB (s)	77 ± 9‡‡	93 ± 22‡‡	88 ± 21
SedB (s)	95 ± 37‡	101 ± 29‡	101 ± 33
5th Graders			
Participants (n)	21	32	23
Girls (%)	47.6	53.0	44.4
ST (%)	67.7 ± 9.1*	62.3 ± 9.3	60.8 ± 9.6*
LPA (%)	24.0 ± 6.7	26.9 ± 6.8	27.3 ± 7.4
MVPA (%)	8.3 ± 2.8‡‡	10.7 ± 4.1	11.8 ± 3.8‡‡
BST (breaks/h)	10.2 ± 1.8$^{\ddagger\ddagger/\ddagger\ddagger\ddagger}$	8.4 ± 1.7$^{\ddagger/\ddagger\ddagger}$	7.8 ± 1.2$^{\ddagger/\ddagger\ddagger\ddagger}$
ActiveB (s)	62 ± 9$^{\ddagger\ddagger\ddagger(A\text{-}B,\ A\text{-}C)}$	83 ± 22$^{\ddagger\ddagger\ddagger(A\text{-}B)}$	99 ± 21$^{\ddagger\ddagger\ddagger(A\text{-}C)}$
SedB (s)	114 ± 28	115 ± 36	125± 35

Values represented are means and standard deviations. Girls (%) is the percentage of girls. Sedentary time (ST), light intensity (LPA) and moderate-to-vigorous physical activity (MVPA) are represented as the percentage of time spent at a given intensity from total classroom-time. Breaks from sedentary time (BST) are represented as times per one hour of classroom time. Active (ActiveB) and sedentary bout (SedB) durations are represented in seconds during classroom-time. Comparisons made for third- and fifth -grade students separately with either one-way ANOVA with Tukey's HSD test (*p < .05, **p <. 01, ***p <. 001), Welch's ANOVA with the Games Howell post hoc-test (†p < .05 ††p < .01, †††p < .001) or Kruskal-Wallis test with Mann-Whitney post hoc test using Bonferroni-adjustment (‡p < .05, ‡‡p < .01, ‡‡‡p < .001). $^{(A\text{-}B)}$ Significant difference between schools A and B. $^{(A\text{-}C)}$ Significant difference between schools A and C.

TABLE 7 Sedentary behaviour by school and grade-level (Study IV).

School	A		B		C	
Classroom type	Open		Conventional		Conventional	
Grade-level	3rd	5th	3rd	5th	3rd	5th
Number of participants	38	21	52	33	22	25
Girls (%)	42.1	52.4	59.6	51.5	50	48
1–4 min SB (bouts/h)	6.80 ± 1.27	6.78 ± 1.99	5.32 ± 1.57	5.13 ± 1.64	5.10 ± 1.41	4.27 ± 1.09
5–9 min SB (bouts/h)	1.51 ± 0.60	1.59 ± 0.68	1.38 ± 0.49	1.58 ± 0.49	1.42 ± 0.51	1.49 ± 0.45
10+ min SB (bouts/h)	0.20 ± 0.15	0.31 ± 0.31	0.39 ± 0.33	0.60 ± 0.43	0.42 ± 0.28	0.52 ± 0.26
10–19 min SB (bouts/h)	0.19 ± 0.15	0.25 ± 0.27	0.35 ± 0.29	0.52 ± 0.38	0.38 ± 0.28	0.41 ± 0.26
20–29 min SB (bouts/h)	0.00 ± 0.02	0.07 ± 0.09	0.04 ± 0.08	0.08 ± 0.12	0.04 ± 0.07	0.11 ± 0.15
30+ min SB (bouts/h)	0	0	0	0	0	0
STS (transitions/h)	6.54 ± 1.84	5.41 ± 2.52	5.77 ± 2.19	5.32 ± 1.66	3.93 ± 1.57	4.65 ± 1.47

Values represented are means and standard deviations. Girls (%) describes percentage of girls in subsamples. SB = Sedentary bouts, STS = sit-to-stand transitions.

5.1.1 Comparisons of classroom-based physical activity before and after school renovation (Study I)

In Study I, classroom-based sedentary time was observed to be higher in the sample of fifth-graders assessed before renovation in conventional classrooms than in the cohort of fifth-graders measured after renovation in the open learning space (mean difference 10.7 percentage-points, $t(61.621) = -4{,}945$, $p < .001$). The relative amount of light intensity physical activity was greater than in the sample measured before the renovation (mean difference 6.10 percentage-points; $t(61, 655) = 3{,}019$, $p = .001$). The cohort of fifth-grade students assessed before renovation had a smaller number of breaks from sedentary time than the sample measured after renovation (mean difference−1.78 breaks/h, $t(45.768) = -5.100$; $p < .001$). For third graders, significant differences were not observed in sedentary time and light intensity physical activity or breaks from sedentary time between samples assessed before or after renovation, but moderate-to-vigorous physical activity was lower in the sample measured before renovation than after (Mean Rank (Before) = 27.22, Mean Rank (After) = 37.58, $U = 524.0$, $p = .033$).

5.1.2 Between school comparisons of classroom-based physical activity (Studies II and IV)

In Study II, sedentary time ($F(2,73) = 3.286$, $p = .043$) and moderate-to-vigorous intensity physical activity ($H(2) = 11.765$, $p = .003$) were significantly different between schools. Students attending the fifth grade in school A with open learning spaces were more sedentary ($p = .046$) and had less moderate-to-vigorous intensity physical activity (Mean Rank (A) = 25.88 vs. Mean Rank (C) =48.63, $p = .002$) than their counterparts in school C. For third-grade students, sedentary time, light, and moderate-to-vigorous intensity physical activity did not differ statistically significantly between schools (Table 6).

Number of breaks from sedentary time differed significantly between schools in both third- (Welch's F(2,50.169) =13.11, p < .001) and fifth-grade students (H(2) =27.374 p < .001). Students attending third grade in school A had a higher number of breaks from sedentary time than students in school B (p < .001) and C (p = .003). In school A, fifth-grade students had a higher number of breaks from sedentary time than their counterparts in school B (Mean Rank (A) =57.40 vs. Mean Rank (B)=37.52, p = .004) and C (Mean Rank (C)=22.61, p < .001). In addition, students in school B had more breaks from sedentary time than their counterparts in school C (p = .041) (Table 6).

Average duration of active bouts (H(2) = 12.816, p = .002) and sedentary bouts (H(2) = 9.416 p = .009) were significantly different between schools among third-grade students. Students in school A had shorter active bouts (Mean Rank (A)=38.94 vs. Mean Rank (C) = 56.50, p = .001) and sedentary bouts (Mean Rank (A)=40.75 vs. Mean Rank (C) = 58.90, p = .01) than students in school C. Furthermore, a significant difference in average active bouts (H (2) = 31.163 p < .001) emerged among fifth-grade students, as students in school A had shorter active bouts than their counterparts in school B (Mean Rank (A) = 17.52, Mean Rank (B) = 40.88, p<.001) and C (Mean Rank (C) = 54.35, p<.001) (Table 6).

In Study IV, 1-to-4–minute sedentary bouts had significant differences between schools (F(2,108) = 14.816, p < .001) in third-grade students when gender was controlled for. Third-grade students in school A had more 1-to-4-minute bouts than their counterparts in school B (mean difference 1.5 bouts/h, p < .001) and C (mean difference 1.7 bouts/h, p < .001) (Table 8). Significant differences were observed also in fifth-grade students between schools (F(2,75) = 14.801, p < .001). Fifth-grade students in school A had more 1-to-4-minute sedentary bouts than students in schools B (mean difference 1.6 bouts/h, p = .011) and C (mean difference 2.5 bouts/h, p < .001) (Table 8).

The 5-to-9–minute bouts were not statistically significantly different between schools for either third- or fifth-grade students (Table 5). The log(x+1) transformed sedentary bouts of more than 10 minutes were significantly different between schools among third-grade students (F(2,108)=8.634, p < .001). In school A, third-grade students had fewer sedentary bouts of more than 10 minutes compared to schools B (p = .011) and C (p = .012) (Table 8). There were also statistically significant differences between schools (F(2,75) = 4.773, p = 0.11) in fifth grade, as students in school A had fewer sedentary bouts over 10 minutes than students in school B (p = .013). Differences between schools A and C or B and C were not statistically significant (Table 8).

Among third-grade students, sit-to-stand transitions differed between schools (F(2,108) = 12.198, p <. 001). Third-grade students in school A had more sit-to-stand transitions than students in school C (mean difference 2.6 transitions/h, p < .001) and there was also a statistically significant difference between schools B and C (mean difference 1.9 transitions/h, p = 011) (Table 5).

In fifth-grade students, differences in sit-to-stand transitions between school were not observed (Table 8).

TABLE 8 Grade-matched between school differences of sedentary behaviour variables controlled for gender (Study IV).

School – Classroom type	Significant difference between schools	Estimated marginal mean	Lower CI95%	Upper CI95%
1-to-4–minute sedentary bouts (Bouts/(h)				
3rd grade				
A – Open	A-B***, A-C***	6.8	6.4	7.3
B – Conventional		5.3	4.9	5.7
C – Conventional		5.1	4.5	5.7
5th grade				
A – Open	A-B*, A-C***	6.8	6.1	7.5
B – Conventional		5.1	4.6	5.7
C – Conventional		4.3	3.6	4.9
5-to-9–minute sedentary bouts (bouts/h)				
3rd grade				
A – Open		1.5	1.3	1.7
B – Conventional		1.4	1.2	1.5
C – Conventional		1.4	1.2	1.7
5th Grade [b]				
A – Open		1.6	1.4	1.8
B – Conventional		1.6	1.4	1.8
C – Conventional		1.5	1.3	1.7
>10-minute bouts (log(bouts/h+1)) [a]				
3rd Grade [b]				
A – Open	A-B*, B-C*	0.17	0.11	0.24
B – Conventional		0.30	0.25	0.36
C – Conventional		0.33	0.25	0.41
5th Grade [b]				
A – Open	A-B*	0.25	0.16	0.35
B – Conventional		0.43	0.36	0.51
C – Conventional		0.41	0.32	0.50
Sit-to-Stand Transitions (transitions/h)				
3rd Grade				
A – Open	A-C***	6.5	5.9	7.2
B – Conventional	B-C*	5.8	5.2	6.3
C – Conventional		3.9	3.1	4.8
5th Grade [b]				
A – Open		5.4	4.6	6.2
B – Conventional		5.3	4.7	6.0
C – Conventional		4.7	3.9	5.4

[a] log(x+1) transformation was utilized. [b] One-way ANCOVA was using heteroskedasticity-consistent HC3 version of Huber-White's robust standard errors. * p < .05, **p < .01, ***p < .001

5.1.3 Associations of classroom type, gender and grade and classroom-based physical activity (Studies II and IV)

Study II showed statistically significant three-way interactions of grade, gender, and classroom type on physical activity variables (Table 6). Sedentary time had statistically significant interactions between grade and classroom type and between gender and grade (Table 9). Fifth-grade students had more sedentary time in open learning spaces compared to conventional classrooms (mean difference 6.0%, p = .014). Moreover, average sedentary time was higher in girls than boys in fifth grade (mean difference -6.9%, p = .001). In third-grade students, similar differences were not observed. Light intensity physical activity had a significant gender and grade interaction in fifth-grade students with girls accumulating less light intensity physical activity than boys (mean difference 3.9%, p = .014). Interaction effect on moderate-vigorous physical activity between classroom type and gender was statistically significant. Boys had less moderate-to-vigorous physical activity (mean difference 2.6%, p = .001) in open learning spaces compared to conventional classrooms. Breaks from sedentary time had significant main effect from classroom type (mean difference 1.8 breaks/h, p < .001) as students in conventional classrooms had fewer breaks from sedentary time compared to students in open learning spaces.

Active bout durations were observed to have statistically significant two-way interactions between grade level and classroom type and between gender and classroom type. Active bouts were shorter in open learning spaces compared to conventional classroom in both third grade (mean difference 15 s, p<.001) and fifth grade (mean difference 28 s, p < .001) students. Both boys (mean difference 26 s, p < .001) and girls (mean difference 15 s, p < .001) had longer active bouts in conventional classrooms compared to open learning spaces. Sedentary bout durations were observed to have significant two-way interaction between grade and gender, as fifth-grade boys had shorter averaged sedentary bout duration than third-grade boys (mean difference 21 s, p = .013).

In Study IV, statistically significant three-way interactions between gender, grade, and classroom type on sedentary behaviour variables were not observed (Table 9). 1-to-4–minute sedentary bouts were observed to have significant two-way interaction between gender and classroom type (Table 9). However, post hoc test indicated that differences between boys and girls were not statistically significant in either open learning spaces or conventional classrooms. Both girls (mean difference 1.2 bouts/h, p = .003) and boys (mean difference 2.4 times/h, p < .001) were observed to have more 1-to-4–minute sedentary bouts in open learning spaces compared to conventional classroom. Therefore, main effect of classroom type on 1-to-4–minute sedentary bouts was significant (Table 6) as students in open classrooms had more 1-to-4–minute bouts (mean difference 1.8 bouts/h, p < .001) than in conventional classrooms.

For 5-to-9–minute sedentary bouts two-way interactions or main effects were not observed (Table 9). For >10-minute bouts, there was significant two-way interaction between gender and grade (Table 6). Post hoc test indicated fifth-grade girls had more >10-minute sedentary bouts than third-grade girls (p = .004).

The main effect for classroom type was significant and students in open learning spaces had fewer >10-minute sedentary bouts (p < .001). For sit-to-stand transitions, significant main effect for classroom-type was observed as students in conventional classrooms had less sit-to-stand transitions (0.9 transitions/h, p = .009) compared to students in open learning spaces.

TABLE 9 Three-way ANOVA test of Between-Subjects Effects of Grade, Gender, and Classroom type on Physical Activity Variables (Study II and IV)

Study II			**F(7,174)**				
PA-variable	Gender	Grade	Classroom	Gender x Grade	Gender x Classroom	Grade x Classroom	Gender x Grade x Classroom
ST(%)	9.019**	29.948***	3.991*	4.730*	0.436	5.374*	1.450
LPA(%)	2.233	21.902***	0.797	7.961**	0.085	4.563*	1.083
MVPA(%)a	25.980***	27.885***	12.949***	0.017	5.608*	3.696	1.299
BST(breaks/h)	0.257	1.089	48.164***	0.037	2.994	2.744	0.649
AB(s)a	24.036***	14.444***	94.915***	0.191	6.467*	5.798*	1.857
SB(s)a	2.474	15.230***	3.099	5.314*	0.181	0.981	0.499
Study IV				**F(7,183)**			
1–4min SB	2.244	0.723	54.380***	2.643	5.940*	1.062	0.160
5–9min SB	0.171	1.442	0.957	0.069	0.525	0.232	0.009
10+ min SB a,b	3.566	9.000**	22.686***	4.612*	0.032	0.227	0.216
STS a	0.144	3.289	5.174*	0.567	0.526	1.572	0.549

*p < .05, **p < .01, ***p < .001 [a] Three-way ANOVA was conducted using heteroskedasticity-consistent HC3 version of Huber-White's robust standard errors. [b] log(x+1) transformation was utilized. Physical Activity (PA)-variables include sedentary time (ST), light intensity (LPA), moderate-to-vigorous physical activity (MVPA), Breaks from sedentary time (BST), Average Active (AB) and sedentary bout (SB) durations, 1–4 minute sedentary bouts, 5–9 minute sedentary bouts, and over 10-minute sedentary bouts.

5.2 Observed teachers' instructions on students' movement (Study II)

This section describes the findings of systematic observation conducted in 15 classrooms across three schools participating CHIPASE-study, and which are reported in Study II. It was observed that teachers' instructions prohibited student movement (coded as T1) most of the observed classroom time as they typically allowed only necessary movement during 78% (range 51%–99%) of the observed classroom time. A much smaller proportion of time, 15% (range 0%–46%) of the observed classroom time, was used in T2 in which teachers did not limit students' movement in the classroom. On average 2% (range 0%–8%) of the observed time was spent in the teacher directed transitions (coded as T3) and 4% (range 0%–11%) in the teacher-organized physical activity, coded as T4. In general, teachers in traditional schools with conventional classrooms seemed to promote physical activity with teacher-organized activity breaks more than in open learning spaces but there were differences even within the same school and same grade level, as seen in Figure 4.

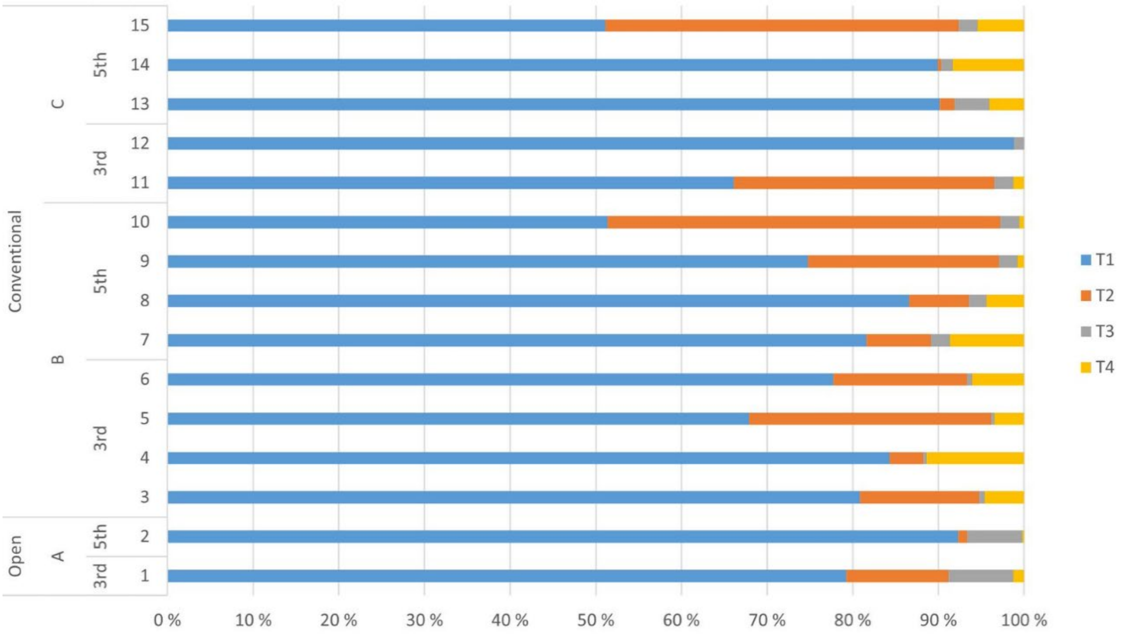

FIGURE 4 Relative amounts of observed teacher instructions on students' movement in 15 different classrooms (numbered from 1 to 15 on the Y-axis) from two grade levels (3rd and 5th) across three schools (A-C). Teachers' instruction categories include T1 = Teacher(s) does not allow movement, T2 = Teacher(s) allows free movement in classroom, T3 = Teacher(s) organizes transition T4 = Teacher(s) organizes physical activity

The prevalence of teacher instruction categories was significantly different between schools for both third ($X^2 = 687.64$; df = 6, p<.001) and fifth graders ($X^2 = 1011.28$, df = 6, p<.001). In school A, fifth-grade teachers were more restrictive towards students' movement in the classroom (T1 = 92%) compared to schools B (T1 = 73%) and C (T1 = 80%). Fifth-grade students in school B were allowed the most freedom for movement (T2 = 22%), and in school A the least (1%). Both third- and fifth-grade teachers in school A organized a high number of transitions (third-grade T3 = 8% and fifth-grade T3 = 6%) compared to schools B (third-grade T3 = 1% and fifth-grade T3 = 2%) and C (third-grade T3 = 2% and fifth-grade T3 = 3%). Teachers in school A had least teacher led physical activity (third-grade T4 = 1% and fifth-grade T4 = 0%), while in school B third-grade (T4 = 6%) and in school C fifth-grade teachers (T4 = 6%) led more physical activity in the classroom (Table 10).

The examination of the associations between the prevalence of teacher instructions and classroom-based physical activity with Spearman's correlation revealed that less restrictive instructions (T1) and more freedom of movement (T2) were associated with more light intensity physical activity. More teacher-led physical activity (T4) was associated with more moderate-to-vigorous physical activity, while directed transitions (T3) and teacher-led physical activity were associated with the higher number of breaks from sedentary time. Fewer directed transitions and more teacher-led physical activity were associated with longer active bouts, and fewer transitions were associated with longer sedentary bouts (Table 11).

TABLE 10 Prevalence of the observed teacher instructions on students' movement in the different classrooms and grade-levels (Study II).

School	Classroom type	Grade	T1(%)	T2(%)	T3(%)	T4(%)
A	Open	3rd	79	12	8	1
		5th	92	1	6	0
B	Conventional	3rd	78	16	1	6
		5th	73	22	2	3
C	Conventional	3rd	80	17	2	0
		5th	80	12	3	6

Values represented are prevalence of individual categories from all observations (%). T1 = Teacher(s) does not allow movement, T2= Teacher(s) allows free movement in classroom, T3= Teacher(s) organises transition T4= Teacher(s) organizes physical activity. Prevalence of TIs were significantly different between schools in both third (X^2=687.64; df = 6 p < .001) and fifth graders (X^2=1011.28; df = 6; p <. 001).

TABLE 11 Spearman correlations r_s (df = 182) for teachers' instructions on students' movement categories and classroom-based physical activity (Study II).

	T1%	T2%	T3%	T4%
ST	0.077	-0.088	0.036	-0.112
LPA	-0.173*	0.169*	0.037	0.016
MVPA	0.092	-0.082	-0.133	0.276**
BST	-0.151*	0.070	0.384**	-0.356**
AB	0.097	-0.043	-0.387**	0.440**
SB	0.137	-0.114	-0.190*	0.110

*p < .05 **p < .01. Physical Activity (PA) variables include sedentary time (ST), light intensity (LPA), moderate-to-vigorous physical activity (MVPA), Breaks from sedentary time (BST), Active (AB) and sedentary bout (SB) durations. Teachers' instruction categories include T1 = Teacher(s) does not allow movement, T2 = Teacher(s) allows free movement in classroom, T3 = Teacher(s) organizes transition T4 = Teacher(s) organizes physical activity.

5.3 School engagement (Study III)

Questionnaire ratings of task-focused behaviour as well as attitude towards school were obtained from 204 students and physical activity assessments from 195 students. Table 12 provides descriptive statistics for the variables examined in Study III.

TABLE 12 Results of structural equation modelling (Study III).

School	**School 1**		**School 2**		**School 3**	
Classroom Type	Open		Conventional		Conventional	
Grade	3rd	5th	3rd	5th	3rd	5th
N	40	26	52	34	25	27
Girls (%)	40	50	59.6	52.9	44	44.4
TFB (1 to 5)	3.8(0.6)	3.6(0.8)	3.6(0.8)	3.6(0.7)	3.9(0.7)	3.6(0.9)
ATT (1 to 5)	4.2(0.8)	4.1(0.5)	3.7(0.8)	3.7(0.8)	4.1(0.8)	3.8(0.9)
CPA (G/60min)	9.493(1.809)	6.966(1.891)	10.085(2.879)	9.016(2.823)	10.345(3.227)	9.846(2.066)

Values presented are means and standard deviations. Girls (%) refers to percentage of girls. Mean scores for task-focused behaviour (TFB) assessed with seven items and attitude towards school (ATT) assessed with three items on a 5-point Likert-scale (Cronbach's α TFB = .799, ATT = .677). Classroom-based physical activity (CPA) assessed with mean amplitude deviation method and expressed as accumulated G per 60 minutes spent in classroom.

The hypothesized and final models of relationships between types of classrooms, individual characteristics, physical activity, task-focused behaviour, and attitude towards school were compared using the Chi-squared difference test which indicated significant (Chi-squared difference = 313.62, df = 6, $p < .001$) improvement of model fit. The final model exhibited good model fit with a comparative fit index of 0.977 and a standardized root mean square residual of 0.079. In Figure 5 showing the final model, solid and straight lines represent significant paths ($p < 0.05$) with unstandardized coefficients shown with their standard errors (dotted lines represent nonsignificant paths). Curved lines indicate covariance between variables. Classroom type was associated with student ratings of attitude towards school (B = −0.336; 95% CI [−0.616, −0.055]) with students in open learning spaces reporting a more positive attitude towards school than students in conventional classrooms. Classroom type was not associated with task-focused behaviour. Relationship between task-focused behaviour and attitude towards school was statistically significant (B = 0.188; 95% CI [0.068, 0.031]).

Classroom-based physical activity was not associated with task-focused behaviour and attitude towards school, while classroom-based physical activity was associated with grade, gender, and classroom-type. Third grade students were more physically active than fifth graders (B = 1.560; 95% CI 0.893 to 2.227), while boys were more physically active than girls (B = 1.732; 95% CI 1.065 to 2.398). Students in conventional classrooms were more physically active than students in open learning spaces (B = 1.818; 95% CI 1.101 to 2.536).

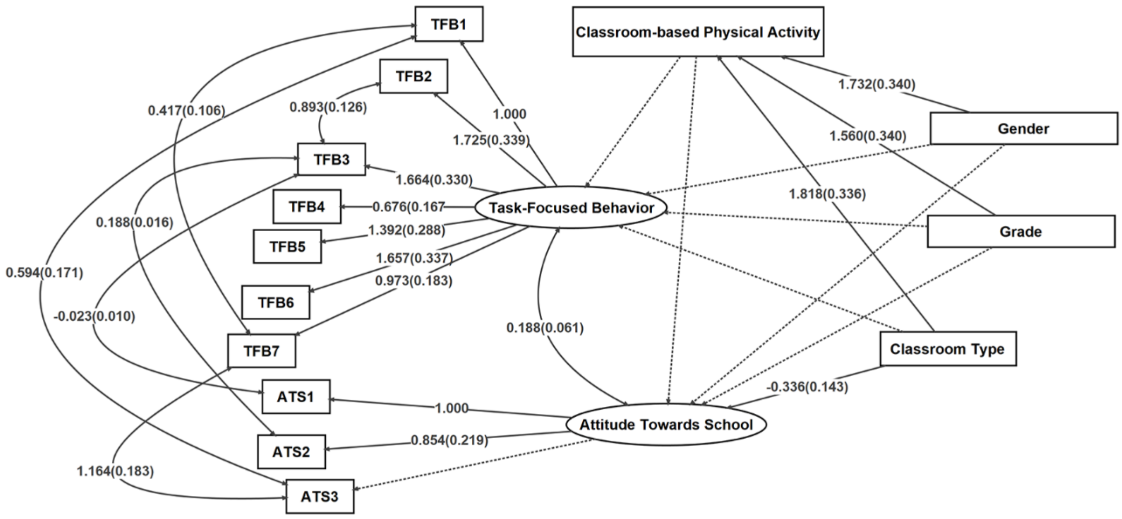

FIGURE 5 Structural equation model results. Latent factors are represented as ovals and observed variables as rectangles. Solid lines represent significant ($p < 0.05$) (and dotted lines nonsignificant paths), the former include unstandardized coefficients (and standard errors). Curved lines indicate covariance between variables. TFB = task-focused behaviour, ATS = attitude towards school. Grade: 5th vs. 3rd grade, gender: girls vs. boys, and classroom type: open learning space vs. conventional classroom. Comparative fit index: 0.977; standardized root mean square residual: 0.079.

6 DISCUSSION

This study aimed to provide evidence for the hypothesis suggesting that open and flexible classroom designs are associated with less classroom-based sedentary behaviour and more physical activity among primary school aged children. Another aim of this dissertation was to investigate teachers' instructions on students' movement, whether the ways in which teachers integrate movement into general educational classroom time influence the forms, intensities, and volume of accumulated physical activity in classroom spaces with different design. Moreover, as both classroom space as well as classroom-based physical activity may influence a student's engagement with school, potential associations between student engagement, classroom type and physical activity were investigated. Overall, the dissertation aimed to contribute to current knowledge about the role of design of learning space with a specific focus on classroom-based physical activity, physical activity related to teachers' instructions and school engagement.

6.1 Classroom-based sedentary behaviour and physical activity

6.1.1 Main effect of classroom type

The main findings of the present study regarding the role of classroom type on physical activity indicated that open learning spaces were associated with more breaks from sedentary time, more 1-to-4–minute sedentary bouts, fewer sedentary bouts over 10 minutes, and more sit-to-stand transitions than conventional classrooms. Furthermore, active bouts were shorter in open learning spaces compared to conventional classrooms. Together with previous findings (Brittin et al., 2017; Kariippanon, Cliff, Okely et al., 2019), these results suggest that classrooms with open and flexible design and furniture may facilitate short activity bursts during lessons, and where sedentary time is accumulated in shorter bouts with more frequent breaks from sedentary time, and more postural transitions. Previous studies have explained this facilitation of shorter sedentary bouts by both affordances provided by the classroom design and student-centred approaches which together provide students opportunities to choose where and how to work in the classroom space (Kariippanon, Cliff, Lancaster et al., 2019; Reinius et al., 2021; Saltmarsh et al., 2015).

Accumulation of fewer sedentary bouts that are more than 10 minutes may provide health benefits based on the prior literature, indicating associations between accelerometer-derived sedentary bout length and cardiovascular disease risk factors in adult populations (Kim et al., 2015). In children with a family history of obesity, breaks in sedentary time and the number of sedentary bouts lasting 1 to 4 minutes have been associated with reduced cardiometabolic risk score and lower BMI Z-score in both boys and girls, whereas the number of sedentary bouts lasting 5 to 9 minutes have been negatively associated with waist circumference in girls only (Saunders et al., 2013). The number of sedentary bouts lasting 10 to 14 minutes have been documented to be positively associated with fasting glucose in girls, and with BMI Z-score in boys (Saunders et al., 2013). Therefore, based on prior literature, reducing sedentary bout durations with increased breaks from sedentary may confer health benefits over the longer term.

Despite breaking up sedentary time, open learning spaces were associated with more total sedentary time among fifth-grade students compared to conventional classrooms in both studies I and II. This finding suggests that sedentary time may be higher in open learning spaces, although sedentary time is accumulated in shorter bouts as was observed in Study IV. These findings somewhat diverge from previous research (Brittin et al., 2017; Kariippanon, Cliff, Okely et al., 2019), reporting that students have less sedentary time in classrooms with open and flexible designs. The divergence from previous studies reporting a decrease of sedentary time may be related to differences in study design, such as prior studies including sedentary behaviour and physical activity in outdoor environments and recess or experimentally enabling students to move around during lessons (Brittin et al., 2017; Lanningham‐Foster et al., 2008).

The present findings may also be explained at least to some extent by our findings of systematic observation of teacher instructions related to movement, which indicated that in the school with open learning spaces the fifth-grade teachers were more restrictive towards students' movement in the classroom compared to other schools. Restrictive instructions were associated with less light intensity physical activity and fewer breaks from sedentary time. This teachers' restrictive guidance contradicts our hypotheses that open learning spaces would facilitate more student-centred pedagogy and higher student autonomy over movement and interaction with other students in the classroom (Kariippanon, Cliff, Okely et al., 2019; Kariippanon, Cliff, Lancaster et al., 2019; Saltmarsh et al., 2015). The findings related to teachers' instructions on student movement are discussed more thoroughly in separate section (see section 6.2).

6.1.2 Gender- and grade-related associations

As both age and gender of students have been associated with levels of physical activity in and out of school time (Grao-Cruces et al., 2020; Salin et al., 2019; Trost et al., 2002; van Stralen et al., 2014), effects if gender and grade on classroom-based physical activity and sedentary behaviour were investigated. Average sedentary time was higher and average light intensity physical activity was lower among girls than boys in fifth grade, while among third-grade students' similar gender-related differences were not observed. Third-grade students were more physically active than fifth graders, and boys were more physically active than girls. The findings suggested some gender and age-specific effects. Boys had less moderate-to-vigorous physical activity in open learning spaces compared to conventional classrooms. Fifth-grade girls had more sedentary bouts longer than 10 minutes than third-grade girls did.

The findings concerning differences by age were consistent with previous studies (Grao-Cruces et al., 2020; Mooses et al., 2017; Salin et al., 2019; Trost et al., 2002; van Stralen et al., 2014). Differences between third- and fifth-grade students' classroom-based sedentary behaviour may be related both to age-related decline in levels of overall physical activity, but also to potential pedagogical differences in lessons conducted in classrooms of third- and fifth-grade students. Age-related decline in overall physical activity levels assessed with accelerometery-based studies has been observed in Finnish studies at the age of school entry around age of seven years and continuing through adolescence (Jussila et al., 2022; Lounassalo et al., 2019). Another possible explanation for differences between third- and fifth-grade students in classroom physical activity concerns increased academic demands from Grade 3 to Grade 5, which may cause teachers to implement learning activities that increase the sedentary time of students by age. Maturity status may explain some differences between boys and girls as the influence of maturity on physical activity levels may be mediated by changes in self-perceptions that originate from the biological and psychosocial changes during maturation (Fairclough & Ridgers, 2010). For example, during recess boys and girls tend to engage in different activities, with boys favouring more intensive and competitive activities and girls preferring socializing with friends (Blatchford et al., 2003), and it is possible that the different activity preferences of boys and girls manifest during classroom time as well. These findings suggest that interventions aiming to reduce sedentary behaviour in school setting should consider the individual preferences of students. Interventions should also aim to pay attention to the teacher's pedagogical choices with respect to the use of breaks in sedentary behaviour and the integration of physical activity into classroom work.

6.1.3 Differences between types of school in classroom-based sedentary behaviour and physical activity

Differences between three schools participating in the CHIPASE project were investigated to examine whether differences emerge in classroom-based sedentary behaviour and physical activity between schools irrespective of the design of classroom spaces. The results indicated that most of the significant differences were found between schools with different classroom designs and there were only small and mostly statistically nonsignificant differences between the two schools with conventional classrooms.

Students attending the fifth grade in school A with open learning spaces were found to manifest sedentary activity and less moderate-to-vigorous intensity physical activity than their counterparts in other schools, but the differences were statistically significant only between schools A and C. For third-grade students, sedentary time, light, and moderate-to-vigorous intensity physical activity did not differ statistically significantly between schools. As suggested above, this finding may be explained by fifth-grade teachers being more restrictive of students' movement in school A with open learning spaces than the teachers in the two other groups while no between-school differences emerged in third-grade teachers' instructions regarding movement.

Students in the school with open learning spaces had more breaks from sedentary time than third- and fifth-grade students in conventional schools and they also had more 1-to-4–minute sedentary bouts. In addition, fifth-grade students in school A had fewer sedentary bouts of more than 10 minutes than did students in school B, while differences between schools A and C or B and C were not significant. Third-grade students in school A had more sit-to-stand transitions than did students in school C and there was also a significant difference between schools B and C with more sit-to-stand transitions. In fifth-grade students, no differences were observed in sit-to-stand transitions between schools.

These findings are in line with previous findings that open and flexible learning spaces may facilitate shorter sedentary bouts, but fifth-grade teachers' restrictive instructions may hinder potential benefits. Although school-level policies and teacher's individual pedagogical practices may influence the accumulation and breaking up of sedentary time (Michael et al., 2019), the present dissertation suggests that the type of classroom design (open vs. conventional spaces) seems to exert a greater influence than the school on classroom-based sedentary behaviour variables. Conversely, the accumulation of different physical activity intensities may need more support from teachers and school-level policies.

6.2 Results of systematic observation

Systematic observation was used in this dissertation to capture teachers' instructions on student movement independently from the assessment of movement of the students. Because the affordances for the classroom-based physical activity and typical pedagogical approaches are believed to be associated with the design of learning spaces (Attai et al., 2021; Kariippanon et al., 2021), it was hypothesised that teachers in open learning spaces may provide more freedom of movement. Teachers in conventional classrooms were expected to facilitate classroom-based physical activity with teacher-led physical activity breaks because approximately half of the Finnish classroom teachers have reported utilizing physically active teaching methods and 65% of teachers report aiming to break up the time spent sitting in all or almost every lesson in Finland (Kämppi et al., 2018).

The present result indicated that the prevalence of teacher instruction categories differed between schools and grades. In contrast to our expectation in school A with open learning spaces, fifth-grade teachers were more restrictive of students' movement in the classroom than they were in the schools with conventional classrooms. Similar differences were not observed among third-grade teachers. The reasons remain unclear why teachers might limit students' physical activity more in open learning than in conventional spaces.

The higher numbers of students in a single space in open learning spaces, typically between 40 to 100 students depending on the number of teachers in a teaching team (Niemi, 2021), and the potential specific features related to organizing learning in open learning spaces may pose challenges for successful movement integration (Michael et al., 2019). Higher total sedentary time observed in open learning spaces may be related to teaching methods used by the teachers. For instance, if a larger number of students are being taught simultaneously in the same large learning space, the teachers may need to restrict students' movement to create a quiet learning setting as open classrooms have been observed to be susceptible to noise (Mealings et al., 2015).

Orchestration of the flexible affordances, co-teaching, and planning, and the push for renewed pedagogical methods set high demands for teachers' adaptation, and pedagogy has not necessarily changed to the extent that physical learning spaces have changed. Open learning spaces challenge teachers to balance facilitating autonomous student learning and managing shared spaces and resources in their pedagogical practice (Saltmarsh et al., 2015). Even though a few years had passed since indoor renovation of school at the time the observational data was collected, teachers might not have gone through in-depth pedagogical transformation yet (Gislason, 2018), and they could still have deficiencies in skills for manipulating the environment (Campbell et al., 2013). Therefore, it should be noted that the redesign of learning environments affects not only the spaces, but it challenges teachers' pedagogical approaches and presupposes changes in their and students' interactional roles. The open learning spaces, such as those in school A, require continuous planning and implementation of team teaching and scaffolding of student collaboration, shared and self-regulated and digitally mediated learning taking place in parallel in several spaces and the guidance of students' small groups with relatively high student autonomy at times. Thus, the share of teacher-directed time for whole class activity constitutes a smaller percentage of learning time than in conventional classrooms.

Potential barriers for movement integration may also include institutional factors, such as administrative support, the availability of resources or the lack of time devoted for movement integration (Michael et al., 2019). In addition, teachers' intrapersonal factors, such as training and the motivation for movement integration, implementation challenges and personal perceptions of the value of physical activity have their own influence on how much teachers integrate physical activity into academic lessons (Michael et al., 2019). School-level policies or teachers' personal views were not assessed directly in the present study, but the systematic observation used in this dissertation provides some information on the extent to which school-level culture and pedagogical solutions provide opportunities for students to engage in classroom-based physical activity. Our observations in 15 classrooms showed that teachers' instructions prohibited student movement from 51% to 99% of the observed classroom time, which illustrates that teachers provide students with possibilities to be physically active to a very different extent. This finding is in line with previous reports indicating that approximately half of the classroom teachers utilize physically active teaching methods (Kämppi et al., 2018).

Teachers in schools B and C with conventional classrooms tended to promote classroom-based physical activity with teacher-organized activity breaks more than teachers in school A with open learning spaces. Both third- and fifth-grade teachers in school A, on the other hand, organized a high number of transitions compared to teachers in schools with conventional classrooms. There were differences even within a school and grade level in the prevalence of different categories of systematic observation. Because the integration of movement in lessons might take multiple forms, such as physically active transitions and physically active breaks (Russ et al., 2017), different approaches can be used in the promotion of classroom-based physical activity. Some teachers might choose to break up sedentary time to support students' attention by using transitions to serve academic purposes, whereas some teachers might seek to promote classroom-based physical activity with active breaks with or without curriculum content, depending on their personal views on classroom-based physical activity.

Less restrictive instructions and more freedom of movement were associated with more light intensity physical activity. More teacher-led physical activity was associated with more moderate-to-vigorous physical activity, whereas directed transitions and teacher-led physical activity were associated with the higher number of breaks from sedentary time. To a lesser extent, directed transitions and more teacher-led physical activity were associated with longer active bouts, and fewer transitions were associated with longer sedentary bouts. Active bouts were negatively associated with teacher-directed transitions but positively associated with organized physical activity. While direct association were not found between teachers' instructions and sedentary time, less restrictive instruction of student movement and teacher-organized physical activity were linked to a higher prevalence of breaks from sedentary time and moderate-to-vigorous physical activity. These findings indicate that more freedom of movement and organized transitions can increase accumulated light intensity physical activity and breaks from sedentary time while teacher-led activities increase moderate-to-vigorous intensity physical activity of students. Thus, organized physical activity may be the most effective way to promote moderate-to-vigorous intensity physical activity and longer activity bouts during lessons. Directed transitions, on the other hand, seem to reduce sedentary bout durations.

6.3 School engagement

Some of the goals of designing open learning spaces is to allow and foster student collaboration, self-regulated learning, and autonomy (Saltmarsh et al., 2015). Therefore, it can be presumed that students in these spaces may be more inclined than in conventional classrooms to experience emotional engagement as indicated by a positive attitude towards school and higher task motivation (i.e., task-focused behaviour). An association was found between classroom type and students' self-reported attitude towards school favouring open learning environments, but the association between classroom type and task-focused behaviour was not significant. Attitude towards school, was associated with task-focused behaviour, which supports the interrelatedness of these dimensions reflecting school engagement and motivation (Fredricks et al., 2004). These findings suggest that classroom design in itself does not have direct strong links with students' task-focused behaviour which may be influenced indirectly via attitude toward school as behavioural and emotional engagement have been shown to be related bidirectionally (Li & Lerner, 2013).

Classroom-based physical activity was not associated with task-focused behaviour or attitude towards school. This finding contradicts our hypotheses and previous findings that have suggested that students who are physically active in the classroom are more engaged in their classroom lessons (Mavilidi et al., 2020; Vazou et al., 2012; Watson et al., 2017). This contradictory finding may be related to different approaches in studies with respect to classroom-based physical activity as it can take multiple forms such as active breaks with or without curriculum content and physically active lessons (Watson et al., 2017). Therefore, suggested associations between classroom-based physical activity and school engagement may be related to the promotion of different types of classroom-based physical activity rather than sheer total amount of classroom-based physical activity. Furthermore, classroom-based physical activity with curriculum links may be more beneficial to school engagement than active breaks without curriculum content (Sneck et al., 2022). Although the dimensions of school engagement, emotions, behaviours, and cognitions are considered to be interrelated, they are typically assessed as separate constructs, and it is possible that different types, intensities, and frequencies of physical activity are beneficial for different dimensions of school engagement (Owen et al., 2016, 2018).

6.4 Strengths and limitations

The studies included in the doctoral dissertation have several strengths as well as limitations, which should be considered when interpreting the present results. The strengths of the present dissertation include a design allowing analysis of differences in classroom-based sedentary behaviour and physical activity by accelerometer-based measures. The assessments were conducted in authentic classroom settings where teaching methods were not experimentally altered. This approach enabled estimation of associations of classroom type (open space design vs. conventional) on classroom-based sedentary behaviour and physical activity in real life conditions. The combination of systematic observation and accelerometer-based measures allowed investigation of the extent to which teachers' instructions were different between schools and the extent to which teacher instructions regarding students' movement influenced the accumulation of classroom-based physical activity. This statistical approach allowed analysis of potential associations of students' gender and grade-level on classroom-based sedentary behaviour and physical activity. Potential differences between schools, in addition to classroom type, were also investigated. The mean amplitude deviation -method used for assessing accelerometer data in this study has showed widely documented validity and reliability across different accelerometer brands, and it has been used previously in studies with primary school-aged children in Finland (Aittasalo et al., 2015, Husu et al., 2019; Vähä - Ypyä, Vasankari, Husu, Suni et al., 2015, Vähä - Ypyä, Vasankari, Husu, Mänttäri et al., 2015).

Main limitations of this set of studies include, first, the cross-sectional nature of the studies included in the dissertation, which excludes confirmation of any causal relationships between the assessed variables, and second, the inclusion of only one school with open learning spaces, which limits the generalizability of findings of this dissertation. The prevalence of different special education needs among the students was not accessed, which could have influenced the instructions provided by the teacher and thereby the classroom-based physical activity.

School-level physical activity policies were not assessed directly, but all three schools participated in the national action programme, Finnish Schools on the Move, aiming to establish a physically active culture in Finnish comprehensive schools. Approximately 90% of Finnish primary schools and 95% of pupils are involved in this programme (Blom et al., 2018). As schools and municipalities participating in the programme implement their own plans to enhance physical activity during recess and academic lessons (Blom et al., 2018), there may be some differences in the activities performed during the school week which were not controlled in this study. Some schools may choose to focus on promoting physical activity in alternate settings including recess activities, physical education lessons or active commuting to school (Blom et al., 2018; R. Carson & Webster, 2020; McMullen et al., 2015). Furthermore, teachers' personal experiences, values regarding physical activity promotion in a classroom setting and skills in implementing the goals of the programme were not assessed, which may limit possibilities to generalize findings derived from systematic observation.

Students' personal views of classroom-based physical activity and learning spaces were not assessed in this dissertation. Therefore, evaluation of how much students' personal agency influences the accumulation of classroom-based physical activity could now be assessed. Some studies have suggested that students in flexible learning spaces engage more in collaborative learning activities, such as working in pairs or small groups, and they incorporate mobility into their own learning activities and practice agency by choosing how, where and with whom they like to work (Reinius et al., 2021). Furthermore, flexible learning spaces have been reported by students to be more enjoyable, comfortable, and inclusive (Kariippanon et al., 2018). Thus, although the design of the classroom provides affordances for movement and for teachers to incorporate physical activity in their classroom instruction to allow students to be physically active, the students themselves might choose not to be physically active. Based on the literature documenting the strong motivational effect of being able to exert personal influence over one's own behaviours and environment through self-reflective and cognitive self-regulatory processes (Bagozzi, 1992; Bandura et al., 1999), it can be presumed that open learning spaces and the concomitant employment of student-centred pedagogy may increase students' sense of autonomy, thereby facilitating classroom-based physical activity. However, it entirely possible that autonomy may manifest also as increased sedentary behaviour of students.

In all observational studies, a conceivable limitation is posed by the Hawthorne effect (i.e., subjects who know they are being observed might behave differently), therefore affecting study outcomes. To overcome this potential bias researchers visited the school during the recruitment phase to familiarize themselves with the participating students and their teachers. During the measurement week, as many lessons as possible were observed and details of focus of observation were not revealed to participating students and teachers. Students and teachers did not know which student was being observed at any given time and exact details of the observational protocol, including categories of codes, were not revealed to either students or teachers. Because the participants were recruited on a voluntary basis, a possible limitation is that the volunteers were not completely representative of the whole populations within the specific schools (Hernán et al., 2004). It is possible that the volunteer students were more or less physically active than those who did not participate in the study.

6.5 Methodological issues

This section discusses various methodological issues that can be raised concerning the study design and methodological choices. The current results need to be interpreted against critical evaluation of the methodological choices made. The methodological issues to be discussed include operationalization of accelerometery-based measures, development of coding and the implementation of systematic observation, assessment of school engagement and chosen statistical analysis methods.

There are currently vast possibilities for defining accelerometery-based measures for sedentary behaviour and physical activity (Altenburg & Chinapaw, 2015; Migueles et al., 2022). The first issue regarding operationalization of accelerometer-based measures is that fixed, intensity-based cut-points (Vähä-Ypyä, Vasankari, Husu, Suni, et al., 2015; Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015) were used in this dissertation. Even though cut-points used previously in studies conducted in Finnish children (Husu et al., 2019) were applied, these cut-points have only been validated against certain tasks (Vähä-Ypyä, Vasankari, Husu, Suni et al., 2015) or with oxygen consumption as indicator for energy expenditure in adults (Vähä-Ypyä, Vasankari, Husu, Mänttäri et al., 2015). Furthermore, absolute and fixed measures of physical activity underestimate the intensity of physical activity in children with lower peak oxygen uptake, oxygen uptake at the ventilatory threshold and motor competence (Haapala, Gao, Hartikainen et al., 2021). It has been suggested that fixed accelerometery cut- points used for defining physical activity intensities should be adjusted for age, sex, body size, and body composition (Haapala, Gao, Rantalainen et al., 2021). There is currently no established methodology to produce individualized cut-points without laboratory measurements in field studies, although the use of self-paced running promises to provide a novel and practical method for determining individualized vigorous intensity physical activity cut-points in children (Haapala et al., 2020).

Another consideration regarding the validity and reliability of accelerometer-based measures is that an epoch length of 15 seconds was used for analysis. Choice of epoch length may influence the results obtained from accelerometer data as children's total time in sedentary behaviour and moderate-to-vigorous intensity physical activity decreases when longer epochs are used because time accumulated in bouts of sedentary behaviour and moderate-to-vigorous physical activity accumulated in bouts increases (Altenburg et al., 2021).

Sedentary behaviour was defined in this dissertation to include all stationary and sedentary behaviours without bodily movement based on accelerometery measures (SBRN, 2012). Waist-worn accelerometers underestimate the intensity of activities that are conducted without ambulatory movement of the whole body and therefore underestimate intensity of tasks conducted mainly with the hands or legs (Arvidsson et al., 2019; van Loo et al., 2017). Thus, it is possible that an open learning space facilitates activities that accelerometers are unable to detect. These types of activities may include teacher organized activities, which comprises tasks like balancing or standing behaviours typical to arts lessons where hands are used to accomplish tasks without movement of the whole body.

There is also a possibility for some inaccuracy in the reporting of daily schedules by teachers and inaccurate reporting of diaries by students, that may affect our analysis. Especially recess transitions in and out of the classroom may have variable amounts of moderate-to-vigorous intensity physical activity, and these transitions need to be better monitored in further studies. This inaccuracy is likely to have been similar before and after the renovation in school A in Study I and across the three schools in studies II, III and IV.

The main issue concerning the evaluation of validity of the observation tool used in this dissertation is that it does not capture contextual information on student movement. Therefore, more studies using such instruments (e.g., the System for Observing Student Movement in Academic Routines and Transitions; Russ et al., 2017), are warranted. Although inter-observer reliability was ascertained during the preliminary testing phase, and observers were required to pass a written exam to participate in data collection, inter-observer reliability should also have been confirmed during assessments, for example, by observing a proportion of the same student during the same lesson by several observers. Because observers could only observe a limited number of lessons, this stricter form of inter-rater reliability assessment could not be assessed. Furthermore, as only direct verbal instructions regarding students' movement were observed and coded, possible rules or restrictions regarding the students' use of space, furniture and learning materials, which in turn could influence the accumulation of classroom-based physical activity could not be separately identified.

A potential limitation concerning our school engagement model is that it did not include the assessment of constructs capturing cognitive or agentic engagement (Christenson et al., 2012; Fredricks et al., 2004). Our choice to use a self-report questionnaire measure is a standard procedure but it necessarily relies heavily on children's abilities to answer questions regarding their engagement. Additionally, information was not collected on participants' potential special needs or learning impairments, such as attention deficit hyperactivity disorder, which influence academic achievement and potentially also school engagement (Rushton et al., 2020). Our structural equation model did not include a measure of family or school-level socioeconomic status, which could have been an alternative option as associations of socioeconomic status and academic achievement rather than school engagement have often been the focus of prior studies (Broer et al., 2019).

A limitation regarding our statistical analysis was that it did not take into account the clustering of students within classes because our sample size was limited to 15 classes, and methods including multi-level structural equation modelling typically require 30 to 50 groups (Hox & Maas, 2001). Furthermore, due to the small sample size, each physical activity intensity category was analysed separately. A larger sample size would have allowed us to use compositional analysis and enabled investigation of the physical activity spectrum as a whole (Chastin et al., 2015). Time spent in different movement behaviours are intrinsically collinear and co-dependent during a selected time period, i.e. during lessons or within a 24-hour period, and compositional analyses can be used to overcome the limitations of traditional regression models (Chastin et al., 2015). Our relatively small sample size limits the generalization of results and therefore studies with larger samples are warranted. Finally, results for classroom-based sedentary behaviour or physical activity were not controlled for possible influence of weight, body fat content, or anthropometry on classroom-based sedentary behaviour, because such a procedure is not commonly applied in epidemiological settings. However, it needs to be acknowledged that children with overweight have been observed to spend significantly less time in moderate-to-vigorous intensity activities than do children with normal weight (van Stralen et al., 2014).

6.6 Conclusions and recommendations for further studies

Based on findings of this dissertation, schools with open learning spaces facilitate shorter sedentary bout durations as well as more breaks from sedentary time and postural transitions, which may translate into potential health benefits over the longer term (Saunders et al., 2013). In contrast to the finding that showed a higher extent of breaking up sedentary time, open learning spaces were associated with more total sedentary time among fifth-grade students compared to students in conventional classrooms. Open learning spaces may promote the emotional aspects of school engagement, which may also have beneficial effects on other dimensions of school engagement.

Current evidence is limited in providing a conclusive answer regarding the extent to which breaking up prolonged sedentary behaviour in school settings provides associated health benefits. Therefore, future studies should investigate whether and to what extent breaking up sedentary time in school settings provides the suggested health benefits. The gender and grade level (or age) of participants both influence the amount of accumulated classroom-based physical activity and possible explanations for these associations should be investigated in future studies. Moreover, interventions should seek to promote especially physical activity among girls during the later school years as they seem to be the most sedentary in classroom settings.

The findings on more total sedentary time among fifth-grade students may be partly explained by the results of observational coding indicating that teachers' restrictive instructions on students' movement were more prevalent in fifth-grade classrooms with open learning spaces. These findings highlight the importance of teacher professional development for promoting classroom-based physical activity in open learning spaces. Future studies should seek to investigate (e.g., by combining observational data and teacher interviews) and develop teacher practices to capitalize on the potential of open classrooms to reduce sedentary time.

It is acknowledged that classroom renovation where conventional spaces are transformed into open learning spaces may not alone be a sufficient intervention to produce a new kind of pedagogy and instructional practices aligning with the affordances of the more interactive spaces. Barriers of movement integration and school policies on physical activity should be assessed and developed to capitalize on the affordances of open learning spaces also with respect to increasing and integrating physical activity into lessons. Teachers' aims to incorporate physical activity into general education classroom time may be crucial for limiting the sedentary behaviour of students and especially for promoting moderate-to-vigorous intensity physical.

Even though the total amount of classroom-based physical activity was not associated with school engagement in this dissertation, the promotion of classroom-based physical activity in any form may be important to support students' engagement at school (Owen et al., 2016; Sneck et al., 2022; Watson et al., 2017). Future studies should seek to utilize especially classroom-based physical activity which is integrated with curriculum content to support both school engagement and academic achievement. Increased student engagement is likely to have potential benefits on academic achievement over the longer term. Longitudinal studies are warranted to investigate the co-development of school engagement and academic achievement in conjunction with physical activity and breaks from sedentary activity integrated into the school day.

Longitudinal studies utilizing randomized controlled trials as well as natural observational studies are warranted. There is a crucial need for interdisciplinary research which seeks to capture and analyse holistically interactions between factors related to physical spaces and the pedagogical approaches. Therefore, studies utilizing both quantitative and qualitative methods are needed. This is important because physical aspects of learning spaces do not influence sedentary behaviour alone but exert their influence together with factors related to the school culture and pedagogical solutions (Deed et al., 2020; Michael et al., 2019). Future studies should also investigate potential school-level policies and potential teachers' intrapersonal factors, such as their perceptions of value of physical activity (Michael et al., 2019).

YHTEENVETO (SUMMARY IN FINNISH)

Paikallaanolo, fyysinen aktiivisuus ja kouluun kiinnittyminen avoimissa ja perinteisissä luokkatiloissa.

Tutkimuksen tausta ja tavoitteet

Lasten ja nuorten fyysisen passiivisuuden ja paikallaanolon määrän on todettu olevan huolestuttavan korkealla tasolla niin koulupäivän kuin koko vuorokauden aikana (Bailey ym., 2012; Grao-Cruces ym., 2020; Harrington ym., 2011; Husu ym., 2019; Nettlefold ym., 2011; van Stralen ym., 2014). Pitkillä passiivisesti vietetyillä ajanjaksoilla ja liikkumattomuuteen liittyvän passiivisuuden kokonaismäärällä on havaittu olevan negatiivinen yhteys lasten ja nuorten terveyteen (V. Carson ym., 2016; Saunders ym., 2013). Fyysisellä aktiivisuudella on puolestaan havaittu olevan positiivinen yhteys lasten ja nuorten fyysiseen ja psyykkiseen terveyteen (Biddle ym., 2019; I. Janssen & LeBlanc, 2010; Poitras ym., 2016), tiedolliseen toimintaan (Verburgh ym., 2014) ja oppimistuloksiin (Bedard ym., 2019). Oppituntien aikaisella fyysisellä aktiivisuudella on osoitettu olevan yhteyksiä myös muihin koulumenestykseen liittyviin tekijöihin, kuten esimerkiksi kouluun kiinnittymiseen ja tehtäväsuuntautuneeseen käyttäytymiseen (Goh ym., 2016; Mavilidi ym., 2020; Watson ym., 2017).

Erilaisia viitekehyksiä on kehitetty edistämään oppilaiden koulupäivän aikaista fyysistä aktiivisuutta, sillä kokonaisvaltaisen ja koulupäivän aikaisen fyysisen aktiivisuuden merkitys lasten ja nuorten hyvinvoinnille on laajalti tunnustettu (World Health Organisation & UNESCO, 2021). Fyysistä aktiivisuutta on pyritty edistämään interventioilla, joissa toimenpiteet on kohdistettu monitahoisesti koulupäivän aikaiseen liikkumiseen, fyysisesti aktiivisiin koulumatkoihin ja liikunnan järjestämiseen ennen ja jälkeen koulupäivän (Blom ym., 2018; R. L. Carson & Webster, 2020; McMullen ym., 2015). Liikunta- ja välituntien lisäksi koulupäivän aikaisen fyysisen aktiivisuuden edistämisessä on kiinnitetty huomiota myös luokkahuoneessa tapahtuvaan vuorovaikutukseen ja toimintaan opetuksen aikana (Webster ym., 2015). Oppituntien aikaista paikallaanoloa on pyritty vähentämään fyysisesti aktiivisin opetusmenetelmin (Riley ym., 2016), järjestämällä liikunnallisia taukoja (Ma ym., 2015; Mahar ym., 2006) ja organisoimalla siirtymiä (Russ ym, 2017) oppituntien aikana. Nämä opettajalähtöiset lähestymistavat ovat kuitenkin riippuvaisia opettajien motivaatiosta, taidoista, käytettävissä olevasta ajasta sekä tila- ja välineresursseista (Michael ym., 2019; Rossi ym., 2016). Tila- ja kalusteratkaisut voivatkin rajoittaa opettajien mahdollisuuksia oppilaiden fyysisen aktiivisuuden edistämisessä (Michael ym., 2019).

Tiloihin ja kalusteisiin kohdistuvat fyysisen aktiivisuuden interventiot ovat osoittaneet lupaavia tuloksia (Ucci ym., 2015). Esimerkiksi seisomapöytien käytön on havaittu vähentävän istumista (Hegarty ym., 2016) ja joustavien ja helposti muokattavissa olevien tilojen ja kalusteiden on havaittu lyhentävän istuen vietettyjä ajan jaksoja (Kariippanon ym., 2019a). Fyysistä aktiivisuutta tukevien tilaratkaisujen on havaittu vähentävän passiivisesti vietettyä kokonaisaikaa ja lisäävän fyysisesti passiivisen ajan tauottamista (Brittin ym., 2015, 2017). Tila- ja kalusteratkaisuihin perustuvat interventiot ovat kuitenkin kalliita ja hankalia toteuttaa, joten niiden laajamittainen hyödyntäminen on haasteellista.

Koulujen avoimet ja joustavat tila- sekä kalusteratkaisut ovat yleistyneet kansainvälisesti koulutusuudistusten seurauksena (Land & Jonassen, 2012; Prain ym., 2015; Saltmarsh ym., 2015) samanaikaisesti kuin oppituntien aikaiseen fyysiseen aktiivisuuteen on kiinnitetty enenevissä määrin huomiota (Webster ym., 2015). Myös Suomessa on viimeisimmän perusopetuksen opetussuunnitelman perusteiden voimaantulon (Perusopetuksen opetussuunnitelman perusteet, 2014) myötä enenevässä määrin remontoitu ja uudisrakennettu koulujen tiloja avoimiksi ja joustaviksi oppimisen tiloiksi (Niemi, 2021; Reinius ym, 2021). Opetussuunnitelman näkökulmasta vuorovaikutusta houkuttavat ja sallivat tilat voivat tukea ilmiö- ja oppijakeskeisiä opetusmenetelmiä (Arvaja ym., 2020; Attai ym., 2021; Kariippanon ym., 2018). Avoimiin ja joustaviin tiloihin liitettyjen oppijakeskeisten opetusmenetelmien, kuten projektimaisen tutkivan työskentelyn (Blumenfeld ym., 1991) ja eriytettyjen ohjeistuksien (Tomlinson, 2014), ajatellaan edesauttavan ja lisäävän oppilaiden vertaistyöskentelyä, itseohjautuvaa oppimista ja myös mahdollisuutta liikkua oppitunnin aikana (Kariippanon ym., 2021; Saltmarsh ym., 2015).

Fyysisen aktiivisuuden, opetustilojen suunnittelun ja toteutettujen tilaratkaisujen, pedagogiikan ja koulumenestykseen vaikuttavien tekijöiden, kuten kouluun kiinnittymisen, välisiä yhteyksiä on pyritty tutkimaan, mutta toistaiseksi tutkimustieto aiheesta on vielä vähäistä (Kariippanon ym., 2021). Aikaisemmat tutkimukset, jotka ovat tarkastelleet tila- ja kalusteratkaisujen yhteyksiä oppilaiden fyysiseen aktiivisuuteen, ovat selvittäneet oppijakeskeisten (Kariippanon ym., 2019a) tai fyysistä aktiivisuutta tukevien (Lanningham-Foster ym., 2008) opetusmenetelmien käyttöä uusituissa tiloissa. Aiemmat tutkimukset ovat myös käsitelleet sisä- ja ulkotilojen vaikutusta yhdessä koko koulupäivän aikaiseen fyysiseen aktiivisuuteen (Brittin ym., 2017). Suomalaisessa kontekstissa koulujen avoimista tilaratkaisuista toteutetut aiemmat tutkimukset (Niemi, 2016; Reinius ym., 2021) eivät ole käsitelleet näiden tilaratkaisujen mahdollisuuksia fyysisen aktiivisuuden näkökulmasta.

Vertaisvuorovaikutusta ja itseohjautuvaa oppimista tukevat luokkatilat muunneltavine kalusteratkaisuineen ja oppituntien aikainen fyysinen aktiivisuus voivat molemmat tukea oppilaiden kiinnittymistä koulunkäyntiin ja kouluun (Kariippanon ym., 2019b; Rands & Gansemer-Topf, 2017; Watson ym., 2017). Aiempi tutkimusnäyttö fyysisen aktiivisuuden (Mavilidi ym., 2020; Owen ym., 2016; Vazou ym., 2012; Watson ym., 2017) ja tilojen (Byers ym., 2018a; Imms & Byers, 2017; Kariippanon ym., 2019b; Rands & Gansemer-Topf, 2017) yhteyksistä esimerkiksi oppilaiden kouluun kiinnitymiseenpainottuu interventiotutkimuksiin ja näyttö autenttisista luokkahuoneiden tilanteista on vähäistä.

Tämän tutkimuksen ensimmäisenä tavoitteena oli selvittää avoimien ja perinteisten luokkatilaratkaisujen yhteyksiä oppilaiden fyysiseen passiivisuuteen ja aktiivisuuteen luonnollisessa tilanteessa, jossa opetusmenetelmiä ei ole kontrolloitu. Kiihtyvyysantureita käytettiin mittaamaan oppilaiden fyysistä aktiivisuutta oppitunneilla. Koska koulun toimintakulttuuri ja etenkin opettajien käytännöt voivat vaikuttaa oppilaiden koulupäivän aikaiseen fyysisen aktiivisuuden määrään (Deed ym., 2020; Michael ym., 2019; Russ ym., 2017), tutkimuksen toisena tavoitteena oli selvittää systemaattisella havainnoinnilla eroja opettajien fyysistä aktiivisuutta rajoittavissa ja tukevissa ohjeistuksissa avoimien ja perinteisten luokkatilojen välillä, sekä näiden ohjeistuksien yhteyksiä fyysisen aktiivisuuden eri intensiteettien määrään oppitunneilla. Tutkimuksen kolmantena tavoitteena oli selvittää luokkatilojen ja fyysisen aktiivisuuden yhteyksiä oppilaiden itsearvioituun behavioraaliseen ja emotionaaliseen kouluun kiinnittymiseen.

Aineisto ja mittausmenetelmät

Tämän neljästä osatutkimuksesta koostuvan väitöskirjan aineisto kerättiin osana kahta toisiinsa temaattisesti liittyvää ja ajallisesti perättäistä suurempaa tutkimusprojektia, joiden tavoitteena oli selvittää luokkatilojen yhteyksiä oppilaiden fyysiseen aktiivisuuteen, kouluun kiinnittymiseen ja opettajien oppilaiden liikkumiseen liittyviin ohjeistuksiin. Ensimmäinen osatutkimus (I) toteutettiin osana *Engaging and Physically Active School as a Collaborative Learning Environment* (EnAct) – projektia kerätyllä kiihtyvyysmittariaineistolla. Tällä poikkileikkausaineistolla selvitettiin eroja kolmas- ja viidesluokkalaisten oppilaiden oppituntien aikaisessa fyysisessä aktiivisuudessa ennen ja jälkeen kouluremontin, jossa luokkatilat remontoitiin avoimiksi luokkatiloiksi. Ensimmäisessä mittauspisteessä syksyllä 2015 oppilaat opiskelivat väistötiloissa parakkikoulussa, jossa luokkatilat olivat perinteisiä ja pulpetein varustettuja. Toisessa mittauspisteessä syksyllä 2016 oppilaat aloittivat ensimmäisen kouluvuoden avoimissa tiloissa, joissa oli käytössä helposti siirreltävät kalusteet ja tilaan sovitettu isompi oppilasmäärä sekä yhteisopettajuutta toteuttavat tiimit.

Muut kolme osatutkimusta (II-IV) olivat osa *Children's physical activity spectrum: daily variations in physical activity and sedentary patterns related to school indoor physical environment* (CHIPASE) – projektia, jossa oppilaiden oppituntien aikaista fyysistä aktiivisuutta mitattiin kiihtyvyysmittareilla, kouluun kiinnittymistä arvioitiin oppilaille tarkoitetulla kyselyllä ja opettajien ohjeistuksia liikkumisen suhteen havainnoitiin systemaattisesti oppitunneilla. Projektin aineistonkeruuseen osallistui kolmas- ja viidesluokkalaisia oppilaita kolmesta eri koulusta, joista yhdessä oli käytössä avoimet luokkatilat ja kahdessa muussa perinteiset luokkatilat kalusteineen.

Jyväskylän yliopiston eettinen toimikunta antoi puoltavan lausunnon EnAct-projektin tähän väitöskirjaan liittyvälle osatutkimukselle *(Students' physical activity, school engagement, motivation and academic achievement in modern and traditional school environments)* 25.9.2015. CHIPASE-projektille puoltava lausunto annettiin 29.5.2018. Molemmissa projekteissa tutkittavia ja heidän vanhempiaan tiedotettiin tutkimuksen kulusta ja heidän oikeuksistaan, muun muassa mahdollisuudesta vetäytyä tutkimuksesta missä vaiheessa tahansa ilman seuraamuksia. Tutkittavat ja heidän huoltajansa sekä osallistuvien luokkien opettajat antoivat kirjallisen luvan tutkimukseen osallistumiselle. EnAct-projektiin osallistui kokonaisuudessaan 220 oppilasta ja CHIPASE-projektiin 206 oppilasta. Koulujen rehtorit ja tarvittaessa kuntien koulutuksesta vastaavat toimihenkilöt antoivat oman suostumuksensa tutkimuksen toteuttamiselle.

EnAct-projektiin sisältyvän ensimmäisen osatutkimuksen lopullinen poikkileikkausaineisto koostui 130 oppilaasta, joista 41 kolmasluokkalaiselta ja 42 viidesluokkalaiselta kerättiin kiihtyvyysmittariaineisto syyslukukaudella 2015 ennen remonttia perinteisissä luokkatiloissa. Syyslukukaudella 2016 remontin jälkeen avoimissa tiloissa kiihtyvyysmittari aineisto kerättiin 19 kolmasluokkalaiselta ja 28 viidesluokkalaiselta. CHIPASE-projektiin sisältyvien osatutkimusten II-IV aineisto kerättiin vuosina 2018–2019.

Avoimet ja joustavat tilaratkaisut sisältävässä koulussa 70–80 oppilasta opiskeli suurimman osan oppitunneistaan omalle luokka-asteelleen varatussa isossa tilassa. Tämä tila oli varustettu helposti liikuteltavilla kalusteilla, jotka mahdollistivat tilan muokkaamisen erilaisia käyttötarkoituksia ja ryhmittelyjä varten. Kussakin tilassa oli erillinen hiljaiseen työhön varattu huone, mutta oppilailla ei ollut omaa itselleen varattua istumapaikkaa tai pulpettia. Avoimissa tiloissa kolme opettajaa toimi tiimiopettajuuden periaatteiden mukaan suunnitellen, opettaen ja arvioiden koko ryhmää yhteisvastuullisesti. Muissa kahdessa CHIPASE-projektiin osallistuneessa koulussa oli käytössä perinteiset luokkatilat, joissa jokaiselle oppilaalle oli varattu oma pulpetti tai työpiste. Näissä tiloissa yksi opettaja oli vastuussa 20–25 oppilaan ryhmästä.

Tutkimukseen osallistuvien luokkien oppilaat, jotka olivat antaneet suostumuksen osallistumiseen, osallistuivat luokkansa kera mittauksiin yhden kouluviikon aikana. Tutkimusviikon maanantaina oppilaiden saapuessa kouluun heille jaettiin kiihtyvyysmittarit pidettäväksi yhtäjaksoisesti mittausviikon ajan, sekä päiväkirja, jonka täyttäminen ohjeistettiin heille. Päiväkirjoihin kirjattiin mittarien pitoaikaan ja mahdollisiin koulupoissaoloihin liittyviä asioita. Lisäksi opettajilta pyydettiin luokkien lukujärjestykset, joiden perusteella tunnistettiin kiihtyvyysmittaritiedosta analysoitavat oppituntien ajanjaksot, joista esimerkiksi väli- ja liikuntatunnit jätettiin pois. Mittarien jakamisen yhteydessä CHIPASE-projektissa oppilailta mitattiin lisäksi pituus ja paino erillisessä tilassa (pituus kuljetettavalla pituusmitalla lähimpään 0,1 cm ja paino digitaalisella vaa'alla 0,1 kg tarkkuudella). Pituuden ja painon perusteella tutkittaville laskettiin ikä- ja sukupuolivakioitu painoindeksi (ISO-BMI) (Saari et ym., 2011). Mittausviikon aikana oppilaat täyttivät kouluun kiinnittymistä arvioivan-kyselyn, joka perustui aiemmin Suomessa käytettyyn kyselyyn (the Achievement Beliefs Scale for Children) (Aunola ym., 2013; Aunola & Nurmi, 2006; Kiuru ym., 2014) Tutkijaryhmän jäsenet havainnoivat opettajien toimintaa systemaattisella havainnointimenetelmällä. Mittausviikon lopuksi oppilailta kerättiin kiihtyvyysmittarit ja päiväkirjat. Tutkimusryhmä ei puuttunut mittausviikon opetuksen järjestämiseen millään tavalla.

Osatutkimuksessa I kiihtyvyysmittaus toteutettiin lantiolle kiinnitettävällä kiihtyvyysmittarilla (Gulf Coast Data Concepts X16-1, Waveland, USA), kun taas osatutkimuksissa II-IV kiihtyvyysmittarit (RM42, UKK Terveyspalvelut Oy, Tampere, Suomi) kiinnitettiin lantiolle ja reiteen. Kiihtyvyystiedon analysointiin sisällytettiin opettajien antamien lukujärjestysten ja oppilaiden päiväkirjojen perusteella luokkahuoneessa tapahtuvaan opetukseen käytetty aika. Ennen analyysin toteuttamista kiihtyvyysmittarin mittausdata tarkastettiin visuaalisesti jokaisen oppitunnin osalta erikseen. Kiihtyvyysmittausdata analysoitiin keskiamplitudipoikkeama-menetelmällä (Vähä-Ypyä ym., 2015a) käyttäen yhden sekunnin mittaisia analyysijaksoja käyttäen Tieteen tietotekniikan keskuksen - CSC:n supertietokonetta. Vyötäröltä mitatusta kiihtyvyysmittariaineistosta laskettiin 15 sekunnin liukuva keskiarvo käyttäen MATLAB R2018a-ohjelmistoa (The MathWorks Inc., Natick, MA, USA), joiden perusteella fyysinen aktiivisuus jaettiin paikallaanoloon, kevyeen fyysiseen aktivisuuteen ja kohtalaiseen sekä rasittavaan fyysiseen aktiivisuuteen. Paikallaanolon ja kevyen fyysisen aktiivisuuden erottavana raja-arvona oli 16,7 mg (Vähä-Ypyä ym., 2015b) ja kevyen ja vähintään kohtalaisen intensiteetin fyysisen aktiivisuuden raja-arvona oli käytössä 91 mg (Vähä-Ypyä ym., 2015a).

Eri fyysisen aktiivisuuden intensiteeteillä vietetty aika ja paikallaanoloaika laskettiin prosenttiosuutena oppitunneista koko viikon ajalta. Paikallaan vietetyn ajan tauotus huomioitiin, kun vähintään minuutin mittainen yhtäjaksoinen paikallaan olo keskeytyi ja tämä laskettiin taukoina jokaista luokkahuoneessa vietettyä tuntia kohden (Altenburg & Chinapaw, 2015; Saunders ym., 2013). Yhtäjaksoisesti paikallaan vietettyjen ajanjaksojen ja fyysisesti aktiivisten ajanjaksojen keskiarvojen lisäksi laskettiin paikallaan vietettyjen yhtäjaksoisten jaksojen määrät luokkahuoneessa vietettyä tuntia kohden 1–4 minuutin, 5–9 minuutin, 10–19 minuutin. 20–29 minuutin sekä yli 30 minuutin jaksoille (V. Carson ym., 2014). Fyysisen aktiivisuuden kokonaismäärä ja intensiteetti yhdistettiin yhdeksi muuttujaksi osatutkimuksessa III rakenneyhtälömallinnusta varten (Lindberg ym., 2018). Reiden etuosaan kiinnitettyä kiihtyvyysmittaria käytettiin tunnistamaan seisomaan nousut oppituntien aikana käyttäen tähän kehitettyä algoritmia (Löppönen ym., 2021). Seisomaannousujen määrä laskettiin luokkatilassa vietettyä tuntia kohden.

Opettajien antamia ohjeistuksia oppilaiden liikkumisen suhteen havainnoitiin systemaattisesti yhteensä 156 oppitunnilla. Kolme havainnoitsijaa koulutettiin tehtävään ja heidän tuli läpäistä kirjallinen koe ennen mittauksiin osallistumista. Oppitunnin aikana havainnoija seurasi yhtä oppilasta ja tähän kohdistuvia liikkumisen ohjeistuksia 20-sekunnin välein kirjaten havainnot internet-pohjaiseen Moveatis-sovellukseen (Jyväskylän yliopisto, Suomi). Sovelluksen kautta kirjattujen koodausten lisäksi havainnoijat kirjasivat luokkahuoneen tapahtumia erilliseen mittauspöytäkirjaan. Havainnointimenetelmä kehitettiin SOSMART-menetelmän (Russ ym., 2017) pohjalta ja havainnointikategoriat muokattiin kohdentumaan opettajan oppilaan liikkumista rajoittavaan ja mahdollistavaan toiminta. Opettajan toiminta jaettiin lopulta esitestauksen perusteella neljään kategoriaan, jotka esitetään seuraavassa lyhyesti pääpiirteissään: (1) *Opettaja ei mahdollista liikkumista*: Opettaja ei salli muuta liikkumista kuin käynnissä olevan tehtävän kannalta välttämättömän (esim. tehtäviään tarkastamisen tarkastuskirjasta); (2) *Opettaja ei rajoita liikkumista*: Opettaja antaa oppilaiden liikkua tilassa vapaasti ja vaihtaa paikkaa oman halunsa mukaan, eikä ohjaa lopettamaan liikkumista, (3) *Opettaja mahdollistaa fyysiset siirtymät:* Opettaja ohjeistaa siirtymän tehtäväpisteeltä toiselle tai tavaroiden noutamiset; (4) *Opettaja johtaa fyysistä aktiivisutta:* Opettaja mahdollistaa oppilaiden fyysisen aktiivisuuden esimerkiksi taukojumpan tai fyysisesti aktiivisten opetusmenetelmien avulla. Havainnointiaineistosta laskettiin eri opettajien ohjeistus kategorioiden esiintyvyysprosentteina havaintojen kokonaismäärästä oppilasryhmäkohtaisesti. Tuloksia vertailtiin luokka-asteittain kolmen eri koulun välillä, jotta pystyttiin selvittämään eroja koulukohtaisissa käytännöissä oppituntien aikaisen fyysisen aktiivisuuden tukemisessa.

Kouluun kiinnittymistä arvioitiin oppilaiden itsarviointiskaaloilla kohdentuen behavioraaliseen ja emotionaaliseen kiinnittymiseen. Behavioraalisen kouluun kiinnittymisen mittarina käytettiin itsearvioitua tehtäväsuuntautunutta käyttäytymistä, jota arvioitiin ABS-C-mittarilla (Aunola ym., 2013; Aunola & Nurmi, 2006; Kiuru ym., 2014). Oppilaille esitettiin seitsemän kysymystä liittyen heidän tyypilliseen käyttäytymiseensä ja suhtautumiseensa haastaviin koulutehtäviin. Asennetta koulunkäyntiä kohtaan käytettiin emotionaalisen kouluun kiinnittymisen mittarina, jota arvioitiin kolmella kysymyksellä liittyen tyypillisiin ajatuksiinsa koulunkäynnistä. Mittarien kysymysten yhdenmukaisuutta arvioitiin Cronbachin alfalla, joka oli 0,799 tehtäväsuuntautuneelle käyttäytymiselle ja 0,677 asenteelle koulunkäyntiä kohtaan.

Kuvaileva tilastoanalyysi toteutettiin Microsoft Excel-ohjelmistolla (Microsoft Corporation, Redmond, WA, USA). Tilastolliset vertailut toteutettiin joko SPSS 26-ohjelmistolla (IBM corp. Armonk, NY, USA) tai R-ohjelmistolla (R Core Team, Wien, Itävälta). Muuttujien normaalijakautuneisuutta arvioitiin kvantiilikuvioiden, histogrammien ja Sharpiro-Wilk-testin avulla ($p<.05$). Muuttujien varianssien homogeenisuutta arvioitiin graafisesti ja Levenen-testin avulla ($p<.05$). Tilastollisen merkitsevyyden raja-arvona käytettiin $p < .05$.

Osatutkimuksessa I käytettiin parittomien otosten t-testiä tai Mann-Whiney-testiä vertailemaan eri fyysisen aktiivisuuden intensiteettien ja paikallaan olon tauottamisen määrää ennen ja jälkeen remontin. Tilastolliset vertailut tehtiin erikseen kolmas- ja viidesluokkalaisille. Pienen otoksen vuoksi sukupuolta ei huomioitu tämän osatutkimuksen tilastollisissa vertailuissa.

Osatutkimuksissa II ja IV käytetiin kolmisuuntaista varianssianalyysiä selvittämään luokkatilojen, sukupuolen ja luokka-asteen yhteisvaikutuksia kiihtyvyysmittarilla mitattuihin oppitunninaikaisen fyysisen aktiivisuuden muuttujiin. Näissä tutkimuksissa koulujen väliset vertailut toteutettiin yksisuuntaisella varianssianalyysillä tai non-parametrisella vastineella. Osatutkimuksessa II vertailtiin opettajien oppilaiden fyysiseen aktiivisuuteen liittyvien ohjeistusten esiintyvyyttä Khiin neliö -testillä. Spearmanin-järjestyskorrelaation kerrointa käytettiin selvittämään yhteyttä opettajien antamien ohjeistuksien ja fyysisen aktiivisuuden muuttujien välillä.

Osatutkimuksessa III rakenneyhtälömallinnusta (R-lavaan) käytettiin selvittämään yhteyksiä fyysisen aktiivisuuden, luokkatilan ja kouluun kiinnittymisen välillä. Mallissa huomiotiin myös oppilaan sukupuoli ja luokka-aste. Mallin sopivuutta arvioitiin CFI:n (>0.95) ja SRMSR:n (<0.08) avulla.

Tulokset

Kiihtyvyysmittarilla mitatun oppilaiden oppitunneilta arvioidun fyysisen aktiivisuuden osalta todettiin, että avoimessa oppimistilassa oppilailta kerätty kiihtyvyysmittariaineisto osoitti suurempaa määrää passiivisen ajan taottamista, suurempaa määrää 1–4-minuutin mittaisia passiivisia jaksoja, vähäisempää määrää yli 10-minuutin passiivisuusjaksoja ja suurempaa määrää seisomaan nousuja oppituntien aikana kuin perinteisissä luokissa kerättyjen oppilaiden aineisto (Osatutkimukset I, II ja IV). Toisaalta viidesluokkalaisten passiivisen ajan osuus luokkahuoneessa vietetystä ajasta oli suurempi avoimien oppimistilojen koulussa kuin perinteisessä koulussa (Osatutkimukset I ja II). Kun fyysisen aktiivisuuden määrä ja intensiteetti yhdistettiin samaan muuttujaan, oppilaat olivat fyysisesti vähemmän aktiivisia avoimissa tiloissa (Osatutkimus III) kuin perinteisissä koulutiloissa. Yleisesti ottaen tytöt olivat fyysisesti vähemmän aktiivisia kuin pojat, kun taas kolmasluokkalaiset olivat aktiivisempia kuin viidesluokkalaiset (Osatutkimus II ja IV). Koulujen väliset vertailut osoittivat, että tilastollisesti merkitsevät erot oppilaiden fyysisessä aktiivisuudessa tapahtuivat pääasiassa koulujen välillä, joissa oli käytössä erilaiset luokkatilat (Osatutkimukset II ja IV).

Osatutkimuksessa II raportoidun opettajan ohjauksen systemaattisen havainnoinnin perusteella opettajat rajoittivat viidesluokkalaisten oppilaiden fyysistä aktiivisuutta enemmän avoimissa tiloissa kuin perinteissä luokkahuoneissa. Kolmasluokkalaisilla vastaavia eroja ei havaittu. Avoimissa tiloissa organisoitiin enemmän fyysisesti aktiivisia siirtymiä, kun taas perinteisissä tiloissa toteutettiin enemmän opettajajohtoista fyysistä aktiivisuutta sisältävää toimintaa. Erot luokkien välillä olivat kuitenkin suuria. Opettajien rajoittavat ohjeistukset olivat negatiivisesti yhteydessä kevyeen fyysiseen aktiivisuuteen, kun taas opettajien sallima vapaa liikkuminen oli positiivisesti yhteydessä kevyen fyysisen aktiivisuuden määrään. Opettajien johtama fyysistä aktiivisuutta sisältävä toiminta oli yhteydessä oppilaiden kohtalaisen- ja rasittavan fyysisen aktiivisuuden määrään ja pidempiin aktiivisten jaksojen kestoihin. Opettajan ohjaamat fyysiset siirtymät olivat yhteydessä lyhempiin aktiivisten ajanjaksojen kestoon ja pidempiin passiivisten ajanjaksojen kestoon.

Osatutkimuksessa III oppilaiden kouluun kiinnittymistä arvioivan kyselyn osalta rakenneyhtälömallinnuksen tulokset osoittivat, että avoimissa oppimistiloissa opiskelu ja oppilaiden myönteinen asenne koulunkäyntiin (emotionaalinen kiinnittyminen) olivat positiivisessa yhteydessä. Asenne koulunkäyntiä kohtaan oli puolestaan yhteydessä tehtäväsuuntautuneeseen käyttäytymiseen, johon oppimistilan tyypillä ei ollut tilastollisesti merkitsevää yhteyttä. Fyysisen aktiivisuuden määrällä ei ollut yhteyttä kumpaankaan oppilaiden kouluun kiinnittymiseen mittaan. Myös tässä tilastollisessa mallissa havaittiin oppilaan luokka-asteella ja sukupuolella olevaan yhteys fyysisen aktiivisuuden määrään, jotka ilmenivät myös osatutkimuksessa II.

Pohdinta

Avoimien ja joustavien tilaratkaisujen positiiviset yhteydet passiivisen ajan tauottamiseen, lyhyempien passiivisten ajan jaksojen sekä seisomaan nousujen määrään ovat samansuuntaisia kuin on havaittu aikaisemmissa tutkimuksissa (Brittin ym., 2017; Kariippanon ym., 2019b). Tätä havaintoa on selitetty sekä luokkatilojen ja kalusteiden tarjoamilla mahdollisuuksilla oppilaiden omaehtoisen ja ohjatun fyysisen aktiivisuuden toteuttamiselle sekä tilaratkaisuihin yhdistetyllä oppilaskeskeisellä pedagogiikalla (Kariippanon ym., 2021; Reinius ym., 2021; Saltmarsh ym., 2015). Suurempi passiivisen ajan tauotus ja lyhyemmät passiivisen toiminnan ajankestot voivat tuoda pidemmällä aikavälillä terveyshyötyjä, sillä niillä on havaittu olevan positiivinen (ts. terveyttä edistävä) yhteys lasten kardiometabolisiin riskitekijöihin ja kehon painoindeksiin (Saunders ym., 2013).

Tämän väitöstutkimuksen tulosten perusteella 5. luokan oppilaat olivat 3. luokan oppilaita passiivisempia ja tytöt vähemmän aktiivisia kuin pojat oppituntien aikana. Tulokset ovat yhteneväisiä aikaisemman vuorokauden ja koulupäivän aikaista liikkumista käsittelevän tutkimustiedon kanssa (Grao-Cruces ym., 2020; Jussila ym., 2022; Salin ym., 2019; Trost ym., 2002; van Stralen ym., 2014). Tyttöjen ja poikien väliset erot voivat johtua mahdollisista eroista kypsyystasossa. Kypsyyden vaikutusta fyysiseen aktiivisuustasoon voivat välittää minäkäsityksen muutokset, jotka johtuvat kypsymisen aikana tapahtuvista biologisista ja psykososiaalisista muutoksista (Fairclough & Ridgers, 2010). Lisäksi tyttöjen ja poikien on havaittu harrastavan välitunneilla erilaisia aktiviteetteja poikien suosiessa tyypillisesti intensiivisempää ja kilpailuhenkistä fyysistä toimintaa ja pelejä, kun taas tytöt keskittyvät enemmän sosiaaliseen kanssakäymiseen (Blatchford ym., 2003). Onkin mahdollista, että nämä erilaiset poikien ja tyttöjen sosiaaliset preferenssit ja niiden tuottamat toimintakulttuurit ilmenevät myös oppituntien aikaisessa fyysisessä aktiivisuudessa.

Oppilaiden ikään liittyen fyysisen aktiivisuuden tasojen on laskevan alkaen jo ensimmäisestä luokasta alkaen suomalaisilla seitsemänvuotiailla (Lounassalo ym., 2019). Passiivisesti vietetyn ajan osuuden lisääntymistä voi selittää mahdollisesti myös viidesluokkalaisiin kohdistuvien akateemisten vaatimusten kasvaminen verrattuna kolmasluokkalaisiin, jolloin opettajat saattavat pedagogiikassaan ja ohjauksessaan sisällyttää oppitunteihin enemmän paikallaan oloa vaativia tehtäviä. Vanhempien oppilaiden ja erityisesti sukupuolien rooleihin fyysisen aktiivisuuteen ohjautuvuuden suhteen oppituntien aikana tulisi kiinnittää erityistä huomiota ottaen huomioon sen, että aktiivista oppimista voi tukea fyysisen aktiivisuuden ohella myös muun tyyppinen aktiivinen vuorovaikutuksellinen ongelmanratkaisu ja yhteistyö. On kuitenkin huomioitava, että yksilölliset erot ovat suuria myös oppilaan iästä ja sukupuolesta riippumatta, joten oppilaiden fyysistä aktiivisuutta olisi hyvä tukea yksilölle sopivin tavoin.

Viidesluokkalaisten suurempi osuus passiivisesti vietetystä ajasta avoimen tilan luokkahuoneessa selittyy todennäköisimmin opettajien antamilla oppilaiden liikkumista rajoittavilla ohjeistuksilla. Suurempi passiivisen ajan osuus on ristiriidassa aikaisempien tutkimusten kanssa, jotka on toteutettu avoimissa oppimisympäristöissä (Brittin ym., 2017; Kariippanon ym., 2019b; Lanningham-

Foster ym., 2008). Näissä aikaisemmissa tutkimuksissa on raportoitu liikkumista mahdollistavien (Lanningham-Foster ym., 2008) ja oppilaskeskeisten opetusmenetelmien (Kariippanon ym., 2019b), sekä ulko- ja sisätilojen yhdistettyjä vaikutuksia fyysiseen aktiivisuuteen (Brittin ym., 2017). Tiloihin sopivat pedagogiset ratkaisut ja myös fyysistä aktiivisuutta edistävät toimenpiteet ovat ratkaisevan tärkeitä oppilaiden oppituntien aikaisen fyysisen aktiivisuuden kannalta.

Väitöstutkimuksessa havaittuja viidesluokkalaisten liikkumista rajoittavia opettajan ohjeistuksia selittävät todennäköisemmin mahdolliset haasteet oppituntien organisoinnissa avoimissa tiloissa. Esimerkiksi avoimille tiloille tyypillinen suurempi oppilasmäärä verrattuna perinteisiin luokkatiloihin (Niemi, 2016) voi tuottaa haasteita työrauhan näkökulmasta. Suurempi oppilasmäärä ja oppilaiden hajautuminen työskentelyyn eri tiloissa voi vaikeuttaa opettajajohtoisen fyysisen aktiivisuuden järjestämistä (Michael ym., 2019). Toisaalta avoin tila ja helposti liikuteltavat huonekalut voisivat mahdollistaa myös opettajajohtoisen fyysisen aktiivisuuden, kuten esimerkiksi fyysisesti aktiivisten opetusmenetelmien käytön (Michael ym., 2019). Toisaalta esimerkiksi avoimissa tiloissa on havaittu olevan akustisia haasteita melun suhteen, joten tästä syystä opettajat voivat joutua rajoittamaan oppilaiden liikettä (Mealings ym., 2015; Michael ym., 2019).

Aiemmissa tutkimuksissa on havaittu, että uusiin tiloihin siirtymisellä on ollut omat haasteensa ja välttämättä pedagogiset ratkaisut eivät ole muuttuneet tilojen vaihtumisesta huolimatta (Campbell ym., 2013; Niemi, 2016; Saltmarsh ym., 2015). Muutokset pedagogiikassa voivat viedä useita vuosia (Gislason, 2018) ja opettajilla ei aina ole tarvittavia valmiuksia ja tarvittavaa tukea ympäristön muokkaamiseen ja hyödyntämiseen (Campbell ym., 2013; Deed & Lesko, 2015; Kariippanon ym., 2018). Opettajien henkilökohtaiset näkemykset ja koulujen käytännöt sekä resurssit fyysisen aktiivisuuden tukemiseksi voivat myös selittää erilaisia tuloksia havainnointituloksissa ja fyysisen aktiivisuuden määrissä (McMullen ym., 2015; Michael ym., 2019). Tässäkin tutkimuksen todetut opetusryhmien välillä havaitut suuret erot, jopa koulujen sisällä, ovat yhdenmukaisia aiempien raporttien mukaan, joiden perusteella noin puolet opettajista käyttää fyysisesti aktiivisia opetusmenetelmiä ja 65 % opettajista pyrkii taottamaan pitkiä istumisjaksoja (Kämppi ym., 2018). Opettajien ohjeistuksia koskevien havainnointitulosten perusteella opettajajohtoinen fyysinen aktiivisuus voi olla tehokkain tapa lisätä oppilaiden kohtalaisen ja rasittavan liikunnan määrää oppitunneilla. Vapaan liikkumisen mahdollistaminen voi lisätä erityisesti kevyen fyysisen aktiivisuuden ja passivisuustaukojen määrää.

Oppilaiden kouluun kiinnittymisen osalta on oletettu, että avoimet tilat ja niihin liitetty oppijakeskeinen pedagogiikka voivat tukea oppilaiden välistä yhteistyötä, itseohjautuvaa oppimista ja autonomiaa (Saltmarsh ym., 2015), joten avoimet tilat voivat parhaimmillaan tukea oppilaiden sekä emotionaalista että behavioraalista kouluun kiinnittymistä. Tässä tutkimuksessa avoimien tilojen ja emotionaalisen kouluun kiinnittymisen välillä havaittu positiivinen yhteys tukee tätä teoriaa. Vaikka behavioraalisen kouluun kiinnittymisen ja avoimen tilaratkaisun välillä ei havaittu tilastollisesti merkitsevää yhteyttä voi emotionaalisen ja behavioraalisen kiinnittymisen välillä havaittu yhteys heijastua myös parempana behavioraalisena kouluun kiinnittymisenä. Fyysisen aktiivisuuden määrällä ei itsessään havaittu olevan yhteyttä kumpaankaan kouluun kiinnittymisen mittaan, joten aiemmissa tutkimuksissa havaitut yhteydet kouluun kiinnittymisen ja fyysisen aktiivisuuden välillä (Mavilidi ym., 2020; Vazou ym., 2012; Watson ym., 2017) voivat liittyä ennemminkin toteutettuihin interventioihin kuin tilaan sinänsä. On myös mahdollista, että eri fyysisen aktiivisuuden tyypit, intensiteetit ja määrät voivat olla hyödyllisiä kouluun kiinnittymisen eri ulottuvuuksille (Owen ym., 2016, 2018).

Tutkimuksen vahvuudet ja rajoitteet

Väitöstutkimukseen sisällytetyillä osatutkimuksilla on vahvuuksia ja heikkouksia, jotka tulisi huomioida tutkimustuloksia tulkittaessa. Väitöstutkimuksen merkittävin vahvuus on tutkimuksen toteuttaminen luokkahuoneissa tapahtuvien oppituntien tilanteessa, jolloin saadaan autenttinen kuva erilaisten tilaratkaisujen yhteyksistä oppilaiden fyysiseen aktiivisuuteen, kouluun kiinnitymiseen sitoutuneisuuteen sekä opettajien antamiin ohjeistuksiin oppilaiden liikkumisen suhteen. Tutkimuksen merkittävimpiä vahvuuksia on myös kiihtyvyysmittarilla mitatun fyysisen aktiivisuuden ja systemaattisen havainnoinnin tulosten rinnakkainen analyysi. Lisäksi tilastolliset menetelmät mahdollistivat oppilaan sukupuolen ja luokka-asteen huomioimisen. Kiihtyvyysmittariaineiston analysointiin käytetyn raakadataan perustuvan keskiamplitudipoikkeaman käytön on raportoitu olevan luotettava menetelmä eri kiihtyvyysmittareilla mitatulle aineistolle, jota on myös käytetty aiemmin suomalaisilla lapsilla tehdyissä tutkimuksissa (Aittasalo ym., 2015; Husu ym., 2019; Jussila ym., 2022; Vähä-Ypyä ym., 2015).

Väitöstutkimuksen suurimpana rajoitteena on tutkimuksen poikkileikkausasetelma, jonka vuoksi ei voida osoittaa kausaalisia suhteita tilaratkaisujen ja muiden mitattujen muuttujien välillä. Tutkimukseen osallistui vain yksi koulu, jossa oli käytössä avoimet tilat, mikä rajoittaa tutkimustulosten yleistettävyyttä. Koulujen kirjattuja käytäntöjä fyysisen aktiivisuuden tukemiseksi ei arvioitu tässä väitöstutkimuksessa, mutta kaikki osallistuneet koulut olivat mukana Liikkuva Koulu-hankkeessa (Blom ym., 2018), jossa jokainen koulu suunnittelee ja toteuttaa itse omat koulupäivän aikaista liikkumista tukevat käytännöt. On mahdollista, että osallistuneet koulut keskittyivät tukemaan fyysistä aktiivisuutta eri tavoin ja todennäköisesti myös muissa yhteyksissä kuin oppitunneilla kuten esimerkiksi aktiivisilla koulumatkoilla tai välituntiliikunnalla (Blom ym., 2018; R. L. Carson & Webster, 2020; McMullen ym., 2015). Opettajien omia näkemyksiä ja kokemuksia mahdollisista rajoitteista fyysisen aktiivisuuden tukemiselle sekä liikkumista koskevan ohjauksensa perusteluita ei selvitetty tässä väitöstutkimuksessa (Michael ym., 2019). Myöskään oppilaiden omia kokemuksia tiloista ja toteutetusta fyysisestä aktiivisuudesta ei sisällytetty tähän tutkimukseen. Vaikka opettajat ja tilat mahdollistaisivat fyysisen aktiivisuuden voivat oppilaat silti valita, etteivät he osallistu fyysisesti aktiiviseen toimintaan.

Tutkimukseen liittyy kaksi mahdollista harhan lähdettä. Näistä ensimmäinen on Hawthorne-ilmiö, jonka mukaan tutkittavat, tässä oppilaat ja opettajat, voivat käyttäytyä eri tavalla, mikäli he tietävät olevansa tarkkailun kohteena. Ilmiön mahdollista vaikutusta pyrittiin vähentämään tutkijoiden vierailulla kouluissa ennen tutkimuksen aloittamista. Toisena mahdollisena rajoituksena on, että tutkimukseen osallistujat voivat olla valikoitunut aiheesta kiinnostunut joukko, joka ei välttämättä ole yleistettävissä kaikkiin tutkimuksessa mukana olleiden koulujen oppilaisiin.

Tulkittaessa tämän väitöstutkimuksen tuloksia on myös huomioitava valittujen tutkimusmenetelmien vaikutus tuloksiin. Kiihtyvyysmittarin antamassa tiedossa merkittävä tuloksiin vaikuttava seikka ovat käytetyt analyysimenetelmät. Kiihtyvyyden intensiteettiin perustuvien kiinteiden raja-arvojen käyttäminen aliarvioi fyysisen aktiivisuuden kuormittavuutta lapsilla, joilla on heikompi kestävyyskunto ja motoriset taidot (Haapala ym., 2021a). Tällä hetkellä ei kuitenkaan ole väestötason tutkimuksiin vakiintunutta käytäntöä, jolla tutkittaville voitaisiin määrittää yksilölliset raja-arvot liikkumisen kuormittavuudelle, vaikkakin omavauhtisen juoksun aikana mitattua kiihtyvyyttä voisi mahdollisesti käyttää rasittavan liikunnan raja-arvona (Haapala ym., 2020).

Toinen kiihtyvyysmittarilla mitattuihin fyysisen aktiivisuuden tuloksiin vaikuttava tekijä on keskiarvojen laskemiseen käytetty ajanjakson kesto, joka oli tämän väitöstutkimuksen osajulkaisuissa 15 sekuntia. Pidemmät keskiarvoistusjaksot, esimerkiksi tyypillisesti koko vuorokauden aikaisissa mittauksissa käytetty 1 minuutin jaksot, lisäävät passiivisen ajan määrää ja vähentävät kohtalaisen sekä rasittavan liikunnan määrää suhteessa lyhyempiin ajanjaksoihin (Altenburg ym., 2021).

Tässä tutkimuksessa mitattiin oppilaiden paikallaanoloa, mikä sisältää myös seisomisen, jolloin energiankulutus voi olla istumista ja makuullaan oloa hieman korkeampi (Tremblay ym., 2017). Vyötärölle ja reiteen kiinnitetyt kiihtyvyysmittarit eivät huomioi käsillä tapahtuvia toimintoja (Arvidsson ym., 2019), joita voi tapahtua tyypillisesti koulupäivän aikana esimerkiksi kuvaamataidon ja käsityötunneilla. On siis mahdollista, että avoimet tilat tai opettajien johtamat aktiviteetit edistävät myös sellaisia fyysisen aktiivisuuden muotoja, jotka eivät näy kiihtyvyysmittaustuloksissa.

Oppilaiden täyttämiä tutkimuspäiväkirjoja käytettiin kiihtyvyysanalyysiin valittavien ajanjaksojen määrittämiseen. Mikäli oppilaat eivät kirjanneet tarkasti mahdollisia poissa-oloja koulusta, on mahdollista, että analyysiin on päätynyt ajanjaksoja, jolloin oppilas ei todellisuudessa ollut koulussa. Lisäksi opettajien lukujärjestysten avulla raportoima luokkahuoneessa vietetty aika saattaa sisältää joissain määriin siirtymiä välitunnille ja välitunnilta takaisin luokkaan.

Väitöstutkimuksessa käytetty opettajien ohjeistuksien havainnointi- menetelmä ei sisältänyt liikkumisen sosiaalisen ja oppitunnin aikaisen kontekstin määrittämistä (Russ ym., 2017). Opettajien oppilaille antamat mahdolliset säännöt tilojen ja kalusteiden käytöstä jäivät siten tutkimusmenetelmien ulkopuolelle. Lisäksi havainnoijien välistä yhteneväisyyttä ei tarkasteltu tutkimusaineistossa, vaikkakin havainnoijien tuli läpäistä koodauksen luotettavuutta arvioivat kirjallinen koe ennen mittauksiin osallistumista.

Kouluun kiinnittymisen osalta pääasiallinen huomioitava seikka on, että tilastollinen malli ei sisältänyt kognitiivisen kouluun kiinnittymisen (Fredricks ym., 2004) arviointia. Behavioraalisen ja emotionaalisen kouluun kiinnittymisen välillä on havaittu kaksisuuntainen yhteys, kun taas behavioraalinen kouluun kiinnittyminen saattaa vaikuttaa kognitiiviseen kouluun kiinnittymiseen (Li & Lerner, 2013). Itseraportoidut kouluun kiinnittymistä arvioivatkyselyt ovat tyypillinen tapa arvioida kiinnittymistä, mutta ne vaativat oppilailta kykyä arvioida omaa toimintaa, mikä voi olla lapsille haasteellista. Oppilaiden mahdollisesti tarvitsemaa tukea ei tässä tutkimuksessa arvioitu, esimerkiksi tarkkaavaisuushäiriöiden osalta, jotka voivat vaikuttaa oppimistuloksiin sekä mahdollisesti myös kouluun kiinnittymiseen (Rushton ym., 2020). Tämän väitöstutkimuksen tilastolliset vertailut eivät myöskään sisältäneet oppilaiden sosioekonomisen taustan määritystä, jolla voi olla vaikutusta oppilaiden koulumenestykseen (Broer ym., 2019).

Tilastollisiin menetelmiin liittyen käytetyt menetelmät eivät huomioineet aineiston hiearkkisuutta, sillä tutkimukseen osallistui vain 15 opetusryhmää ja hiearkkisten monitasomallien ajatellaan vaativan vähintään 30 ryhmää (Hox & Maas, 2001). Tämän vuoksi myös fyysisen aktiivisuuden intensiteettejä tarkasteltiin tilastollisissa vertailuissa irrallisina toisistaan, eikä ollut mahdollista käyttää tilastomenetelmiä (esim. compositional analysis of physical activity), jotka mahdollistaisivat näiden tarkastelun näitä suhteessa toisiinsa (Chastin ym., 2015).

Johtopäätökset

Tämän väitöstutkimuksen havaintojen perusteella saatiin tukea sille, että koulun avoimet tilaratkaisut voivat olla yhteydessä lyhyempiin paikallanolon jaksoihin, sekä paikallaanolon ja istumisen tauottamiseen. Nämä tekijät, jotka voivat olla terveydelle tärkeitä pitkällä aikavälillä (V. Carson ym., 2016; Saunders ym., 2013). Tutkimustietoa tarvitaan kuitenkin lisää siitä, että missä määrin koulupäivän aikaista paikallaanoloa tulisi tauottaa terveyshyötyjen saavuttamisen näkökulmasta.

Vanhempien oppilaiden eli tässä tutkimuksessa viidesluokkalaisten oppilaiden oppituntien aikaisen fyysisen aktiivisuuden tukemiseen tulisi kiinnittää huomiota. Selitystä sille, miksi viidesluokkalaisten oppilaiden oppitunneilla liikkumisen osuutta rajoitettiin opettajien taholta enemmän avoimissa tilaratkaisuissa kuin perinteisissä luokissa ei tämän tutkimuksen aineiston perusteella voidaan yksiselitteisesti tarjota, mutta mahdollisia syitä voivat olla käyttäytymisen säätelyn vahvemmat tarpeet isommissa tiloissa. Opettajille tulisikin tarjota tukea avoimien tilojen hyödyntämiseen myös fyysistä aktiivisuutta tukevan toiminnan näkökulmasta. Mahdolliset koulujen ja opettajien itsensä kokemat esteet fyysisen aktiivisuuden tukemiselle vaativat lisäselvitystä.

Avoimet tilaratkaisut vaikuttaisivat olevan positiivisessa yhteydessä emotionaaliseen kouluun kiinnittymiseen, mikä voi tukea myös muita kouluun kiinnittymisen ulottuvuuksia. Fyysisen aktiivisuuden määrällä ei itsessään ollut yhteyttä kouluun kiinnittymiseen. Tätä voivat kuitenkin tukea erilaiset fyysisen aktiivisuuden muodot ja esimerkiksi fyysisesti aktiiviset tauot tai aktiiviset opetusmenetelmät, sillä näihin liittyvillä interventioilla on havaittu positiivisia vaikutuksia (Owen ym., 2016; Sneck ym., 2022; Watson ym., 2017). Pitkittäistutkimuksia tarvitaan selvittämään tilaratkaisujen tukeman fyysisen aktiivisuuden, oppilaiden kouluun kiinnittymisen ja opettajien toiminnan välistä syy-yhteyksiä ja kehityskaaria.

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ORIGINAL PAPERS

I

COMPARISON OF CLASSROOM-BASED SEDENTARY TIME AND PHYSICAL ACTIVITY IN CONVENTIONAL CLASSROOMS AND OPEN LEARNING SPACES AMONG ELEMENTARY SCHOOL STUDENTS

by

Hartikainen, J., Haapala, E. A., Poikkeus, A. M., Lapinkero, E., Pesola, A. J., Rantalainen, T., Sääkslahti A., Gao, Y., & Finni, T. (2021)

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Comparison of Classroom-Based Sedentary Time and Physical Activity in Conventional Classrooms and Open Learning Spaces Among Elementary School Students

Jani Hartikainen[1], Eero A. Haapala[1,2], Anna-Maija Poikkeus[3], Eero Lapinkero[1], Arto J. Pesola[4], Timo Rantalainen[1], Arja Sääkslahti[1], Ying Gao[5] and Taija Finni[1]*

[1] Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland, [2] Institute of Biomedicine, School of Medicine, University of Eastern Finland, Kuopio, Finland, [3] Department of Teacher Education, University of Jyväskylä, Jyväskylä, Finland, [4] Active Life Lab, South-Eastern Finland University of Applied Sciences, Mikkeli, Finland, [5] Department of Sports Science, College of Education, Zhejiang University, Hangzhou, China

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***Correspondence:**
Jani Hartikainen
jani.p.hartikainen@jyu.fi

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European children and adolescents spend most of their daily life and especially their school hours being sedentary which may increase their risk for chronic non-communicable diseases later in life. After the curriculum reform of Finnish basic education in 2014, most of the new or renovated comprehensive schools in Finland incorporate open and flexible classroom designs. Their open learning spaces may provide students opportunities to reduce sedentary behavior during school hours. Thus, waist-worn accelerometers were used to assess classroom-based sedentary time (ST), the number of breaks from sedentary time (BST), and physical activity (PA) among cross-sectional samples of 3rd and 5th grade students during two separate academic years in a school that underwent a renovation from conventional classrooms to open learning spaces. The cohort of 5th grade students before renovation had a smaller proportion of ST from total classroom time (56.97 ± 12.24%, $n = 42$ vs. 67.68 ± 5.61%, $n = 28$, mean difference = 10.71%-points, 95%CI = −15.65 to−5.77, $p < 0.001$), a greater number of BST per 60 min of classroom time (7.41 ± 1.16 breaks/h vs. 9.19 ± 1.59 breaks/h, mean difference = −1.78 breaks/h, 95%CI = −2.486 to −1.079, $p < 0.001$) and a greater proportion of light intensity PA (28.66 ± 9.99% vs. 22.56 ± 4.59%, mean difference = 6.10%, 95%CI = 2.56 to 9.64, $p = 0.001$) than the 5th grade cohort assessed after renovation. The cohort of 3rd grade student had a greater proportion of moderate-to-vigorous intensity PA (MVPA) after the renovation compared to the cohort assessed before the renovation [Mean Rank (Before) = 27.22, Mean Rank (After) = 37.58, U =524.0, $p = 0.033$]. Despite the greater ST found in 5th graders, schools with open learning spaces may facilitate BST or MVPA as observed in the 5th and 3rd grade cohorts in open learning spaces compared to the cohorts in conventional classrooms, respectively. Future studies should seek to investigate and develop teacher practices to capitalize the potential of open classrooms to reduce ST, since classroom renovation alone may not be a sufficient intervention as of itself. Longitudinal studies utilizing randomized controlled trials are warranted.

Keywords: sedentary behavior, breaks from sedentary time, physical activity, elementary school, classroom, open learning space

INTRODUCTION

Sedentary behavior (SB) refers to any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents of task, while in a sitting, reclining, or lying posture (Tremblay et al., 2017). Public health guidelines recommend that children and adolescents should limit their total sedentary time (ST), as a sedentary lifestyle may increase their risk for chronic non-communicable diseases later in life (Carson et al., 2016; Tremblay et al., 2016). Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985). Sedentary bouts can be defined as a minimum period of uninterrupted sedentary time and breaks from sedentary time (BST) can be defined as a non-sedentary period in between two sedentary bouts (Altenburg and Chinapaw, 2015). Current evidence has shown positive associations between PA and physical and mental health in school-aged children, with potential positive health effects of reduced duration of sedentary bouts and increased number of BST (Janssen and LeBlanc, 2010; Healy et al., 2011; Saunders et al., 2013; Altenburg and Chinapaw, 2015; Biddle et al., 2019).

It has been estimated that children spend 40–60% of their time sedentary, which equals 5–8 hours a day (Colley et al., 2013; Ortega et al., 2013; Konstabel et al., 2014). In many Western countries, including Finland, less than half of the children and youth achieve the recommended daily 60 min of moderate-to-vigorous physical activity (MVPA) daily (Aubert et al., 2018; Bull et al., 2020). Schools can be considered as feasible locations for intervention aiming to reduce ST and increase overall PA among children because they spend a large proportion of their waking hours in school (Hegarty et al., 2016). European primary school children aged 10–12 have been shown to spend 65–70% of school time being sedentary and 5% on MVPA, boys having less ST, and more MVPA than girls (van Stralen et al., 2014; Salin et al., 2019).

Recently, general education classrooms have received more attention as possible settings to reduce ST and increase PA of students in addition to physical education classes and recess (Webster et al., 2015; Hegarty et al., 2016). In addition to studies focusing on teacher implemented PA during classroom time, some studies have focused on the role of built school environment in increasing PA and reducing ST of students (Lanningham-Foster et al., 2008; Brittin et al., 2015, 2017; Webster et al., 2015; Hinckson et al., 2016). In addition to potential health benefits of reduced ST and increased PA, increased classroom-based PA may have a positive impact on academic outcomes and students' on-task behavior (Goh et al., 2016; Watson et al., 2017).

A review of 13 studies reported that classroom design approaches reduced youth sitting time 44 to 60 min per day and increased standing time by 18 to 55 min per day during classroom time at school (Hinckson et al., 2016). Furthermore, evidence suggests that when supplemented with appropriate teaching methods, environments designed to encourage active learning increase PA levels in children compared to traditional classroom environments (Lanningham-Foster et al., 2008). Furthermore, a guideline-informed school physical environment (Brittin et al., 2015) may also decrease ST and length of sedentary bouts in children aged 8-10 years (Brittin et al., 2017). In classrooms utilizing flexible spaces including a variety of furniture and resources, adolescents were found to spend less class time sitting and accumulated more breaks in sitting, more bouts of intermittent (≤9 min) sitting, and fewer bouts of prolonged (≤30 min) sitting, than in traditionally furnished and arranged classroom when coupled with a greater use of student-centered pedagogies (Kariippanon et al., 2019).

After the curriculum reform of Finnish basic education in 2014, most of the new or renovated comprehensive schools in Finland incorporate open and flexible classroom designs and principles; the conventional self-contained classrooms are changed into more flexible, multipurpose, informal, and transformative open learning spaces (Ministry of Education Finnish National Curriculum, 2014; Niemi, 2020). These types of schools with non-partitioned instructional spaces have re-emerged as a result of educational reforms in some countries including Finland, the United Kingdom, Germany, and Spain (Mäkitalo-Siegl, 2010; Saltmarsh et al., 2015). The open learning spaces are typically equipped with moveable furniture and varying possibilities, such as privacy screens, to divide spaces (Kokko and Hirsto, 2021). Open learning spaces can take varied forms but some of the defining features include integration of physical and virtual space, multifunctionality, and affording students autonomy over their learning (Melhuish, 2011). Open learning spaces may reduce ST, increase the number of BST, and increase PA of students, as in terms of interior design, their characteristics resemble those of activity permissive classrooms including ample, multipurpose, and adaptable spaces (Brittin et al., 2015; Saltmarsh et al., 2015).

Nevertheless, the role of school indoor spaces *per se* in reducing ST, increasing number of BST, and increasing PA of students is still unclear. The studies published so far have reported use of physically active, or student-centered teaching methods accompanied with environmental renovation, or combined effects of improved indoor and outdoor facilities (Lanningham-Foster et al., 2008; Brittin et al., 2017; Kariippanon et al., 2019). There is currently, however, scant information on whether open learning spaces increase PA and reduce ST in classrooms where teaching methods are not experimentally altered. We investigated ST, BST, and PA levels among children in 3rd and 5th grades in two separate academic years before and after a school renovation into open learning spaces. We hypothesized that cohorts of 3rd and 5th grade students attending school in open learning space settings would have less ST and more BST and PA than their counterparts in the conventional classroom setting.

MATERIALS AND METHODS

Participants and Procedures

The data in this cross-sectional case study comprise accelerometer measures drawn from two separate academic years with a total of 130 Finnish 3rd and 5th grade students in a school undergoing renovation from conventional classrooms to open learning spaces. Complete accelerometer data were obtained from 41 3rd and 42 5th grade students before renovation. After renovation data were obtained from 19 3rd and 28 5th grade students. In the Finnish school system 3rd graders are usually 9-years and 5th graders are 11-years of age.

The first phase of data collection took place in autumn 2015 in conventional self-contained classrooms with designated desks. The second phase of data collection took place in autumn 2016 when the next cohort of children was studying in the new open learning spaces in the same school after the renovation. The renovated open learning spaces contained a large space with mobile furniture, which afforded multiple options in classroom layout. The instructional area also enabled teaching of arts, physics, and chemistry, while lessons for music and handcrafts were held in their own separate learning spaces. The student did not have an assigned place, such as a designated desk, in the open learning spaces (**Figure 1**).

Before the renovation, each class was taught by their own classroom teachers in their separate conventional classrooms. After the renovation, students of the same grade-level attended instruction in large open learning spaces, all 3rd graders in their own space and all 5th graders in another space. Teachers of one grade-level collaborated to some extent throughout the week and school days. During the measurement weeks contents of instruction followed the curriculum of the grades in question, and instruction was not in any way altered by the researchers.

ST, BST, and PA were measured during school hours of one school week from Monday to Friday by a waist-mounted triaxial accelerometer (Gulf Coast Data Concepts X16-1, Waveland, USA). Data included in the analyses were determined manually for each student based on the teacher reported weekly schedule for the students. Only time spent inside the classroom was included in the analysis. Physical education, recess, and unusual activities, such as fieldtrips, or activities not part of general education curriculum, such as practice of school festival presentation, were excluded based on the teacher's reported schedule. Examples of 3rd grade curriculums in conventional classrooms and open learning space are provided in **Table 1**. Furthermore, possible absences from school due to illness or short visits to dentist, for example, during school hours were identified from diaries kept by the students and their parents. The data were also visually inspected to ensure that accelerometers were worn as reported by the participants.

The measurement range of the accelerometer was ±16 g and the sample rate 40 or 50 Hz with a 16-bit A/D conversion. The resultant acceleration of the triaxial accelerometer signal was calculated from $\sqrt{x^2 + y^2 + z^2}$, where x, y, and z are the measurement sample of the raw acceleration signal in x-, y-, and z-directions. The number of consecutive data points was 40 or 50 and the corresponding epoch length was one second. Mean amplitude deviation (MAD) was calculated from the resultant acceleration in non-overlapping 1-second epochs. MAD is described as the mean distance of data points about the mean of the given epoch

$$MAD = \frac{1}{n}\sum_{i=1}^{n} |r_i - \overline{r}|$$

where n is the number of samples in the epoch, r_i is the i^{th} resultant sample within the epoch and $\overline{r}$ is the mean resultant value of the epoch (Aittasalo et al., 2015; Vähä-Ypyä et al., 2015a). The MAD-method used for assessing PA has documented validity and reliability as an accurate method across different accelerometer brands (Aittasalo et al., 2015; Vähä-Ypyä et al., 2015b). Use of universal PA metrics, such as MAD, in the analysis enables comparison and synthetization of results using different accelerometers (Aittasalo et al., 2015). MAD-values were averaged over 15-second intervals, and averaged values were used to examine time spent at different PA-intensities. Cut-offs were determined as follows: light intensity PA (LPA) 16.7 mg, and MVPA 91 mg (Vähä-Ypyä et al., 2015a). Time spent at different PA intensities was calculated as total minutes of measurement week. Time spent at different intensities was normalized to total classroom time. A BST was determined as any interruption in sedentary time lasting at least 1 min (Saunders et al., 2013). BST was operationalized as the number of breaks per 60 min of classroom time.

Data Analysis

Statistical analyses were carried out using IBM SPSS Statistics 26 –software (IBM corp. Armonk, NY, USA). We used the Shapiro-Wilk Test for assessing the normality of data distribution. For normally distributed variables, we used independent samples *t*-test to compare the average PA and ST of cohorts assessed before and after renovation. 2-Tailed significances below 0.05 were considered statistically significant. For variables that were not normally distributed, we used Mann-Whitey *U*-test to examine differences in ST, BST, and PA between cohorts. Statistical analyses were made separately for 3rd and 5th grade students. Because of the small sample size, we did not perform further comparisons between boys and girls.

RESULTS

ST was lower in the cohort of 5th graders assessed before renovation in conventional classrooms than in the cohort of 5th graders measured after renovation in the open learning space. The mean difference of 10.71%-points between cohorts was

FIGURE 1 | The conventional self-contained classroom **(A)** and the open learning space **(B)**. The pictures from the open learning space show that a one large space has several areas for work allowing division of the class of about 70 students to smaller groups.

TABLE 1 | Examples of 3rd grade students' curriculum during measurement week in conventional classrooms and open learning spaces.

3rd grade curriculum, conventional classrooms, autumn 2015

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:00–8:45	Distribution of accelerometers			General education	General education
8:45–9:30		General education	General education	General education	General education
9:30–10:00	Recess	Recess	Recess	Recess	Recess
10:00–11:45	Physical education, lunch	General education, lunch*	General education, lunch*	General education, lunch*	General education, lunch*
11:45–12:15	Recess	Recess	Recess	Recess	Recess
12:15–13:00	General education	General education	General education	General education	General education
13:00–13.45	General education				

*Lessons marked with white were included in analysis and dark gray excluded, *Lunch 11:10–11:30 excluded from analysis.*

3rd grade curriculum, open learning spaces, autumn 2016

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8:00–8:45	Distribution of accelerometers	General education			General education
8:45–9:30		General education	General education	General education	General education
9:30–10:00	Recess	Recess	Recess	Recess	Recess
10:00–11:45	General Education, Lunch*	General education, lunch*	General education, lunch*	General education, lunch*	General education, lunch*
11:45–12:15	Recess	Recess	Recess	Recess	Recess
12:15–13:00	General education			Physical education	General education
13:00–13.45	General education				

*Lessons marked with white were included in analysis and dark gray excluded, *Lunch 11:00–11:30 excluded from analysis.*

considered as statistically significant with independent samples t-test [95%CI−15.65 to −5.77; $t_{(61.621)} = -4{,}945$, $p < 0.001$]. Levene's test indicated unequal variances between cohorts, so degrees of freedom were adjusted accordingly. For 3rd graders, significant differences were not observed in ST between cohorts assessed before or after renovation (**Table 2**, **Figure 2**).

The cohort of 5th grade students assessed before renovation had a smaller number of BST than the cohort measured after renovation. The mean difference of −1.78 breaks/h was considered statistically significant with independent samples t-test [95%CI −2.486 to −1.079; $t_{(45.768)} = -5.100$; $p < 0.001$]. Levene's test indicated unequal variances between cohorts and degrees of freedom were adjusted accordingly. For 3rd graders, significant differences were not observed between the cohort assessed before or after the renovation (**Table 2**, **Figure 2**).

In the cohort of 5th grade students assessed before the renovation, the average LPA duration was greater than in the cohort measured after the renovation. The mean difference of 6.10 %-points between cohorts was considered statistically significant with independent samples t-test [95%CI 2.563 to 9.636; $t_{(61,655)} = 3{,}019$, $p = 0.001$]. The Levene's test indicated unequal variances between cohorts and degrees of freedom were

TABLE 2 | Study cohorts and results for sedentary time and physical activity before and after school renovation.

Measurement	Grade	Boys/Girls	n	Duration (min)	ST (%)	LPA (%)	MVPA (%)	BST (times/h)
Before	3rd	19/22	41	792.44 ± 152.60	55.92 ± 14.00	31.55 ± 11.04	11.18 ± 4.56	8.48 ± 2.03
	5th	16/26	42	759.88 ± 180.32	56.97 ± 12.24	28.66 ± 9.99	12.91 ± 7.10	7.41 ± 1.16
After	3rd	11/8	19	609.21 ± 125.03	58.04 ± 10.59	30.01 ± 4.77	14.89 ± 6.43	9.30 ± 1.87
	5th	7/21	28	776.07 ± 201.08	67.68 ± 5.61	22.56 ± 4.59	10.53 ± 2.99	9.19 ± 1.59

Total classroom of time included in analysis in minutes (Duration), percentages of sedentary time (ST), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) from total classroom time. Breaks from sedentary time (BST) normalized to 60 min of classroom time (times/h). Values expressed are means and standard deviations.

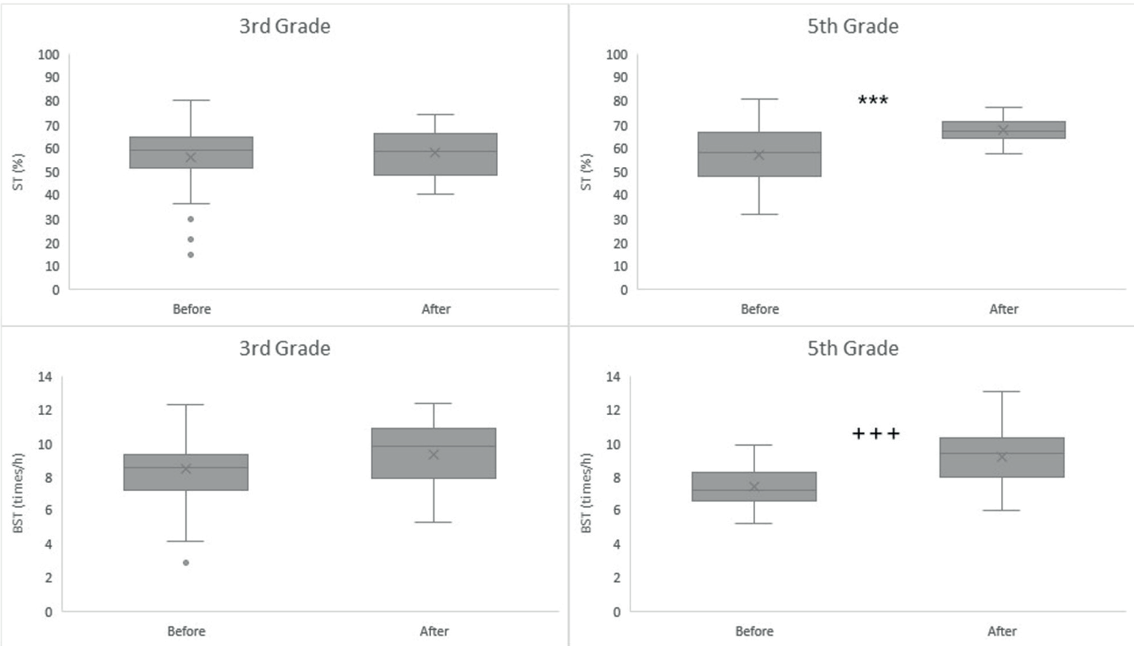

FIGURE 2 | 3rd and 5th Grade students' percentages of classroom time spent sedentary (ST) and breaks from sedentary time normalized to 60 min of classroom time (BST) before and after renovation. ***Independent samples t-test: Before 56.97 ± 12.24%, $n = 42$ vs. After 67.68 ± 5.61%, $n = 28$, mean difference = 10.71%-points, 95%CI = −15.65 to −5.77, $p < 0.001$. Equal variances were not assumed ($F = 17.642$, $p < 0.001$). $^{+++}$Independent samples t-test: Before 7.41 ± 1.16 breaks/h vs. After 9.19 ± 1.59 breaks/h, mean difference = −1.78 breaks/h, 95%CI = −2.486 to −1.079, $p < 0.001$. Equal variances were not assumed ($F = 2{,}776$, $p = 0.100$).

adjusted accordingly. In 3rd grade students, MVPA was lower in the cohort measured before renovation than after. A Mann-Whitney-test indicated that the difference was significant [Mean Rank (Before) = 27.22, Mean Rank (After) = 37.58, $U = 524.0$, $p = 0.033$] (**Table 2**, **Figure 3**).

DISCUSSION

We investigated differences in classroom-based ST, BST, and PA in 3rd and 5th grade students before and after a school renovation from conventional classrooms to open learning spaces. We found that the cohort of 5th grade students assessed after renovation in the open learning space had a higher ST, more BST, and less LPA than the cohort measured before renovation in conventional classrooms. In cohorts of 3rd grade students, MVPA was higher after renovation than before.

The results of previous studies have shown that when students are shift to an activity permissive environment and activity permissive teaching methods are used, students ST decreases, number of BST increases, and PA time increases (Lanningham-Foster et al., 2008; Brittin et al., 2017). The current evidence suggests that, elements of flexible learning spaces including a variety of furniture and resources, and a greater use of student-centered pedagogies, facilitate improvements in adolescents' sedentary profiles during class time (Kariippanon et al., 2019). In our present study, we did not observe the expected benefits of reduced ST and increased PA for 5th grade students, although characteristics of an activity permissive classroom are similar to

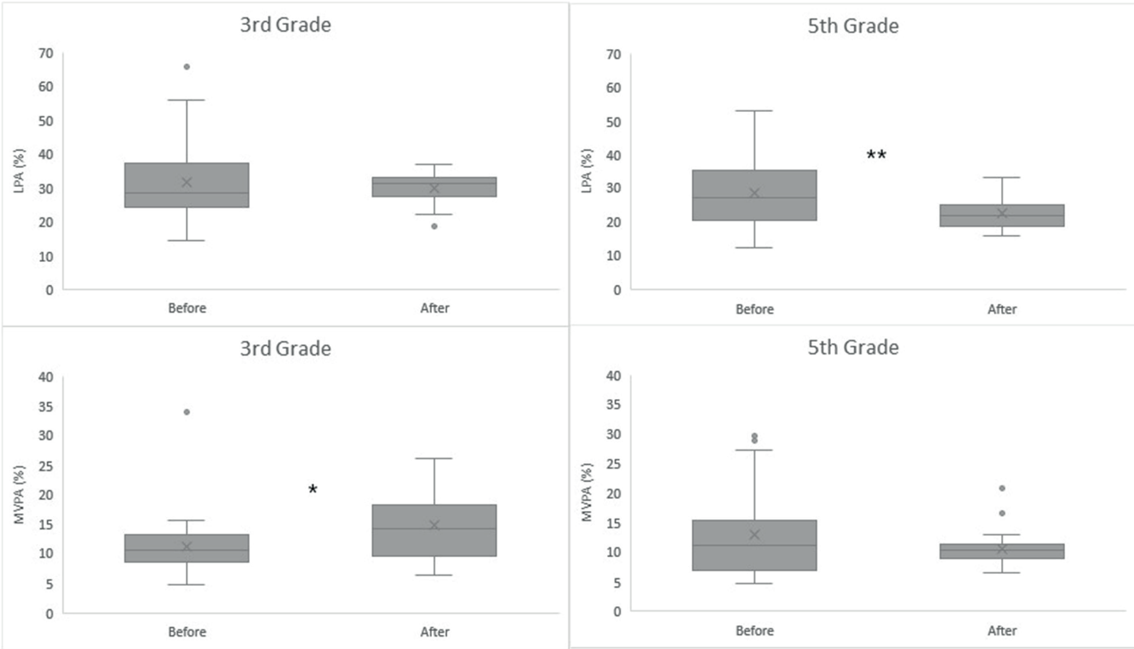

FIGURE 3 | 3rd and 5th Grade students' percentages of Light (LPA) and moderate-to-vigorous (MVPA) physical activity from total classroom time before and after renovation. **Independent samples *t*-test: Before 28.66 ± 9.99% vs. After 22.56 ± 4.59%, mean difference = 6.10%, 95%CI = 2.56 to 9.64, $p = 0.001$. Equal variances were not assumed ($F = 14.618$, $p < 0.001$). *A Mann-Whitney-test: Mean Rank (Before) = 27.22, Mean Rank (After) = 37.58, $U = 524.0$, $p = 0.033$.

open learning spaces and flexible classrooms (Brittin et al., 2015; Saltmarsh et al., 2015; Kariippanon et al., 2019).

The contrast to findings in previous studies reporting a decrease of ST may be related to differences in study design, such as the inclusion of SB and PA in an outdoor environment (Lanningham-Foster et al., 2008; Brittin et al., 2017). In contrast to many previous studies, the present study examined only indoor classroom PA and SB whereas previous studies have also included recess times. Higher ST observed in open learning spaces may be related to teaching methods used by the teachers. For instance, if two lessons for separate student groups are held simultaneously in the same large learning space, the teachers may need to restrict students' movement to create a quiet learning setting (Michael et al., 2019). Organizing learning in open learning may create barriers for promotion of PA during lessons. These barriers may include institutional factors such as administrative support, availability of resources or lack of time devoted for movement integration, and personal factors such as training and motivation for movement integration, implementation challenges and personal perceptions of value of PA (Michael et al., 2019).

It should be noted that only the 5th graders showed statistically significant differences in ST and LPA, whereas 3rd graders statistically insignificant differences. Our results indicated that among 5th grade students the number of BST was higher after the renovation than before it, which is in line with previous findings (Brittin et al., 2017). Thus, open learning spaces may facilitate short activity bursts during lessons especially among 5th graders.

The cohort of 3rd grade students assessed after the renovation had higher levels of MVPA than the cohort assessed before the renovation. Therefore, our results suggest that younger students may benefit more from open learning spaces than 5th graders. However, typically only a short durations of higher intensity activities are measured during the in-class time, and any increases in MVPA may be more related to transitions from classroom to recess activities. Because we used teacher-reported schedules to select data for analysis, some transitions may have been included, for example, in cases where the teacher had ended the lesson before the scheduled time, or started the lesson later allowing more time for movement in the classroom.

The strengths of the present study include a design allowing analysis of differences in ST, BST, and PA before and after a major school environment renovation using accelerometers and the possibility to focus on classroom behavior. The major limitation of our study was that the teaching practices with respect to allowing movement were not assessed, and therefore the role of interactions between differences in physical environment and teacher instructions could not be specified. Future studies should seek to investigate teachers' and students' interaction with respect to promoting classroom-based PA in open learning spaces. It is also possible that an open learning space facilitates activities that accelerometers are unable to detect. These types of activities may include teacher organized activities, which comprises tasks like balancing. Possible inaccurate reporting of schedules by teachers and inaccurate reporting of diaries by students may also affect our analysis. Especially recess transitions in and out of the classroom may have variable amounts of MVPA, and these transitions need to be better monitored in further studies. However, this inaccuracy has likely been stable before and after the renovation. The limitation of our cross-sectional study design is that it does not determine cause and effect, and thus, studies utilizing longitudinal randomized controlled trials are warranted. There are many types of definitions for SB measurements and unfortunately, there is no clear consensus about the most valid methods among researchers (Altenburg and Chinapaw, 2015). Therefore, a direct comparison between the present study and previous studies is challenging. Furthermore, our relatively small sample size limits generalization of results and therefore studies with larger samples are warranted. As boys have been shown to have less ST, and more MVPA than girls during school hours (van Stralen et al., 2014; Salin et al., 2019), it should be studied if there are any gender specific differences in classroom-based PA in different types of learning environments.

CONCLUSIONS

Despite the greater ST found in 5th graders, schools with open learning spaces may facilitate BST or MVPA as observed in the 5th and 3rd grade cohorts in open learning spaces compared to the cohorts in conventional classrooms, respectively. As prior studies have reported successful environmental interventions in reducing SB and increasing PA, when coupled with student centered pedagogies, content and methods of teaching may be potentially more important contributors to the classroom PA than the classroom environment *per se*. Therefore, teachers should be encouraged to promote PA and use of student-centered pedagogies during classroom time to facilitate opportunities for children to be physically active. The potential PA-limiting or -promoting teacher practices in different types of learning environments need further investigation. Furthermore, studies utilizing longitudinal randomized controlled trials are warranted.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The University of Jyväskylä Ethics Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

Study was originally designed by A-MP, EL, and TF. Data was collected by EL and AP. Data preparation was made by JH and TR. JH was responsible for statistical analyses and drafting of the paper. All authors provided support for data interpretation, feedback on drafts, and approved the final manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

II

CLASSROOM-BASED PHYSICAL ACTIVITY AND TEACHERS' INSTRUCTIONS ON STUDENTS' MOVEMENT IN CONVENTIONAL CLASSROOMS AND OPEN LEARNING SPACES

by

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ORIGINAL PAPER

Classroom-based physical activity and teachers' instructions on students' movement in conventional classrooms and open learning spaces

Jani Hartikainen[1] · Eero A. Haapala[1,2] · Anna-Maija Poikkeus[3] · Arja Sääkslahti[1] · Arto Laukkanen[1] · Ying Gao[1,4] · Taija Finni[1]

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Abstract

As a result of educational reforms in many countries, including Finland, new or renovated comprehensive schools have increasingly begun to incorporate open and flexible designs and principles. Multipurpose and adaptable open learning spaces can provide children with amplified opportunities to be physically active during general education. Classroom-based physical activity has been associated with better academic-related outcomes and students' on-task behaviour, while overall physical activity has been associated with better health. In the present study, we investigated the effects of classroom type, gender and grade level on classroom-based physical activity, and the associations between systematically-observed teachers' instructions about students' movement and classroom-based physical activity. The participants consisted of 182 3rd and 5th grade students in one school with open learning space and two schools with conventional classrooms. Overall, classroom-based physical activity, assessed with accelerometery, was not higher in open learning space than in conventional classrooms. However, 5th grade students had more sedentary time and less moderate-to-vigorous physical activity in open learning spaces than conventional classrooms, but both 3rd and 5th graders had more breaks from sedentary time in open learning spaces than conventional classrooms. Girls were more sedentary than boys, while 5th graders were less physically active than 3rd graders. Teachers' instructions regarding 5th graders' movement in open learning spaces were more restrictive and both 3rd and 5th graders had more instructed transitions in open learning spaces. In conventional classrooms, students had more teacher-organised physical activity. Teachers' restrictive guidance was associated with less light physical activity, while teachers' organised physical activity was associated with more moderate-to-vigorous physical activity.

Keywords Open learning spaces · Conventional classrooms · Physical activity · Sedentary time · Breaks from sedentary time · Movement integration

Extended author information available on the last page of the article

Introduction

Educational institutions worldwide seek to prepare students across all curriculum areas and learning stages to succeed in a rapidly-changing and interconnected world (Kuhlthau et al., 2015; OECD, 2017). Many countries have undertaken extensive educational reforms of the pedagogical core in which the concept of the school is seen as flexible and innovative learning environment (Deed et al., 2020). This is manifested in the joining of classrooms, utilization of outdoor and informal space, active surfaces, and novel educational technologies (Leiringer & Cardellino, 2011). In Finland, the most-recent curriculum reform of basic education was introduced in 2014 with an emphasis on fostering student autonomy, self-regulated learning, collaboration, and digital competencies (Ministry of Education, 2014).

Physical learning environment is considered as an additional resource contributing to learning outcomes. Schools have begun to replace traditional furniture with flexible furniture that allows multiple reconfigurations to facilitate teaching and learning (Attai et al., 2021). In recent years, new or renovated comprehensive schools in Finland have increasingly incorporated open and flexible designs and principles, with conventional self-contained classrooms (CC) being largely replaced by more-flexible, multipurpose, informal, and transformative open learning spaces (OLS) (Niemi, 2021). Because the learning environment of a school is considered to comprise not only the physical design, but also organization, educational culture, and student dynamics (Gislason, 2010, 2018), novel physical learning environments are envisioned to have systemic effects on the operational culture of the school (Reinius et al., 2021).

Teaching practices are influenced by the physical, social, and cultural landscape of a school (Deed et al., 2020). Working in OLS typically also implies re-distribution of teachers' roles and responsibilities towards teams sharing space and resources (Saltmarsh et al., 2015). The new affordances and pedagogical methods of novel learning spaces encourage teachers to utilize more interactive teaching and collaborative learning (Sigurðardóttir & Hjartarson, 2016). Furthermore, teachers working in OLS have experienced facilitating effects of collaborative learning and emphasised the importance of professional co-planning (Reinius et al., 2021). However, OLS also challenge teachers because they need to balance facilitating autonomous student learning with managing shared spaces and resources in their pedagogical practice (Saltmarsh et al., 2015). Because adaptation to changes in physical learning space is demanding for teachers, sometimes they have continued utilizing the same pedagogical practices that were used in CC (Carvalho & Yeoman, 2018; Niemi, 2021; Saltmarsh et al., 2015; Sigurðardóttir & Hjartarson, 2016). Negative effects include difficulties in changing institutional routines, creating coherent pedagogy for OLS, clashes between the teaching team, and deficiency in teachers' skills for manipulating the environment (Campbell et al., 2013; Deed & Lesko, 2015; Kariippanon et al., 2018). In-depth pedagogical transformations take years rather than months because teachers must change both their classroom practices and own pedagogical thinking (Gislason, 2018).

Open physical space and flexible furniture are presumed to promote student-centred learning (Kariippanon et al., 2018) because students attending schools with OLS are encouraged to work with peers and engage in self-directed learning, as well as being granted more freedom of movement (Saltmarsh et al., 2015). Students studying in learning spaces with flexible furniture have reported greater satisfaction with learning environments than students in classrooms with traditional furniture because the former provide more opportunities for student autonomy (Attai et al., 2021). This is in line with literature indicating that individuals are motivated by being able to exert personal influence over their own behaviours and environment through self-reflective and cognitive self-regulatory processes (Bagozzi, 1992; Bandura et al., 1999). This sense of personal control is often referred to as personal agency (Bandura, 2001). Students' attending open flexible learning spaces have been observed to engage more in collaborative learning activities, such as working in pairs or small groups, while incorporating mobility into their own learning activities and developing agency by choosing how and where to work (Reinius et al., 2021). Thus, OLS can broaden students' possibilities by enabling types of agencies other than the traditional learning environments (Charteris & Smardon, 2018).

Schools can also be considered as feasible sites for interventions aimed at reducing sedentary time (ST) and increasing overall physical activity (PA) because children spend a large proportion of their waking hours at school (Hegarty et al., 2016). PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985), while sedentary behaviour is defined as any waking behaviour characterized by an energy expenditure $\leq$ 1.5 metabolic equivalents, while in a sitting, reclining, or lying posture (Tremblay et al., 2017). Earlier studies have shown that PA is positively associated with children's cognitive functions (Verburgh et al., 2014) and learning outcomes (Bedard et al., 2019). Moreover, higher levels of PA have been associated with better cardiometabolic, vascular, bone and mental health in children and adolescents (Biddle et al., 2019; Janssen & LeBlanc, 2010). Furthermore, current evidence suggests that decreasing ST and duration of sedentary bouts (SB) can confer health benefit regardless of PA (Carson et al., 2016; Saunders et al., 2013). Therefore, public health guidelines recommend that children and adolescents limit their total ST and accumulate a daily average of 60 min of moderate-to-vigorous intensity PA (MVPA) (Bull et al., 2020). However, in many Western countries, children spend 40–60% of their waking time (equal to 5–8 h a day) in being sedentary, and less than half of the children achieve the recommended levels of daily PA (Aubert et al., 2018; Colley et al., 2013; Konstabel et al., 2014; Ortega et al., 2013). Furthermore, European primary school children aged 10–12 years spend 65–70% of their school time in sedentary pursuits and approximately 5% in MVPA, with boys having less ST and more MVPA than girls (Salin et al., 2019; van Stralen et al., 2014). ST increases and MVPA decreases with age in and out of school time, with some evidence suggesting that these changes emerge during early elementary school years (Grao-Cruces et al., 2020; Harding et al., 2015; Jago et al., 2017; Trost et al., 2002).

Studies aimed at reducing sedentary behaviour among children and adolescents in school settings have focused on the physical environment or furniture (Aminian et al., 2015; Clemes et al., 2016), the curriculum (Fairclough et al., 2013), in-class activities (Breslin et al., 2012), homework activities (Kipping et al., 2014), or a mixture of these (Carson et al., 2013; Yıldırım et al., 2014). School interventions including multicomponent approaches (e.g., utilization of a standing desk) have been suggested as being effective for reducing children's ST (Hegarty et al., 2016). Furthermore, current frameworks, such as a Comprehensive School Physical Activity Programs (CSPAP), have emphasised multicomponent approaches for PA interventions, which include PA during the school day, before and after school PA programs, staff involvement and family and community engagement (Carson & Webster, 2020).

During the school day general education classrooms have received increasing attention as possible settings for influencing children's daily PA in addition to physical education classes and recess (Webster et al., 2015). Teachers' actions incorporating PA, at any level of intensity to general education classroom time, is called movement integration (Kohl & Cook, 2013). In practice, movement integration includes PA breaks during and between lessons, teachers' use of PA enabling learning methods, and transitions requiring students to change place from one part of the classroom to another (Russ et al., 2017). Classroom-based physical activity (CPA), defined as PA carried out during the regular class time, can take multiple forms (Watson et al., 2017). Active breaks are defined as short bouts of PA during academic instruction without link to content (Ma et al., 2015). Curriculum-focused active breaks are short bouts of PA that include curriculum content (Mahar et al., 2006), and physically active lessons contain integration of PA in key learning areas other than physical education (e.g., mathematics) (Riley et al., 2016). In addition to potential health benefits, CPA also can have a positive impact on academic-related outcomes and students' on-task behaviour (Goh et al., 2016; Watson et al., 2017). CPA provides possibilities for children to increase energy expenditure, enhance physical competency, diversify social interactions, and ingrain habits of daily PA (Mullins et al., 2019), while studies in CPA have revealed that students enjoyed participating and became more excited about school because of the activities (Barr-Anderson et al., 2011; Gibson et al., 2008). There is some research indicating that health behaviour (i.e., PA and nutrition) can be promoted by interventions that develop personal agency (Contento et al., 2007).

Teachers often experience barriers for movement integration, including both institutional (i.e., administrative support) and personal (i.e., personal perceptions of value of PA) factors (Michael et al., 2019). Therefore, limitations because of space, resources and school interior design can be critical in influencing teachers' possibilities for movement integration (Michael et al., 2019). Because the goals set for the interior design of the OLS bear resemblance to activity permissive classrooms with respect to including ample, multipurpose, and adaptable spaces (Brittin et al., 2015; Saltmarsh et al., 2015), OLS can enhance opportunities to reduce ST, increase breaks from ST (BST), shorten SB durations and increase PA of students. When supplemented with appropriate teaching methods, environments designed to encourage active learning increase PA levels in children compared with traditional classroom environments (Lanningham-Foster et al., 2008). Active school design has been shown to have beneficial effects on sedentary behaviour and light intensity PA (LPA), but not on MVPA (Brittin et al., 2017). Furthermore, elements of flexible learning spaces, including a variety of furniture and resources, and greater use of student-centred pedagogies, facilitate improvements in adolescents' sedentary profiles during class time (Kariippanon et al., 2019).

Direct evidence of actual effects of classroom-design on CPA is still mostly lacking because previous studies have reported use of physically-active or student-centred teaching methods or the combined effects of improved indoor and outdoor facilities (Brittin et al., 2017; Kariippanon et al., 2019; Lanningham-Foster et al., 2008). Physical aspects of learning spaces do not influence PA in the classroom alone, but they exert their influence together with factors related to the school culture and pedagogical solutions (Michael et al., 2019; Russ et al., 2017). Therefore, in this present study, we first investigated differences in CPA among 3rd and 5th grade students in one school with OLS and in two schools with CC. Second, we examined the interactions of classroom type, gender, and grade-level of participant on CPA. Finally, we studied the associations between teacher instructions with respect to students' objectively-assessed CPA.

Table 1 Characteristics of participants and results of physical activity assessments by school and grade-level

Participant characteristics	School A (Open)	School B (Conventional)	School C (Conventional)
3rd Graders			
Participants (n)	36	50	20
Girls (%)	38.9	58.0	55.0
Age (years)	9.3±0.3$^{**/***}$	9.5±0.3$^{*/**}$	9.7±0.3$^{*/***}$
Stature (cm)	136.7±4.3	137.0±4.6	138.4±7.1
Weight (kg)	31.9±5.7	31.5±4.2	33.9±8.3
ISO-BMI (kg/m^2)	21.8±3.6	21.0±2.4	21.8±3.7
ST (%)	57.0±7.6	57.4±9.1	58.0±8.8
LPA (%)	30.9±6.9	29.5±5.4	30.7±7.1
MVPA (%)	12.1±2.2	13.1±5.0	11.4±4.7
BST (breaks/h)	9.5±1.2$^{\dagger\dagger/\dagger\dagger\dagger}$	8.1±1.8†††	8.1±1.6††
AB (s)	77±9‡‡	93±22‡‡	88±21
SB (s)	95±37‡	101±29‡	101±33
5th Graders			
Participants (n)	21	32	23
Girls (%)	47.6	53.0	44.4
Age (years)	11.2±0.3$^{**(A–B)}$	11.5±0.3$^{**(A–B)/**(B–C)}$	11.2±0.3$^{**(B–C)}$
Stature (cm)	147.8±4.8	150.1±7.1	149.1±4.4
Weight (kg)	38.6±5.8	41.1±10.0	41.3±7.9
ISO-BMI (kg/m^2)	21.2±2.4	21.3±3.4	22.2±3.6
ST (%)	67.7±9.1*	62.3±9.3	60.8±9.6*
LPA (%)	24.0±6.7	26.9±6.8	27.3±7.4
MVPA (%)	8.3±2.8‡‡	10.7±4.1	11.8±3.8‡‡
BST (breaks/h)	10.2±1.8$^{\ddagger\ddagger/\ddagger\ddagger\ddagger}$	8.4±1.7$^{\ddagger/\ddagger\ddagger}$	7.8±1.2$^{\ddagger/\ddagger\ddagger\ddagger}$
AB (s)	62±9$^{\ddagger\ddagger\ddagger(A–B, A–C)}$	83±22$^{\ddagger\ddagger\ddagger(A–B)}$	99±21$^{\ddagger\ddagger\ddagger(A–C)}$
SB (s)	114±28	115±36	125±35

Means and standard deviations are shown in table

Because OLS can facilitate CPA by providing flexible classroom layout, it also potentially could facilitate both student-centred and physically-active teaching practices, we hypothesized that students in OLS have less ST, more CPA, and more BST than students in schools with CC. Boys were expected to be more physically active than the girls, while 3rd grade students were more physically active than 5th grade students. Teachers in OLS were expected to enable more freedom of movement during lessons and CC teachers were expected to facilitate CPA with teacher-led PA breaks.

Methods

Participants and procedures

The participants were 3rd and 5th grade students who were recruited on a voluntary basis from 15 classes in three different schools and two different provinces in Finland. Schools were chosen first by permission from principals and teachers, after which students were recruited. Because most Finnish schools contain conventional classroom settings, one school with OLS and two schools with CC were included in this study. The school with OLS was chosen based on a relatively long adjustment time because complete indoor renovation of the school from CC towards OLS. During the time of the data collection, the third academic year had started since the renovation and therefore both teachers and students had time to adjust to these spaces.

A total of 206 students gave consent for participation and accelerometer data were obtained from 197 students. None of the participants reported health-related issues that could potentially affect PA analysis. There were no other exclusion criteria because the sample aimed to be as heterogenous as possible, including students with special education needs. After excluding participants with any missing information (15 cases for age or/and anthropometrics), complete data were available for 182 students (see Table 1 for sample characteristics).

In Table 1, most values represent means and standard deviations. Girls (%) is the percentage of girls in subsample. Age and sex adjusted body mass index (ISO-BMI), which adjusts children's and adolescents' BMI to correspond with adults, was calculated using Finnish references on BMI standard deviation score (Saari et al., 2011). Sedentary time (ST), light intensity (LPA) and moderate-to-vigorous physical activity (MVPA) are represented as the percentage of time spent at given intensity from total classroom time. Breaks from sedentary time (BST) are represented as times per one hour of classroom time. Active (AB) and sedentary bout (SB) durations are represented in seconds during classroom time. Comparisons made for 3rd and 5th grade students separately with either one-way ANOVA with Tukey's HSD test (*$p<.05$, **$p<.01$, ***$p<.001$), Welch's ANOVA with the Games Howell post hoc test ($^{\dagger}p<.05$ $^{\dagger\dagger}p<.01$, $^{\dagger\dagger\dagger}p<.001$) or Kruskal-Wallis test with Mann-Whitney post hoc test using Bonferroni-adjustment ($^{\ddagger}p<.05$, $^{\ddagger\ddagger}p<.01$, $^{\ddagger\ddagger\ddagger}p<.001$).

In School A, 70–80 students attending each of 3rd and 5th grade had most of their lessons in OLS. Both grades had three teachers responsible for teaching the student group of the grade as a collective teacher team. The two grade's open learning environments contained a large space with mobile furniture, which afforded multiple options for classroom layout, as well as a quiet workroom (Fig. 1a). Students did not have an assigned place, such as a

Fig. 1 Illustration of Open Learning Space in School A (a) and Conventional Classrooms in Schools B and C (b & c). The pictures from open learning space show that one large space has several areas for work, allowing a division of the class of about 70–80 students into smaller groups with mobile and dynamic furniture. The pictures from conventional classrooms show smaller self-contained rooms for around 20 students with a designated desk for each student

designated desk, in OLS. The instructional area did not contain instruments and equipment needed for music and crafts lessons, and therefore those lessons were held in their own separate learning space as were physical education lessons. In the other two schools participating in this study (schools B and C), students attended most of their lessons in CC, with designated desks for each student and one teacher responsible for teaching a classroom of 20–25 students (Fig. 1b and c).

The data were collected during 2018–2019, with each participating class of students being assessed once. Assessments were conducted for each class during one school week. On Monday, accelerometers were distributed and anthropometric assessments were obtained from participants. Accelerometers and parent diaries were collected from the participants at the end of the measurement week on Friday. During this school week, teachers' instructions (TI) on student movement were systematically observed in lessons held in the students' own learning space or classroom. Students and their parents or legal guardians kept a diary during the school week of measurement, and a curriculum for the week was provided by the teachers who were used for verification of PA data.

Assessments and data extraction

Anthropometrics

Body weight and stature were assessed using standard procedures. Age and sex adjusted body mass index (ISO-BMI), which adjusts children's and adolescents BMI to correspond to that of adults, was calculated using Finnish references on BMI standard deviation score (Saari et al., 2011).

Physical activity

Accelerometers are used to monitor human movement by providing measures of activity states and rest. CPA, ST, BST, SB, and active bouts (AB) were measured by waist-mounted triaxial accelerometer (RM42, UKK Terveyspalvelut Oy, Tampere, Finland). The measurement range of the accelerometer was ±16 g and the sample rate was 100 Hz with a 13-bit A/D conversion. Only the time that students spent inside the classroom during general education in OLS or CC was included in the analysis, and this was based on the teacher-reported weekly schedule of classroom time. Possible absences from school for individual students (e.g. due to illness or visits to dentists during school hours) were identified from parental diaries and excluded from analysis. The data were first visually inspected to ensure that accelerometers had been worn as reported by the participants. The resultant acceleration of the triaxial accelerometer signal was calculated as $\sqrt{x^2 + y^2 + z^2}$, where x, y and z are the measurement sample of the raw acceleration signal in x-, y-, and z-directions. Mean amplitude deviation (MAD) was calculated from the resultant acceleration in non-overlapping one-second epochs on the supercomputer of CSC, the Finnish IT Center for Science. MAD is described as the mean distance of data points about the mean of the given epoch,

$$\mathrm{MAD} = \frac{1}{n}\sum_{i=1}^{n}\left|r_{i-}\bar{r}\right|$$

where *n* is the number of samples in the epoch, r_i is the i^{th} resultant sample within the epoch and $\bar{r}$ is the mean resultant value of the epoch. The MAD-method used for assessing PA has been shown to be an accurate method across different accelerometer brands (Aittasalo et al., 2015; Vähä-Ypyä et al., 2015a).

MAD-values were averaged over 15-second intervals and used to examine time spent at different PA-intensities on Matlab R2018a (The MathWorks Inc., Natick, MA, USA). Cut-offs were determined as follows: light intensity PA (LPA) 16.7 mg (Vähä-Ypyä et al., 2015a), and MVPA 91 mg (Vähä-Ypyä et al., 2015b). All 15-second intervals that did not meet the LPA-threshold contributed to ST. Time spent at different PA intensities was first calculated as the total number of minutes of measurement week. Then time spent at different intensities was proportioned to total classroom time (i.e., time in lessons). BST were determined as any interruption in ST lasting at least one minute (Altenburg & Chinapaw, 2015; Saunders et al., 2013). BST were expressed as the number of breaks per 60 min of classroom time. AB and SB durations were determined as continuous 15-second epochs using LPA-threshold as a cut-off and were expressed as the average duration of bouts in seconds.

Systematic observation

We utilized a modified observational system validated by Russ et al. (2017) for capturing student's movement in academic routines and transitions. This observation system was modified to capture teachers' instructions (TI) in the classroom with respect to allowing or facilitating student movement. The final TI categories used in this study were selected based on several phases of preliminary testing in which inter-observer reliability was assured. One of the presumed key strengths or promises of OLS over CC is facilitation of and support for student-centred approaches of learning, and greater freedom of students' movement is one component of this type of pedagogy (Kariippanon et al., 2018; Saltmarsh et al., 2015). Observational categories developed to capture teacher management of student movement were developed based on prior suggestions in the literature about movement integration strategies used for transitions and teacher led PA (Russ et al., 2017). Teacher-led PA included all common CPA strategies such as active breaks with and without curriculum content and physically-active teaching methods. It is acknowledged that change of physical environment does not guarantee change in pedagogical practices (Carvalho & Yeoman, 2018; Niemi, 2021; Saltmarsh et al., 2015; Sigurðardóttir & Hjartarson, 2016), and thus observation of teacher instructions regarding student movement was considered a relevant measure impacting student PA independently or having an interactive effect with the type of classroom space where lessons took place.

TIs regarding movement integration were categorised in four categories as follows:

T1. Teacher(s) does not allow movement: Teacher does not allow movement that is not necessary for the task at hand. Example: Teacher does not allow movement, except for students being allowed to go and check the accuracy of their answers from an answer book situated at another side of the classroom without the need to ask for permission separately.
T2. Teacher(s) allows free movement in the classroom: Teacher does not limit students' movement in the classroom. Examples: Students may move around and change places at their own will. Teacher does not instruct students to pick their place or stop movement.
T3. Teacher(s) organises transition: Teacher organises transition that serves an educational purpose, such as students changing working stations or picking up books from lockers.
T4. Teacher(s) organises PA: Teacher organizes PA that is not categorised as T2 or T3. PA can be directed by a teacher, a student, or video.

Three observers were carefully trained to use the observation coding manual, and they needed to pass a rater-reliability check (passing the criteria of adherence to the coding manual) before participating in data collection. TIs were observed in a total of 156 lessons, which included lessons held in the student group's own learning space assigned for that class. Because comparisons were made between schools, lessons held by subject teachers rather than classroom teachers (i.e., subject teachers for English lessons) were included in the analyses to reflect more overall school policies toward CPA.

During a lesson, the TIs towards one student (i.e., a focal student assigned for coding of the specific lesson), were observed using continuous 20-second observation intervals (i.e., three observations in a minute). Within a 20-second interval, researchers coded the current TI towards the observed student using web-based observation software (Moveatis, University of Jyväskylä, Finland). In addition to using the observation software, observers manually filled in sheets to describe the events during lessons. To analyse the observational data, we calculated the percentage prevalence of four observation categories for classroom (averaged across students observed in the lessons of that classroom) in different grade levels and schools.

Statistical analyses

Statistical analyses were mainly carried out using IBM SPSS Statistics 26 –software (IBM corp. Armonk, NY, USA). We used Shapiro-Wilks Test ($p<.05$) for assessing normality of data distribution and Levene's test to estimate homogeneity of variance ($p<.05$) for anthropometric measures and PA-related variables. Outliers were identified and, in two cases, outliers were excluded from analysis because of either accelerometer malfunction or non-wear time, that were not identified at data extraction phase.

We assessed possible differences between students in the three schools for 3rd and 5th graders separately using either one-way ANOVAs with Tukey's HSD post hoc procedures, Welch's ANOVA with the Games Howell post hoc-test or Kruskal-Wallis test with Mann-Whitney post hoc test using Bonferroni-adjustment, with a 0.05 level of significance. Choice of statistical test was determined for each assessed variable separately based on normality and homogeneity of variance. To report effect size, omega squared (ω^2) for one-way ANOVA, adjusted omega squared (est. ω^2) for Welch's ANOVA, and epsilon squared (ε^2) for Kruskal-Wallis H-test were selected.

Three-way factorial ANOVA ($2\times2\times2$) was used to examine the effect of type of classroom (CC vs. OLS), grade level (3rd vs. 5th grade) and gender (boys vs. girls) on classroom PA. Because of violations of normality and homogeneity of variance in MVPA, AB and SB, a robust three-way ANOVA was conducted by using heteroskedasticity-consistent standard errors with HC3 procedure by utilizing R-package *car*. To report effect sizes, partial omega squared (ω_p^2) was utilized. To control the Type I error for multiple testing, accepted *p*-values were adjusted by dividing 0.05 by the number of tests conducted for simple two-way interactions and simple main effects using independent samples *t*-test.

For systematic observation codings, descriptive statistics were calculated, using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA), to determine relative amounts of each TI category for each participating class and across the two grade levels in each school. A chi-square test was utilized to examine grade-matched differences between schools in prevalence of TIs. A Spearman's rank-order correlation was run to assess the relationship between TIs and CPA, because normality of the data could not be assumed for all variables as assessed with the Shapiro-Wilks test ($p<.05$).

Results

Differences between schools

Average stature, weight and ISO-BMI were similar across schools for both 3rd and 5th grade students. Because assessments were conducted progressively during the academic year, there were statistically-significant differences between schools in age of participants in both 3rd and 5th grades. The 3rd grade students in school A were younger than in school B ($p = .001$) and C ($p < .001$), while 3rd grade students in school B were younger than students in School C ($p = .28$). In School A ($p = .001$) and C ($p = .009$), 5th grade students were younger than their counterparts in school B because of the school's position in the assessment schedule within the academic year (Table 1).

There was a statistically-significant difference in average ST ($F(2,73) = 3.286$, $p = .043$, $\omega^2 = 0.06$) and MVPA (H(2) = 11.765, $p = .003$, $\varepsilon^2 = 0.15$) between schools for 5th grade students. Students attending 5th grade in school A with OLS were more sedentary than their counterparts in school C ($p = .046$) and had less MVPA (Mean Rank (A) = 25.88 vs. Mean Rank (C) = 48.63, $p = .002$). For 3rd grade students, ST, LPA and MVPA did not differ statistically significantly between schools (Table 1).

Number of BST was significantly different between schools for 3rd grade students (Welch's $F(2,50.169) = 13.11$, $p < .001$, est. $\omega^2 = 0.19$). Students attending 3rd grade in school A had a higher number of BST than students in school B ($p < .001$) and C ($p = .003$). In addition, 5th grade students' number of BST was different between schools (H(2) = 27.374 $p < .001$, $\varepsilon^2 = 0.36$). In school A, 5th grade students had a higher number of BST than their counterparts in school B (Mean Rank (A) = 57.40 vs. Mean Rank (B) = 37.52, $p = .004$) and C (Mean Rank (C) = 22.61, $p < .001$). In addition, students in school B had more BST than their counterparts in school C (p = .41) (Table 1).

Statistically-significant differences were observed between schools in the average duration of AB (H (2) = 12.816, $p = .002$, $\varepsilon^2 = 0.12$) and SB (H (2) = 9.416 $p = .009$, $\varepsilon^2 = 0.09$) in 3rd grade students. Students in school A had shorter AB (Mean Rank (A) = 38.94 vs. Mean Rank (C) = 56.50, p = .001) and SB (Mean Rank (A) = 40.75 vs. Mean Rank (C) = 58.90, $p = .01$) than students in school C. Furthermore, a significant difference in average AB (H (2) = 31.163 $p < .001$, $\varepsilon^2 = 0.42$) emerged among 5th grade students: students in school A had shorter AB than their counterparts in school B (Mean Rank (A) = 17.52, Mean Rank (B) = 40.88, $p < .001$) and C (Mean Rank (C) = 54.35, $p < .001$) (Table 1).

Interactions between grade, gender, and classroom type for CPA

Table 2 shows the results for each main effect, two-way interaction and three-way interaction in addition to model fit parameters. There were no statistically-significant three-way interactions between grade, gender, and classroom type for CPA, ST, BST, SB, and AB.

There were statistically-significant interactions between grade and classroom type ($\omega_p^2 = 0.02$) and between gender and grade ($\omega_p^2 = 0.02$) for ST. In addition, a statistically-significant mean difference (md) was found in 5th graders' average ST between classroom types (md 6.0%, CI95% [CI95% -1.2,10.8], $t(74)$=-2.507, $p = .014$). Moreover, girls average ST in 5th grade was higher than that of boys (md -6.9%, CI95% [-11.1, -2.8]), t (74) =-3.336, $p = .001$).

Table 2 Three-way ANOVA for between-subjects effects of grade, gender, and classroom type on physical activity variables

		$F(7,174)$						
PA variable	Model fit F/R^2/Adj. R^2	Gender	Grade	Classroom	Gender x Grade	Gender x Classroom	Grade x Classroom	Gender x Grade x Classroom
ST(%)	6.52/0.21/0.18***	9.019**	29.948***	3.991*	4.730*	0.436	5.374*	1.450
LPA(%)	4.27/0.15/0.11***	2.233	21.902***	0.797	7.961**	0.085	4.563*	1.083
MVPA(%)[a]	9.32/0.27/0.24***	25.980***	27.885***	12.949***	0.017	5.608*	3.696	1.299
BST(breaks/h)	7.871/0.24/0.21***	0.257	1.089	48.164***	0.037	2.994	2.744	0.649
AB(s)[a]	12.74/0.34/0.31***	24.036***	14.444***	94.915***	0.191	6.467*	5.798*	1.857
SB(s)[a]	5.182/0.17/0.14***	2.474	15.230***	3.099	5.314*	0.181	0.981	0.499

*$p<.05$, **$p<.01$, ***$p<.001$ [a] Three-way ANOVA was conducted using robust HC3-procedure. Physical Activity (PA) variables include sedentary time (ST), light intensity (LPA), moderate-to-vigorous physical activity (MVPA), Breaks from sedentary time (BST), Active (AB) and sedentary bout (SB) durations

There was a statistically-significant interaction between gender and grade for LPA (ω_p^2=0.04) as girls in 5th grade accumulated less LPA than boys (md 3.9%, CI95% [0.8,7.1], t (74)=2.520, p=.014). The main effect for grade for MVPA (md 2.0%, CI95% [0.9,3.2], p<.001, ω_p^2=0.15) was statistically significant as 3rd graders had higher levels of MVPA compared with 5th graders. A statistically-significant interaction emerged between classroom type and gender (ω_p^2=0.03) for MVPA as boys had less MVPA in OLS than in CC (md 2.6%, CI95% [1.0,4.2] t(88,998)=3.281, p=.001)(Table 2).

The main effect of classroom type on BST was statistically significant (md 1.8 breaks/h, CI95% [-2.3, -1.3], p<.001, ω_p^2=0.21) as students in CC had less BST compared with students in OLS. Statistically significant two-way interactions were observed between grade level and classroom type (ω_p^2=0.03) and between gender and classroom type on AB (ω_p^2=0.03). AB in both 3rd grade (md 15 s, CI95% [8,21], t(99.745)=4.973, p<.001) and 5th grade (md 28 s, CI95% [20,38], t(73.824), p<.001) were shorter than in OLS compared with CC. Both boys (md. 26 s, CI95% [19,33], t(87.755)=7.606, p<.001) and girls (md=15 s, CI95%[9,21], t(71.230)=4.628, p<.001) had longer AB in CC compared with OLS. A statistically-significant two-way interaction was observed between grade and gender (ω_p^2=0.02) for SB as 5th grade boys had shorter SB than 3rd grade boys (md. 21 s, CI95% [-38, -5], t(74)=-2.543, p=.013 (Table 2).

Associations between TIs and CPA

Teachers' instructions prohibited student movement during most of the observed classroom time (i.e., they typically allowed only necessary movement, coded as T1) during 78% (range=51–99%) of the observed classroom time. A much smaller proportion of time, 15% (range=0–46%) of the observed classroom time was used in T2 for which teachers did not limit students' movement in the classroom. On average, 2% (range=0–8%) of the observed time was spent in teacher-directed transitions (coded as T3) and 4% (range=0–11%) in teacher-organized PA (coded as T4). In general, teachers in traditional schools with CC seemed to promote CPA with teacher-organized activity breaks more than in OLS, but there were differences even within the same school and same grade level as seen in Fig. 2.

Prevalence of observed TI categories were significantly different between schools for both 3rd grades (X^2=687.64; df=6 p<.001) and 5th graders (X^2=1011.28; df=6; p<.001). In school A, 5th grade teachers were more restrictive towards students' movement in the classroom (T1=92%) compared with schools B (T1=73%) and C (T1=80%). Fifth-grade students were allowed the most freedom for movement (T2=22%) in school B (see. Table 3) and the least (1%) in school A. Both 3rd and 5th grades, teachers in school A organized a high number of transitions (3rd grade T3=8% and 5th grade T3=6%) compared with schools B (3rd grade T3=1% and 5th grade T3=2%) and C (3rd grade T3=2% and 5th grade T3=3%). Teachers in school A had the least teacher-led PA (3rd grade T4=1% and 5th grade T4=0%), while in school B 3rd grade (T4=6%) and in school C 5th grade teachers (T4=6%), teachers had more PA in the classroom (Table 3).

Examination of associations between the prevalence of TIs and CPA revealed that lower T1 and higher T2 was associated with higher LPA. Higher T4 was associated with more MVPA, while high T3 and T4 were associated with the higher number of BST. Less T3 and more T4 were associated with longer ABs and less T3 was associated with longer SB (Table 4).

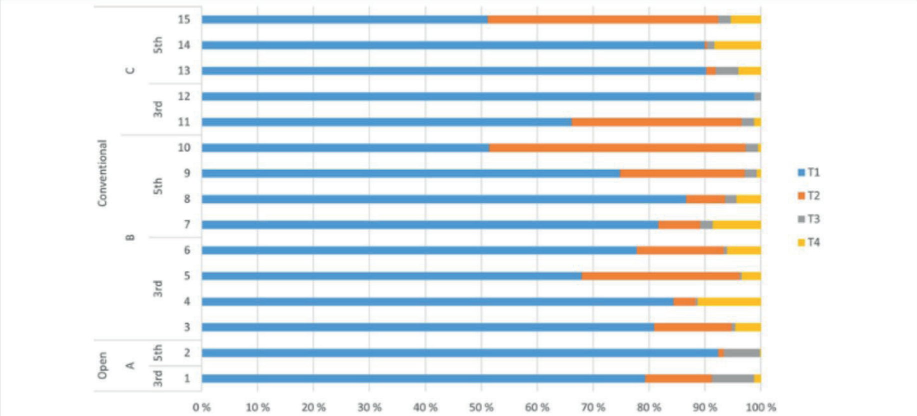

Fig. 2 Relative amounts of observed teachers' (N=15) instructions on students' movement in each participating school (A-C) and grade. Teachers' instruction categories include T1=Teacher(s) does not allow movement, T2=Teacher(s) allows free movement in classroom, T3=Teacher(s) organizes transition, T4=Teacher(s) organizes physical activity

Table 3 Teacher instructions on students' movement in classroom by school and grade-level

School	Environment	Grade	T1(%)	T2(%)	T3(%)	T4(%)
A	Open	3	79	12	8	1
		5	92	1	6	0
B	Conventional	3	78	16	1	6
		5	73	22	2	3
C	Conventional	3	80	17	2	0
		5	80	12	3	6

Values represented are prevalence of individual categories from all observations. *T1=Teacher(s) does not allow movement, T2=Teacher(s) allows free movement in classroom, T3=Teacher(s) organises transition, T4=Teacher(s) organises physical activity.* Prevalence of TIs were significantly different in both 3rd (X^2=687.64; df=6 $p<.001$) and 5th graders (X^2=1011.28; df=6; $p<.001$) in between-school comparisons

Table 4 Spearman correlations r_s (df=182) for teachers' instructions on students' movement categories and classroom-based physical activity

PA variable	T1%	T2%	T3%	T4%
ST	0.077	-0.088	0.036	-0.112
LPA	-0.173*	0.169*	0.037	0.016
MVPA	0.092	-0.082	-0.133	0.276**
BST	-0.151*	0.070	0.384**	-0.356**
AB	0.097	-0.043	-0.387**	0.440**
SB	0.137	-0.114	-0.190*	0.110

*$p<.05$ **$p<.01$. Physical Activity (PA) variables include sedentary time (ST), light intensity (LPA), moderate-to-vigorous physical activity (MVPA), Breaks from sedentary time (BST), Active (AB) and sedentary bout (SB) durations. Teachers' instruction categories include T1=Teacher(s) does not allow movement, T2=Teacher(s) allows free movement in classroom, T3=Teacher(s) organizes transition T4=Teacher(s) organizes physical activity

Discussion

In contrast to our hypothesis, we found that 5th grade students who attended open learning spaces (OLS) had higher levels of ST and lower levels of MVPA, as indicated by accelerometer measurements, compared with students in conventional classrooms (CC), although differences were statistically significant only between school A with OLS and school C with CC. Similar differences were not observed for 3rd grade students and, surprisingly, there were no statistically-significant differences between schools in the accumulation of LPA. Both 3rd and 5th grade students in CC had had less BST and shorter activity bouts (AB) compared with students in OLS. Therefore, the expected positive effect of OLS on overall classroom physical activity (CPA) was not observed, but the organisation of lessons in classrooms with OLS could promote breaks from ST (BST).

In line with previous studies (Salin et al., 2019; Trost et al., 2002; van Stralen et al., 2014), girls had higher ST and lower LPA than boys in 5th grade. Moreover, 3rd graders had higher levels of MVPA compared with 5th graders. Boys had lower levels of MVPA in OLS than in CC, but such differences were not observed among girls. Both boys and girls had longer AB in CC compared with OLS, and 5th grade boys had shorter SB than their girl counterparts. These findings suggest that the effects of gender on CPA classroom-based PA are more significant for older students and the effect of classroom type on classroom PA differs between boys and girls.

In contrast to our hypothesis, observational codings of teacher instructions (TI) showed restrictive guidance of movement regarding 5th graders in school A with OLS. However, in 3rd grade, similar differences in TIs were not observed to the same extent as the prevalence of T1 and T2 were more similar between schools for 3rd graders. In OLS, more transitions were observed compared with CC while, in general, teachers in schools with CC seemed to promote classroom PA with teacher-organized activity breaks more than in OLS. There were, however, differences even within a school and grade level. Because integration of movement in lessons might take multiple forms, such as physically-active transitions and physically-active breaks (Russ et al., 2017), different approaches can be used towards promotion of CPA. Some teachers might choose to break up ST to support students' attention by using transitions to serve academic purposes, whereas some teachers might seek to promote CPA with active breaks with or without curriculum content, depending on their personal views on CPA.

Reasons why teachers might limit PA more in OLS than in CC are unclear. Higher numbers of students in a single space (~ 70 in OLS vs. ~20 in CC) and potential specific features related to organizing learning in OLS or movement integration itself could create barriers for promotion of PA during lessons. These barriers could include institutional factors, such as administrative support, the availability of resources or lack of time devoted for movement integration, and personal factors, such as training and motivation for movement integration, implementation challenges and personal perceptions of the value of PA (Michael et al., 2019). Furthermore, despite the affordances and pedagogical methods that OLS promotes, teachers' adaptation has been demanding and, regardless of change in the physical learning space, pedagogy has not necessarily changed. OLS also might challenge teachers because they need to balance facilitating autonomous student learning and managing shared spaces and resources in their pedagogical practice (Saltmarsh et al., 2015). Even though a few years have passed since indoor renovation of the school with OLS, teachers might not yet have overcome in-depth pedagogical transformation (Gislason, 2018), while they could also be deficient in skills for manipulating the environment, while mastering multiple ongoing engagements (Campbell et al., 2013; Deed & Lesko, 2015; Kariippanon et al., 2018). Therefore, it should be noted that redesign of learning environments does not only affect the spaces, but it challenges teachers' pedagogical approaches and presupposes changes in interactional roles. OLS, such as those in School A, require planning and implementation of team teaching and scaffolding of student collaboration, shared and self-regulated and digitally-mediated learning taking place in parallel in several spaces and in students' small groups with relatively high student autonomy at times. Thus, time of full classroom teacher-directed time is likely to constitute a smaller percentage of learning time than in CC. These changes and their effects on teacher practices and student activity, such as PA, have not yet been studied extensively. While we found no association between TI and ST, less restrictive instruction and teacher-organized PA were linked to higher levels of BST and MVPA, respectively. These findings indicate that more freedom of movement and organized transitions can increase accumulated LPA and BST in particular, while teacher led activities increase MVPA of students. Thus, organized PA could be the most-effective way to promote the MVPA of students and longer activity bouts (AB). Directed transitions might also reduce SB durations.

Student's personal views of CPA and learning spaces were not assessed in this study and therefore we cannot directly evaluate how much students' personal agency influences CPA. Some studies have suggested that students in flexible learning spaces engage more in collaborative learning activities, such as working in pairs or small groups, and they incorporate mobility into their own learning activities and practice agency by choosing how and where they would like to work (Reinius et al., 2021). Furthermore, flexible learning spaces have been reported by students to be more enjoyable, comfortable, and inclusive (Kariippanon et al., 2018). Thus, although the design of the classroom provides affordances for movement and for teachers to incorporate PA in their classroom instruction to allow students to be physically active, they themselves might choose not to be physically active. Based on literature on the strong motivational effects of being able to exert personal influence over one's own behaviours and environment through self-reflective and cognitive self-regulatory processes (Bagozzi, 1992; Bandura et al., 1999), it can be presumed that, to the extent that OLS environments and the concomitant employment of student-centred pedagogy increase students' sense of autonomy, they should facilitate CPA. Future studies should include measures of students' agency experience and personal views of the affordances of learning spaces and support for CPA.

The strengths of present study include a design allowing analysis of device-measured PA during the classroom time and combining it with the observational data on teacher instruction (TI) regarding allowing or supporting student movement. However, because the observation tool used in our study does not capture contextual information on student movement, more studies using such instruments (e.g., the System for Observing Student Movement in Academic Routines and Transitions; Russ et al., 2017), are warranted. Inter-observer reliability was ascertained during preliminary testing, but it should also have been confirmed during assessments, for example, by observing the same student during the same lesson by several observers. Because observers could only observe a limited number of lessons and personnel, this stricter form of inter-rater reliability assessment could not be assessed.

Furthermore, there are many types of definitions for BST, AB, and SB and unfortunately, there is no clear consensus about the most valid operationalization of them among researchers (Altenburg & Chinapaw, 2015) Therefore, direct comparison between the present study and previous studies is challenging. In all observational studies, a major limitation is the Hawthorne effect (i.e., subjects who know they are being observed might behave differently, therefore affecting study outcomes.) To overcome this potential bias researchers visited the school during the recruitment phase to familiarize themselves with participating students and their teachers. During measurement week, as many lessons as possible were observed and details of observation were not revealed to participating students and teachers. Students' personal views on CPA and learning spaces were not assessed in this study and therefore we cannot evaluate how much students' personal agencies influence CPA. Furthermore, as only instructions regarding students' movement were observed, we cannot identify possible rules or restrictions regarding use of furniture, which in turn could influence accumulation of CPA. We did not assess the prevalence of different special education needs, which could have influenced the instructions provided by the teacher and thereby the CPA. Moreover, because we recruited the participants on a voluntary basis, it is possible that the volunteers were not completely representative of the whole populations within the specific schools. Our sample of 182 children from three different schools and separate 15 classes did not allow use of sophisticated multilevel modelling such as hierarchical linear regression, which would have enabled multilevel examination of individual students CPA variables and group-level TIs. Finally, larger-scale studies are warranted because only one school with OLS was included in this study, while our sample compromised relatively small subgroups and unequal gender distribution which could have influenced results and their generalisability.

Conclusions

Contrary to the hypothesis, the expected benefits of OLS on CPA were not observed in this study, while OLS seemed to contribute to a higher amount of ST. Observed higher levels of ST and lower levels MVPA among 5th grade students in OLS could be related to more restrictive teacher instructions than the type of classroom per se. Because teachers play an important role in reducing ST and increasing CPA, intrapersonal and institutional barriers and contextual and pedagogical effects for movement integration should be examined. Studies with larger sample sizes enabling multilevel modelling and providing contextual information of movement integration in OLS are warranted. Assessment of students' personal views and agencies on CPA should be included in future studies.

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Availability of data and materials The datasets used and/or analysed during the current study are available from the corresponding author on request.

Declarations

Competing interests The authors declare that they have no competing interests.

Ethics approval The University of Jyväskylä Ethics Committee has approved the research protocol.

Consent to participate Students and their parents or legal guardians gave their written informed consent for the students' participation in the study.

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Authors and Affiliations

Jani Hartikainen[1] · Eero A. Haapala[1,2] · Anna-Maija Poikkeus[3] · Arja Sääkslahti[1] · Arto Laukkanen[1] · Ying Gao[1,4] · Taija Finni[1]

✉ Jani Hartikainen
jani.p.hartikainen@jyu.fi

[1] Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

[2] Institute of Biomedicine School of Medicine, University of Eastern Finland, Kuopio, Finland

[3] Department of Teacher Education, University of Jyväskylä, Jyväskylä, Finland

[4] Department of Sports Science, College of Education, Zhejiang University, Hangzhou, China

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ASSOCIATIONS OF CLASSROOM DESIGN AND CLASSROOM- BASED PHYSICAL ACTIVITY WITH BEHAVIORAL AND EMOTIONAL ENGAGEMENT AMONG PRIMARY SCHOOL STUDENTS

by

Hartikainen, J., Poikkeus, A-M., Haapala, E.A., Sääkslahti, A., & Finni, T.
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Article

Associations of Classroom Design and Classroom-Based Physical Activity with Behavioral and Emotional Engagement among Primary School Students

Jani Hartikainen [1,*], Anna-Maija Poikkeus [2], Eero A. Haapala [1,3], Arja Sääkslahti [1] and Taija Finni [1]

[1] Faculty of Sport and Health Sciences, University of Jyväskylä, 40014 Jyväskylä, Finland; eero.a.haapala@jyu.fi (E.A.H.); arja.saakslahti@jyu.fi (A.S.); taija.m.juutinen@jyu.fi (T.F.)
[2] Department of Teacher Education, University of Jyväskylä, 40014 Jyväskylä, Finland; anna-maija.poikkeus@jyu.fi
[3] Institute of Biomedicine, University of Eastern Finland, 70211 Kuopio, Finland
* Correspondence: jani.p.hartikainen@jyu.fi; Tel.: +358-406-260-393

Abstract: Educational reforms worldwide have resulted in schools increasingly incorporating open and flexible classroom designs. Open learning spaces may contribute to a student's behavioral and emotional school engagement directly and by facilitating classroom-based physical activity (CPA). We investigated the associations between accelerometer-assessed CPA and student ratings of task-focused behavior and attitude towards school as indicators for behavioral and emotional engagement, respectively, with the associations of gender, grade, and classroom design on CPA among 206 3rd and 5th grade students in open learning spaces and conventional classrooms. Structural equation modelling showed open classroom design to be directly associated with better attitude towards school (B = −0.336; CI95% −0.616 to −0.055), but not with task-focused behavior. The relationship between task-focused behavior and attitude towards school was statistically significant (B = 0.188; 95%CI 0.068 to 0.031). CPA was not associated with task-focused behavior and attitude towards school, while classroom design (B = 1.818; 95%CI 1.101 to 2.536), gender (B = 1.732; 95%CI 20 1.065 to 2.398), and grade (B = 1.560; 95%CI 0.893 to 2.227) were statistically significantly associated with CPA. Open learning spaces seem to be associated with better emotional engagement, which is associated with behavioral engagement. Longitudinal studies investigating associations of open learning spaces and CPA on students' behavioral, emotional, and cognitive engagement concurrently are warranted.

Keywords: classroom; open learning space; physical activity; school engagement; behavioral engagement; emotional engagement

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1. Introduction

Based on educational reforms in countries worldwide, including for example Finland, the United Kingdom, Germany, and Spain, schools have increasingly begun to incorporate non-partitioned, open, and flexible designs and principles with an emphasis on fostering student autonomy, self-regulated learning, collaboration, and digital competences [1–3]. After the most recent curriculum reform of Finnish basic education was introduced in 2014 (issued in 2016), conventional self-contained classrooms have increasingly been replaced by more flexible, multipurpose, informal, and transformable open learning spaces [2,4]. Students attending schools with open learning spaces are typically encouraged to collaborate with peers, engage in self-directed learning, and optimally are also granted greater freedom of movement [1]. For teachers, working in open learning spaces typically also implies re-distribution of roles and responsibilities towards working as a team sharing space and resources [1,2]. Working in open learning spaces may also challenge teachers, as they need to balance between facilitating autonomous student learning, while managing shared spaces and resources in their pedagogical practice [1].

School engagement is typically conceptualized as a multidimensional construct including behavior, emotions, and cognitions, which are considered interrelated [5–8]. Students' behavioral engagement refers to the range of actions that reflect involvement in school activities and it is commonly assessed via indicators of students' classroom behavior, time on-task, and concentration [5]. Emotional engagement and disengagement encompass positive and negative affective reactions to school, such as enjoyment and experience of belonging, while cognitive engagement refers to investment in learning, which involves motivation, strategic learning skills, and problem solving [5]. Behavioral and emotional engagement have been suggested to be related bidirectionally, while behavioral engagement influences cognitive engagement [9].

The varied, adaptable, and flexible learning spaces, coupled with the use of student-centered pedagogies, are expected to facilitate a higher proportion of class time with students interacting, collaborating, and engaging with the lesson content, which may, in turn, translate into beneficial long-term learning outcomes [10]. Classroom design is posited to foster engagement through low-cost learning tools, and a flexible, open, student-centered space may afford a variety of active learning strategies [11]. Furthermore, open learning spaces may enhance opportunities to increase classroom-based physical activity among students, as the goals set for interior design of the open learning space bear resemblance to activity permissive classrooms with respect to including multipurpose and adaptable spaces [1,12].

Higher levels of physical activity, defined as any bodily movement produced by skeletal muscles that results in energy expenditure, have been associated with better cardiometabolic, vascular, bone, and mental health in children [13–15]. Furthermore, decreasing sedentary time and duration of sedentary bouts may confer health benefits regardless of the type of physical activity [16–19]. Thus, public health guidelines recommend that children and adolescents should accumulate on average 60 min of moderate-to-vigorous physical activity daily and engage in limited total sedentary time [20]. Children are shown to spend 40 to 60% of their waking time, equaling 5 to 8 h day, in sedentary pursuits, and less than half of the children in Western countries achieve the recommended levels of daily PA [21–24]. European primary school children aged 10–12 years have been reported to spend 65 to 70% of their school time sedentary and approximately 5% in moderate-to-vigorous physical activity, boys accumulating less sedentary time and more moderate-to-vigorous physical activity than girls [25,26]. Current evidence suggests that both in and out of school time sedentariness increases, while moderate-to-vigorous physical activity decreases, and these changes emerge from the early elementary school years [27–30].

In addition to various physical and mental health benefits, habitual physical activity has positive relationships to cognitive functioning among youth [14,15], while there is some evidence that classroom-based physical activity has a positive impact on academic-related outcomes and students' on-task behavior [31,32]. Current evidence suggests that students who are physically more active are also more engaged in their classroom lessons, with increased engagement considered as a possible mechanism by which physical activity could have a positive influence on academic achievement [32–34]. Physical activity integrated with instruction of academic subjects can positively impact children's academic motivation, however, it is not possible to draw definitive conclusions about this link due to the level of heterogeneity in the assessment of intervention components of classroom-based physical activity and academic-related outcomes [32]. Thus, objective (i.e., device-assessed) measures of physical activity are warranted [32,35]. Furthermore, there seems to be only a few studies examining associations of physical activity on emotional and cognitive engagement [36], while there seems to be a single study examining associations of physical activity on behavioral, emotional, and cognitive engagement all together [33]. There is some evidence that emotional engagement can be improved by integrating physical activity into classroom lessons [35], while moderate-intensity activity prior to mathematics lessons could improve students' cognitive engagement [33].

Current information is limited on the extent to which open learning spaces exert direct and indirect effects via classroom-based physical activity on student' school engagement. As behavioral engagement and emotional engagement have been shown to be related bidirectionally and behavioral engagement to influence cognitive engagement [9], while classroom-based physical activity seems to be associated with mainly behavioral and emotional engagement [32,35], the associations of accelerometer-assessed classroom-based physical activity and student ratings of task-focused behavior and attitude towards school as indicators for behavioral and emotional engagement, respectively, were investigated. Furthermore, associations of gender, grade, and classroom type on classroom-based physical activity were investigated.

2. Materials and Methods

Data for this study were collected from 15 classrooms of 3rd and 5th grade students from three different schools and two different provinces in Finland. Schools were chosen first on voluntary basis first by permission from principals and teachers, after which students were recruited. In one of the schools, the students attending 3rd and 5th grades, 70–80 students in each grade, had most of their lessons in open learning spaces. Both grades had three teachers responsible for teaching the student group of the grade as a collective teacher team. The open learning environments of each grade contained a large space with mobile furniture which afforded multiple options for classroom layout, as well as a quiet work room. Students did not have an assigned place, such as a designated desk, in the open learning space. The school with open learning spaces was chosen as we have previously conducted a study in same school before and after renovation from conventional classrooms to open learning spaces [37]. In the other two schools, students attended most of their lessons in conventional classrooms with designated desks for each student and one teacher was responsible for teaching a classroom of 20–25 students. Figure 1 illustrates an example of an open learning space and a conventional classroom.

Figure 1. Illustration of open learning space (**left**) and conventional classroom (**right**). The picture from the open learning space shows one of the several areas for work allowing division of the class of about 70–80 students to smaller groups with mobile and dynamic furniture. The picture of a conventional classrooms represents the typical smaller self-contained rooms for around 20 students with a designated desk for each student.

The data were collected during years 2018–2019 and each participating class was assessed once during the data collection. Assessments were conducted for each class during one school week. On Monday, accelerometers were distributed for students to use continuously during the measurement week and anthropometric assessments were obtained from the participants. Body weight and stature were assessed using standard procedures. Age- and sex-adjusted body mass index (ISO-BMI), which adjusts children's and adolescents BMI to correspond to that of adults, was calculated using Finnish references on BMI standard deviation score [38]. During the measurement week, students filled out the school engagement rating scale. Students and their parents or legal guardians kept a diary during the school week of measurement. Classroom teachers were asked to provide a curriculum of the activities for the week. Accelerometers and diaries were collected from the participants at end of the measurement week on Friday. During the measurement weeks, contents of instruction followed the curriculum of the grades in question and instruction was not in any way altered by the researchers.

Physical activity was measured by a waist mounted triaxial accelerometer (RM42, UKK Terveyspalvelut Oy, Tampere, Finland, Range ±16 g, sample rate: 100 Hz, A/D conversion: 13-bit). Data included in the analyses were determined based on the teacher-reported weekly schedule of classroom time. Only the time spent inside in the classroom during times of general education was included in the analysis, while Physical Education lessons and recess were excluded. Furthermore, possible absences from school, for example due to illness or visits to health care appointments during school hours, were identified from diaries and excluded from the analysis.

The data were first visually inspected to ensure that accelerometers were worn as reported by the participants. The resultant acceleration of the triaxial accelerometer signal was calculated as $\sqrt{x^2 + y^2 + z^2}$, where x, y, and z are the measurement samples of the raw acceleration signal in x-, y-, and z-directions. Mean amplitude deviation (MAD) was calculated from the resultant acceleration in non-overlapping 1 s epochs on the supercomputer of CSC, the Finnish IT Center for Science. MAD is described as the mean distance of data points about the mean of the given epoch,

$$\text{MAD} = \frac{1}{n}\sum_{i=1}^{n}|r_i - \overline{r}|$$

where n is the number of samples in the epoch, r_i is the i th resultant sample within the epoch, and $\overline{r}$ is the mean resultant value of the epoch. The MAD-method used for assessing physical activity has been shown to be an accurate method across different accelerometer brands [39,40].

MAD values were averaged over 15-s intervals with Matlab R2018a (The MathWorks Inc., Natick, MA, USA). The cumulative sum of 15-s intervals was calculated in G for each participant and divided by the duration of time spent in the classroom to calculate physical activity level for each participant for the whole school week. Total physical activity level was expressed as accumulated G per 60 min spent in classroom to be used as a single parameter for structural equation modeling. The method captured the overall intensity of movement throughout the entire school week. As students tend to be sedentary for the majority of their time during school days [25], this method provides a finer granularity of physical activity, while the method has been used in a study investigating associations of office workstation type on physical activity and stress [41]. An analysis method that does not require the use of fixed cut-offs was chosen as increasing evidence suggests that estimating physical activity intensities using specific fixed thresholds could cause remarkable errors in intensity estimation between individuals and, for example, underestimate moderate and vigorous intensity activity in low fit and less motorically competent children [42–44].

Children's engagement was assessed using two scales. Task-focused behavior as an indicator of behavioral engagement was assessed with a scale based on the Achievement Beliefs Scale for Children, which has been used to assess primary school students in Finland [45–47]. Children were presented with seven statements regarding their typical task motivation with respect to approaching or avoiding challenging academic tasks (e.g., "I enjoy working with challenging school tasks"; "Difficult tasks make me try hard"). Attitude towards school as an indicator of emotional engagement was assessed using three statements regarding their typical thoughts about school (e.g., "It is nice to come to school"). Answers were coded on a Likert scale 1–5 with a higher value presenting higher task focused behavior or a more positive attitude towards school. Negatively worded statements were reverse-coded. The internal consistency of items as assessed with Cronbach's alpha was 0.799 for task-focused behavior and 0.677 for attitude towards school.

Structural equation modeling was chosen as a statistical analysis method as it can be used to study the relationships among latent constructs that are indicated by multiple measures [48]. Furthermore, this multivariate statistical analysis technique allowed for the exploration of complex relationships between types of classrooms, individual characteristics, physical activity, task-focused behavior, and attitude towards school with a single model [48]. Task-focused behavior (seven items) and attitude towards school (three items) were modeled each as a latent construct, and all the other constructs in the structural model were directly assessed. Our hypothesized model is illustrated in Figure 2.

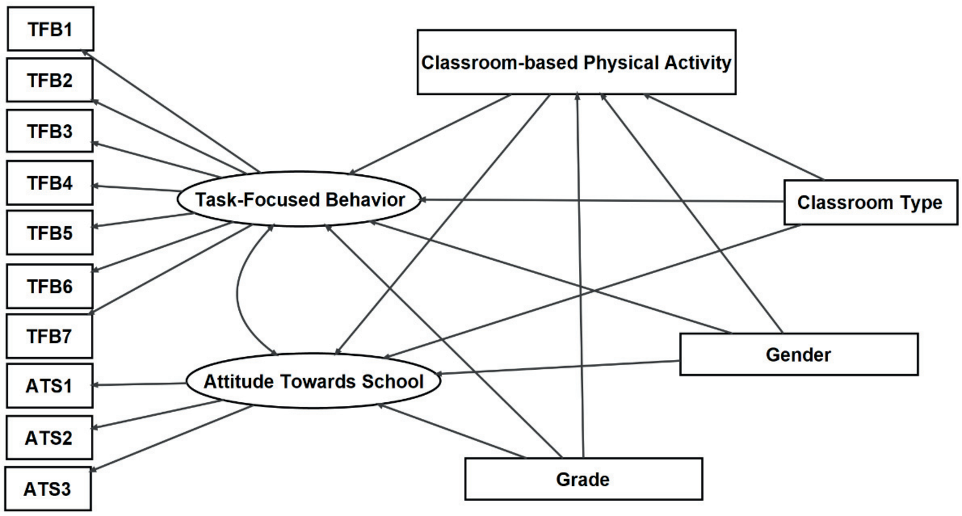

Figure 2. The hypothesized structural equation model. Latent factors are represented as ovals and observed variables as rectangles. Straight lines indicate hypothesized paths and curved lines indicate covariance between variables. TFB = task-focused behavior, ATS = attitude towards school. Grade: 5th vs. 3rd grade, gender: girls vs. boys, and classroom type: open learning space vs. conventional classroom. Comparative Fit Index: 0.764; Standardized Root Mean Square Residual: 0.130.

The lavaan package in R was used for model fit and validation. Full information maximum likelihood estimation was used to estimate the significant path coefficients in the model. Missing values were not replaced or imputed but handled within the analysis model. The Comparative Fit Index and Standardized Root Mean Square Residual were used to estimate model fit. The hypothesized model exhibited poor model fit as Comparative Fit Index was 0.764 and Standardized Root Mean Square Residual was 0.130. To achieve the recommended levels on the Comparative Fit Index (>0.95) and Standardized Root Mean Square Residual (<0.08), covariances between items assessing latent constructs were added by estimating modification indices and adding covariances with highest modification indices one at a time.

3. Results

3.1. Participants

A total of 206 students gave consent for participation representing approximately 50% of the students attending classes where recruitment took place. From this sample, questionnaire ratings were obtained from 204 students and physical activity assessments from 195 students. Participant characteristics and descriptive data for measures of interest are provided in Table 1.

Table 1. Participant characteristics and descriptive data.

School Classroom Type	Missing N (%)	All	School 1 Open		School 2 Conventional		School 3 Conventional	
Grade			3rd	5th	3rd	5th	3rd	5th
N		204	40	26	52	34	25	27
Girls (%)			40	50	59.6	52.9	44	44.4
Age (y)	10 (4.9)	10.3 (1.0)	9.3 (0.3)	11.2 (0.3)	9.5 (0.3)	11.5 (0.3)	9.7 (0.3)	11.2 (0.3)
Height (cm)	3 (1.5)	142.4 (8.2)	136.5 (4.5)	148.0 (5.2)	137.0 (4.6)	150.2 (6.9)	139.0 (6.8)	149.2 (6.0)
Weight (kg)	3 (1.5)	36 (8.6)	31.8 (5.6)	39.5 (6.7)	31.6 (4.2)	41.0 (9.7)	34.8 (9.8)	41.7 (10.0)
ISO-BMI (kg/m^2)	10 (4.9)	21.5 (3.1)	21.7 (3.5)	21.4 (2.5)	21.0 (2.4)	21.3 (3.4)	21.7 (3.5)	22.2 (3.7)
TFB (mean score; 1 to 5)	1 (0.5)	3.7 (0.8)	3.8 (0.6)	3.6 (0.8)	3.6 (0.8)	3.6 (0.7)	3.9 (0.7)	3.6 (0.9)
ATT (mean score; 1 to 5)	1 (0.5)	3.9 (0.8)	4.2 (0.8)	4.1 (0.5)	3.7 (0.8)	3.7 (0.8)	4.1 (0.8)	3.8 (0.9)
CPA (G/60 min)	9 (4.4)	9.568 (2.709)	9.493 (1.809)	6.966 (1.891)	10.085 (2.879)	9.016 (2.823)	10.345 (3.227)	9.846 (2.066)

Values presented are means and standard deviations. Girls (%) refers to percentage of girls. Age- and sex-adjusted body mass index (ISO-BMI), which adjusts children's and adolescents BMI to correspond with adults, was calculated using Finnish references on BMI standard deviation score [35]. Mean scores for task-focused behavior (TFB) assessed with seven items and attitude towards school (ATT) assessed with three items on a 5-point Likert-scale (Cronbach's α TFB = 0.799, ATT = 0.677). Classroom-based physical activity (CPA) assessed with mean amplitude deviation method (40) and expressed as accumulated G per 60 min spent in classroom.

3.2. Structural Equation Model Results

The final model is shown in Figure 3. The hypothesized and final models were compared using the Chi-squared difference test which indicated significant (Chi-squared difference = 313.62, df = 6, $p < 0.001$) improvement with model fit. The final model exhibited good model fit with a Comparative Fit Index of 0.977 and a Standardized Root Mean Square Residual of 0.079. In Figure 3, solid lines represent significant paths ($p < 0.05$) with unstandardized coefficients shown with their standard errors (dotted lines represent nonsignificant paths). Curved lines indicate covariance between variables.

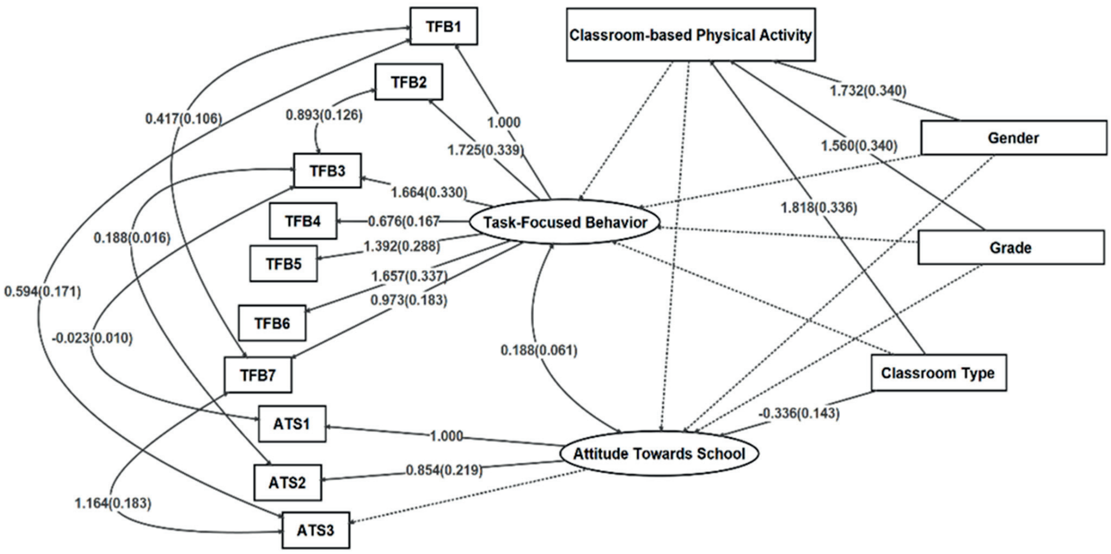

Figure 3. Structural equation model results. Latent factors are represented as ovals and observed variables as rectangles. Solid lines represent significant ($p < 0.05$) (and dotted lines nonsignificant paths), the former include unstandardized coefficients (and standard errors). Curved lines indicate covariance between variables. TFB = task-focused behavior, ATS = attitude towards school. Grade: 5th vs. 3rd grade, gender: girls vs. boys, and classroom type: open learning space vs. conventional classroom. Comparative Fit Index: 0.977; Standardized Root Mean Square Residual: 0.079.

Classroom type was associated with student ratings of attitude towards school (B = −0.336; CI95% −0.616 to −0.055) with students in open learning spaces reporting a more positive attitude towards school than students in conventional classrooms. Classroom type was not associated with task-focused behavior. Relationship between task-focused behavior and attitude towards school was statistically significant (B = 0.188; 95%CI 0.068 to 0.031).

Classroom-based physical activity was not associated with task-focused behavior and attitude towards school, while classroom-based physical activity was associated with grade, gender, and classroom-type. Third grade students were more physically active than 5th graders (B = 1.560; 95%CI 0.893 to 2.227), while boys were more physically active than girls (B = 1.732; 95%CI 1.065 to 2.398). Students in conventional classrooms were more physically active than students in open learning spaces (B = 1.818; 95%CI 1.101 to 2.536).

4. Discussion

One of the goals of designing schools with open learning spaces is to allow for and foster student collaboration, self-regulated learning, and autonomy [1]. It can be presumed that students in these environments may be more inclined than in conventional classrooms to experience emotional engagement as indicated by a positive attitude towards school and higher task motivation (i.e., task-focused behavior). We found an association between classroom type and students' self-reported attitude towards school favoring open learning environments, but the association between classroom type and task-focused behavior was not statistically significant. Attitude towards school was, however, associated with task-focused behavior, which supports interrelatedness of these dimensions reflecting school engagement and motivation [5]. These findings suggest that classroom design itself does not have direct strong links with students' task-focused behavior which may, however, be influenced indirectly via attitude toward school as behavioral and emotional engagement have been shown to be related bidirectionally [9].

Classroom-based physical activity was not associated with task-focused behavior or attitude towards school. This finding contradicts our hypotheses and previous findings that have suggested that students who are physically active in classroom are more engaged in their classroom lessons [32,34,35]. This contradictory finding may be caused by different approaches on classroom-based physical activity as it can take multiple forms such as active breaks with or without curriculum content and physically active lessons [32]. Therefore, suggested associations between classroom-based physical activity and school engagement may be related to promotion of different types of classroom-based physical activity rather than sheer amount of classroom-based physical activity. Although the dimensions of school engagement, emotions, behavior, and cognitions are considered to be interrelated, they are typically assessed as separate constructs, and it is possible that different types, intensities, and frequencies of physical activity are beneficial for different dimensions of school engagement [33,36].

Students were physically less active in open learning spaces, which contradicts our hypotheses that open learning spaces should enable more classroom-based physical activity. We have previously observed that open learning spaces were not associated with less sedentary time, while they may facilitate breaks from sedentary time and moderate-to-vigorous physical activity [37]. These findings may be related to either challenges in utilizing these novel spaces or barriers for promoting classroom-based physical activity. We observed that teachers' adaptation has been demanding and regardless of change in the physical learning space, teachers have continued utilizing same pedagogical practices that were used in conventional classroom settings [1,2,49,50]. Furthermore, difficulties in changing institutional routines, creating coherent pedagogy for open learning spaces, clashes between the teaching team, and deficiency in teachers' skills for manipulating the environment, while mastering multiple ongoing engagements have been reported as negative outcomes during implementation of open learning spaces [51–53]. Additionally, barriers for organizing classroom-based physical activity include both institutional, i.e., administrative support, and personal, i.e., personal perceptions of value of physical activity, factors [54], that were not investigated in this study.

Both findings that open learning spaces were not associated with more classroom-based physical activity and that classroom-based physical activity was not associated with school engagement may be partly explained by the already active promotion of overall school-based physical activity in Finland. The national action program, Finnish Schools on the Move, aiming to establish a physically active culture in Finnish comprehensive schools, is already widespread across the country as approximately 90% of Finnish elementary schools and 95% of pupils are involved in the program [55]. Thus, the majority of Finnish children are already participating in this nationwide program, which potentially reduces disparities in school-based physical activity between students in different schools. Reduced disparities in physical activity may cause statistical analyses to be unable to detect the relationship between physical activity and school engagement. Furthermore, possible active promotion of classroom-based physical activity, regardless of classroom type, may influence our results. As schools and municipalities participating in the program implement their own plans to enhance physical activity during the school day, mostly during recess and academic lessons [55], there may be significant differences in the activities performed during the school week, which were not controlled in this study.

The methodology used for assessing both school engagement and classroom-based physical activity pose both strengths and limitations for this study. Studies assessing school engagement, academic achievement, and classroom-behavior have used various outcome measures such as questionnaires, direct observation, and standardized tests [32]. The use of student-reported task-focused behavior limits comparisons between other studies; a lot of studies in this field use observation to assess time on-task [32]. Furthermore, as students' ratings for task-focused behavior and attitude towards school were used, it is possible that those ratings were subject to social desirability, although the scales utilized produced internally consistent scores.

Physical activity itself can be assessed in multiple ways such as via questionnaires, direct observation, and accelerometer assessments, which makes comparison of different studies difficult. This study used device-assessed measures of classroom-based physical activity and thus measures of physical activity were not influenced by students' abilities to recall or estimate the frequency and intensity of their physical activity. Furthermore, as increasing evidence suggests that estimating physical activity intensities using specific fixed thresholds could cause remarkable errors in intensity estimation between individuals [42–44], a method that does not use of fixed cut-offs was used. In turn, as we assessed only accelerometer-derived data, we do not have information on the forms of classroom-based physical activity and the extent to which physical activity was promoted during general education.

Structural equation modeling was chosen as a statistical analysis method as it can be used to study the relationships among latent constructs that are indicated by multiple measures, and it allows for the exploration of complex relationships between types of classrooms, individual characteristics, physical activity, task-focused behavior, and attitude towards school with a single model [48]. As our sample size was relatively small, the number of variables that we could include in the structural equation model was prioritized to those with the strongest theoretical relevance and support from prior findings, and covariates were limited to a minimum required to achieve sufficient model fit. Furthermore, our sample size of 15 classes and unbalanced design, that included one school with open learning space and two schools with conventional classroom, reduces statistical power and possibilities for clustering students within classes and schools for using a more sophisticated approach such as multilevel structural equation modeling [56].

Our model did not include an indicator for cognitive engagement, as we hypothesized behavioral engagement and emotional engagement to be related bidirectionally and behavioral engagement to influence cognitive engagement [9]. Furthermore, as classroom-based physical activity seems to be associated with behavioral and emotional engagement [32,35], these dimensions of school engagement were investigated. As school engagement is typically conceptualized as a multidimensional construct including behavior, emotions, and cognition, which are considered interrelated [5–8], future studies should seek to examine all these dimensions concurrently. Furthermore, our model did not include an assessment of socioeconomic status, which may have an influence especially on the academic achievement of students, although the magnitude of such associations depends on the social context and education system [57]. As the vast majority of research has focused on associations of socioeconomic status and academic achievement rather than school engagement, the assessment of family-level or school-level socioeconomic status was not included in the model.

Other limitations of this study include that this was a cross-sectional study without an intervention so we cannot confirm any causal relationships between the assessed variables. Therefore, studies utilizing longitudinal settings are warranted. As recruitment of this study was based on voluntary participation, there is a risk for volunteer or self-selection bias meaning that those students and their parents that were interested in physical activity, school engagement, and learning spaces were most likely to participate in our study [58]. As only approximately 50% students in participating classes volunteered, our sample does not necessarily fully represent all students and particularly those with low interest in the topic of our study. Furthermore, we did not consider participants' medical background in the presence of conditions, such as attention deficit hyperactivity disorder, influencing academic achievement, and potentially also school engagement [59].

Future research should seek to investigate the effects of open learning spaces and classroom-based physical activity on students' behavioral, emotional, and cognitive engagement concurrently in longitudinal settings. Additionally, effects of different types, intensities, and frequencies of classroom-based physical activity school engagement should be studied more extensively. As open learning spaces were not associated with more classroom-based physical activity, the potential differences in teacher practices in terms of classroom-based physical activity between different types of learning space require further investigation. Further development of teacher practices and school policies is crucial to further capitalize on the full potential of these open learning spaces in terms of both pedagogical goals and classroom-based physical activity to promote school engagement, which could extend further into beneficial long-term learning and health outcomes.

5. Conclusions

The findings of the present study indicated that classroom type was associated with students' emotional engagement, with students in open learning spaces reporting higher emotional engagement. Moreover, attitude towards school was associated with behavioral engagement. Classroom-based physical activity was not associated with either behavioral or emotional engagement, but classroom-based physical activity was associated with classroom type, gender, and grade. Longitudinal studies investigating associations of open learning spaces and classroom-based physical activity on students' behavioral, emotional, and cognitive engagement concurrently are warranted. Furthermore, the differences in teacher practices in terms of classroom-based physical activity between different types of learning space require further investigation.

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Institutional Review Board Statement: The University of Jyväskylä Ethics Committee has approved the research protocol.

Informed Consent Statement: Students and their parents or legal guardians gave their written informed consent for the students' participation in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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IV

SEDENTARY PATTERNS AND SIT-TO-STAND TRANSITIONS IN OPEN LEARNING SPACES AND CONVENTIONAL CLASSROOMS AMONG PRIMARY SCHOOL STUDENTS

by

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Article

Sedentary Patterns and Sit-to-Stand Transitions in Open Learning Spaces and Conventional Classrooms among Primary School Students

Jani Hartikainen [1,*], Eero A. Haapala [1,2], Arja Sääkslahti [1], Anna-Maija Poikkeus [3] and Taija Finni [1]

[1] Faculty of Sport and Health Sciences, University of Jyväskylä, 40014 Jyväskylä, Finland; eero.a.haapala@jyu.fi (E.A.H.); arja.saakslahti@jyu.fi (A.S.); taija.m.juutinen@jyu.fi (T.F.)
[2] Institute of Biomedicine, University of Eastern Finland, 70211 Kuopio, Finland
[3] Department of Teacher Education, University of Jyväskylä, 40014 Jyväskylä, Finland; anna-maija.poikkeus@jyu.fi
* Correspondence: jani.p.hartikainen@jyu.fi

Abstract: Educational reforms worldwide have resulted in schools increasingly incorporating open and flexible classroom designs that may provide possibilities to reduce sedentary behavior among students during lessons. Cross-sectional associations of classroom type on accelerometry assessed sedentary bout durations and sit-to-stand transitions were investigated in 191 third and fifth grade students recruited from one school with open learning spaces and two schools with conventional classrooms. A three-way ANOVA for classroom type, gender and grade level indicated that students in open learning spaces had more 1-to-4-min sedentary bouts (mean difference 1.8 bouts/h, $p < 0.001$), fewer >10-min sedentary bouts (median 0.20 vs. 0.48 bouts/h, $p = 0.004$) and more sit-to-stand transitions (mean difference 0.9 STS/h, $p = 0.009$) than students in conventional learning spaces. Comparisons between schools by grade, which were conducted with a one-way ANCOVA adjusted for gender, indicated that most of the significant differences occurred between schools with different classroom types. There were only small and mostly statistically nonsignificant differences between the two schools with conventional classrooms. In conclusion, open learning spaces may improve children's sedentary profiles towards shorter sedentary bout durations and facilitate also postural transitions during lessons, which may translate into beneficial health impacts over a longer period.

Keywords: sedentary behavior; physical activity; school; open learning spaces; sit-to-stand transitions

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1. Introduction

International physical activity guidelines recommend an average of 60 min/day of moderate-to-vigorous intensity aerobic physical activity, regular muscle-strengthening activity and a reduction in sedentary behavior, such as prolonged sitting [1,2]. Higher levels of physical activity, defined as bodily movement produced by skeletal muscles that results in increased energy expenditure, have been associated with better cardiometabolic, vascular, bone and mental health in children [3,4]. Decreasing sedentary behavior, defined as an energy expenditure of ≤1.5 metabolic equivalents of task while being awake in a sitting or reclining posture [5], and shorter duration of sedentary bouts may confer health benefits in children and youth [6,7]. Experimental studies have suggested that both short bouts of physical activity and frequent interruptions in sitting have beneficial effects on cardiometabolic biomarkers, which may reduce the risk for type 2 diabetes and metabolic syndrome in children [6,8].

Despite the evidence for the benefits of promotion of physical activity and reducing sedentary behavior, a substantial proportion of children globally grow increasingly sedentary and do not attain the recommended levels of daily physical activity [9,10]. In school settings, European primary school children aged 10–12 years have been reported to spend

65 to 70% of their school time sedentary and approximately 5% in moderate-to-vigorous physical activity, with boys accumulating less sedentary time and more moderate-to-vigorous physical activity than girls [11].

Schools are seen as feasible sites for interventions that aim to reduce sedentary time and increase overall physical activity because children spend a large proportion of their waking hours at school [12]. Lessons taking place in general education classrooms have received increasing attention as possible settings to influence children's daily physical activity in addition to physical education and recess [13]. During lessons it is possible to reduce and break up children's prolonged sedentary behavior by multiple different classroom-based strategies, such as physically active lessons and active breaks with or without curriculum content [14]. However, some studies have suggested that classroom-based physical activity interventions yield mostly small or no effects on physical activity and sedentary behavior [15]. Therefore, alternative approaches to reduce the sedentary behavior of students are warranted.

The affordances for physical activity provided by the indoor built environments of schools are not yet well understood, although some studies have suggested that radical changes in the architecture and furniture of a classroom may increase physical activity and reduce sedentary behavior [16]. Active school design has been shown to have some beneficial effects on sedentary behavior and light intensity physical activity but not on moderate-to-vigorous physical activity [17]. Furthermore, the elements of flexible learning spaces, including adjustable furniture with multiple uses combined with student-centered pedagogies, have been shown to facilitate positive changes in adolescents' sedentary profiles during class time; for instance, the number of breaks in sitting (i.e., postural transitions from sitting to another posture) has been reported to be greater in flexible learning spaces compared to traditional classrooms [18].

At the same time that general education classrooms have received increasing attention as possible settings to influence children's daily physical activity [13], schools have increasingly incorporated non-partitioned, open, flexible designs and instructional approaches that foster student autonomy, self-regulated learning, collaboration and digital competences [19]. In Finland, conventional self-contained classrooms have increasingly been replaced by more flexible, multipurpose, informal and transformable open learning spaces, in particular, after the most recent curriculum reform of Finnish basic education was issued in 2016 [20,21]. Open learning spaces may enhance opportunities for classroom-based physical activity among students to the extent that the goals set for open learning spaces bear resemblance to activity permissive classrooms [22] and flexible learning spaces [18] with multipurpose and adaptable spaces for movement.

The physical, social and cultural landscapes of a school influence teaching practices [23] and working in open learning spaces usually also implies a redistribution of teachers' roles and responsibilities towards teams sharing space and resources [19]. The affordances and pedagogical methods enabled by open and flexible learning spaces encourage teachers to utilize more interactive teaching and collaborative learning with an emphasis on professional co-planning [24,25]. However, adaptation to novel spaces has been shown to be demanding, and teachers have faced new challenges. These include balancing between facilitating autonomous student learning and managing of shared spaces and resources in their pedagogical practice, difficulties in changing one's institutional routines, creating coherent pedagogy for an open learning space, potential clashes between the teaching team and insufficient teachers' skills for manipulating the environment [19,20,24,26–28].

Despite the expected benefits of open and flexible classrooms, we have previously observed that students' engagement in open learning spaces may involve a surprisingly high proportion of sedentary time but more breaks from sedentary time during lessons compared to conventional classrooms [29,30]. Students have been observed to be sedentary 55–68% of classroom time, which equals 33 to 41 min of sedentary time per 60 min spent in classroom [29,30]. An increased number of breaks from sedentary time despite the higher sedentary time may indicate that sedentary time is accumulated in shorter bouts.

Therefore, in the present study involving a comparison between open and conventional learning spaces, accelerometry-assessed sedentary patterns were investigated with postural transitions from sitting to standing. To examine the potential differences between schools rather than between different classroom types, we investigated the differences among three schools: one with open learning spaces and two with conventional classrooms.

2. Materials and Methods

2.1. Study Design and Participants

This cross-sectional study was conducted using data collected in years 2018–2019 in the *Children's Physical Activity Spectrum: Daily Variations in Physical Activity and Sedentary Patterns Related to School Indoor Physical Environment* (CHIPASE) study. The University of Jyväskylä Ethics Committee approved the research protocol. Third and fifth grade students and their parents (or legal guardians) were provided with a plain language study description and consent form. Both the students' and parents' (or legal guardians') consents were obtained from a total of 206 participants.

The CHIPASE data collection has been previously described in [30,31]. Fifteen classrooms of third and fifth grade students from three public schools from two different provinces in Finland participated in this study. First permissions were obtained from school principals and teachers, after which students were recruited on a voluntary basis. The school with open learning spaces participated in our previous study [29]. The two schools representing conventional school designs were chosen so that they had similar number of students for both of the grade levels recruited for this study. Third graders were chosen as the youngest grade level recruited for this study because this was the youngest age level in open learning spaces (grade 1–2 students attended conventional classrooms). Fifth grade students were chosen as the other age grade level because fifth graders participate in the national physical functional capacity monitoring and feedback system for Finnish students (MOVE!, https://www.oph.fi/en/move (accessed on 20 June 2022)). MOVE! data were collected as part of a larger research project investigating the associations between open learning space and functional capacity in children.

One of the schools contained separate open learning spaces for each grade level from third to sixth, where the students attending third and fifth grades (70–80 students in each grade) had most of their lessons. A collective teacher team of three teachers was responsible for teaching the student group of each grade. Each grades' open learning space contained a large space with mobile furniture that afforded multiple options for classroom activity, as well as a quiet work room (Figure 1). The students did not have a designated desk for them in the open learning spaces. In other two schools, the students attended most of their lessons in conventional classrooms with designated desks (Figure 2). One teacher was responsible for teaching a classroom of 20–25 students in the conventional schools.

Each class was assessed once during one school week. Accelerometers were distributed to be used by the students continuously during the measurement week on Monday. The students kept a diary of accelerometer wear time and absences from school during the week of measurement with assistance from their parents or legal guardians. Both the diaries and accelerometers were collected back from the participants at end of the measurement week on Friday. The classroom teachers provided a curriculum of activities for the week and the contents of the instruction followed the curriculum of the grades in question and was not in any way altered by the researchers.

2.2. Accelerometry Outcomes

Classroom-based sedentary patterns were assessed by waist-worn accelerometers, while postural transitions from sitting to standing (sit-to-stand transitions) were assessed with an accelerometer attached on the mid-anterior thigh. The waist-worn accelerometers are positioned near the center of the mass of the human body and, therefore, are thought to best reflect the movement of the whole body [32]. The thigh-worn accelerometers can be used to assess posture and, therefore, also to separate sitting or lying down from standing and physical activity [32,33]. Triaxial accelerometers (RM42, UKK Terveyspalvelut Oy, Tampere, Finland, Range ±16 g, sample rate: 100 Hz, A/D conversion: 13-bit) were used.

Figure 1. The open learning space shows several areas for work as well as a quiet work room allowing for division of the class of about 70–80 students into smaller groups with mobile and dynamic furniture.

Figure 2. Pictures of the conventional classrooms represent typical, smaller, self-contained rooms for around 20 students with a designated desk for each student.

Accelerometer data reduction methods have been previously described in [29–31]. The teacher-reported weekly schedule was used to determine time spent inside in the classroom during general education, which was included in the analysis. Physical education and recess were excluded from the analysis. The students' diaries were used to exclude possible absences from school, for example, due to illness. The accelerometer data were visually inspected for each lesson for each participant separately to ensure that the accelerometers were worn as reported by the participants.

For assessment of sedentary patterns, the mean amplitude deviation (MAD) method was used, as it utilizes universal g values instead of arbitrary counts, and it has been shown to be an accurate method across different accelerometer brands [34,35]. For waist-worn accelerometers, the MAD was calculated from the resultant acceleration in non-overlapping 1 s epochs on the supercomputer of CSC, the Finnish IT Center for Science. The MAD values were averaged over 15-s intervals to capture short bursts of physical activity [36] with MATLAB R2018a (The MathWorks Inc., Natick, MA, USA). The cut-off for sedentary behavior was determined as 16.7 mg, which has been previously used in assessing school-aged children in Finland [35,37]. To quantify sedentary patterns, the number of sedentary bouts were calculated for the following categories: 1-to-4 min, 5-to-9 min, 10-to-19 min, 20-to-29 min and ≥30 min [38]. Sedentary bouts of less than one minute were excluded, and a sedentary bout was considered to end with any interruption in sedentary time [39]. Sit-to-stand transitions were assessed using a thigh-worn accelerometer, attached on the thigh, with the sit-to-stand transition algorithm [40] using MATLAB (R2019a, The MathWorks Inc., Natick, MA, USA). To account for any differences in wear time of the accelerometers during classroom time, outcome variables were calculated in proportion to 60 min of classroom time [18].

2.3. Statistical Analyses

Descriptive statistics reported as means and standard deviations were calculated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Further statistical analyses were carried out using R 4.0.5 (R Studio Team, Boston, MA, USA). The normality of the data distribution was assessed using normal Q–Q plots, histograms and the Shapiro–Wilk test ($p < 0.05$). Variables violating the normality assumption were treated with a log(x + 1) transformation to meet the requirements of the normality distribution. Homogeneity of the variances was assessed using a residuals vs. fitted values plot and Levene's test ($p < 0.05$) for all outcome variables. For variables violating the homogeneity of variance, the heteroskedasticity-consistent HC3 version of Huber–White's robust standard errors were used.

A three-way factorial ANOVA (2 × 2 × 2) with Type III Sum of Squares, implemented with R-package car [41], was used to examine associations of the type of classroom (open vs. conventional), grade (third vs. fifth grade) and gender (boys vs. girls) on outcome variables. To examine differences between schools rather than between classroom types, comparisons were made for both grade levels separately with a one-way ANCOVA, with gender set as the covariate. The statistical significance was set at $p \leq 0.05$ with 95% confidence intervals. Tukey's honest significance test was utilized for multiple comparisons.

3. Results

3.1. Descriptive Statistics

A total of 204 students participated in the assessments, and waist-worn accelerometry was obtained from 197 students. After excluding participants with missing thigh-worn accelerometer data, the final sample size was reduced to 191 students. Table 1 displays the means and standard deviations of the accelerometer outcomes across the three participating schools and two grade levels.

Table 1. Results of the sedentary behavior assessments by school and grade level.

School	A		B		C	
Classroom type	Open		Conventional		Conventional	
Grade level	3rd	5th	3rd	5th	3rd	5th
Number of participants	38	21	52	33	22	25
Girls (%)	42.1	52.4	59.6	51.5	50.0	48.0
1–4 min Sedentary bouts (bouts/h)	6.80 ± 1.27	6.78 ± 1.99	5.32 ± 1.57	5.13 ± 1.64	5.10 ± 1.41	4.27 ± 1.09
5–9 min Sedentary bouts (bouts/h)	1.51 ± 0.60	1.59 ± 0.68	1.38 ± 0.49	1.58 ± 0.49	1.42 ± 0.51	1.49 ± 0.45
>10 min Sedentary bouts (bouts/h)	0.20 ± 0.15	0.31 ± 0.31	0.39 ± 0.33	0.60 ± 0.43	0.42 ± 0.28	0.52 ± 0.26
10–19 min Sedentary bouts (bouts/h)	0.19 ± 0.15	0.25 ± 0.27	0.35 ± 0.29	0.52 ± 0.38	0.38 ± 0.28	0.41 ± 0.26
20–29 min Sedentary bouts (bouts/h)	0.00 ± 0.02	0.07 ± 0.09	0.04 ± 0.08	0.08 ± 0.12	0.04 ± 0.07	0.11 ± 0.15
30+ min Sedentary bouts (bouts/h)	0	0	0	0	0	0
Sit-to-stand transitions (bouts/h)	6.54 ± 1.84	5.41 ± 2.52	5.77 ± 2.19	5.32 ± 1.66	3.93 ± 1.57	4.65 ± 1.47

Means and standard deviations. Girls (%) describes percentage of girls in subsamples.

3.2. Associations of Gender, Grade Level and Classroom Type on Sedentary Behavior

A three-way factorial ANOVA was used to examine the three- and two-way interaction and main effects of gender (girls vs. boys), grade level (fifth grade vs. third grade) and classroom type (open vs. conventional) on different sedentary bout duration categories and sit-to-stand transitions. Due to the small observed number of bouts >10-min, the sedentary bout categories of 10-to-19-min and 20-to-29 min were combined for the three-way ANOVA analysis. Sedentary bouts lasting over 30-min were not observed. Table 2 shows results of the three-way ANOVA test of between-subjects effects of grade, gender and classroom type on sedentary behavior variables.

Table 2. Three-way ANOVA test of between-subjects effects of grade, gender and classroom type on sedentary behavior variables.

	F(7,183)						
Sedentary Behavior Variable	**Gender**	**Grade**	**Classroom**	**Gender x Grade**	**Gender x Classroom**	**Grade x Classroom**	**Gender x Grade x Classroom**
1–4 min Sedentary bouts	2.244	0.723	54.380 ***	2.643	5.940 *	1.062	0.160
5–9 min Sedentary bouts	0.171	1.442	0.957	0.069	0.525	0.232	0.009
>10 min Sedentary bouts [a,b]	3.566	9.000 **	22.686 ***	4.612 *	0.032	0.227	0.216
Sit-to-Stand Transitions [b]	0.144	3.289	5.174 *	0.567	0.526	1.572	0.549

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, [a] log(x + 1) transformation was utilized. [b] Three-way ANOVA was conducted using the heteroskedasticity-consistent HC3 version of Huber–White's robust standard errors.

Statistically significant three-way interactions between gender, grade and classroom type on the sedentary behavior variables were not observed (Table 2). A significant two-way interaction was observed between gender and classroom type on the 1-to-4-min sedentary bouts (Table 2). However, the post hoc test indicated that the differences between boys and girls were not significant in either open learning spaces or conventional classrooms. Both girls (mean difference 1.2 bouts/h, $p = 0.003$) and boys (mean difference 2.4 times/h, $p < 0.001$) had more 1-to-4-min sedentary bouts in the open learning spaces compared to the conventional classroom, when the means were adjusted for the grade level (Table 3). The main effect of classroom type on 1-to-4-min sedentary bouts was significant (Table 2), as the students in open classrooms had more 1-to-4-min bouts (mean difference 1.8 bouts/h, $p < 0.001$) than in the conventional classrooms when the means were adjusted for grade level and gender (Table 3).

Table 3. Estimated marginal means of post hoc analyses after three-way ANOVA.

1-to-4-min Sedentary Bouts (Bouts/h) Adjusted for Grade Level				
Gender	***Classroom Type***	***Estimated Marginal Mean***	***Lower CI95%***	***Upper CI95%***
Girls	Open	6.3	5.7	6.9
Boys	Open	7.3	6.7	7.8
Girls	Conventional	5.1	4.8	5.5
Boys	Conventional	4.9	4.5	5.2
1-to-4-min sedentary bouts (bouts/h) adjusted for grade level and gender				
Classroom type		***Estimated marginal mean***	***Lower CI95%***	***Upper CI95%***
Open		6.8	6.4	7.2
Conventional		5.0	4.7	5.3
>10-min bouts (log(bouts/h + 1)) [a] adjusted for classroom type				
Gender	***Grade***	***Estimated marginal mean***	***Lower CI95%***	***Upper CI95%***
Girls	5th	0.40	0.33	0.48
Boys	5th	0.27	0.20	0.35
Girls	3rd	0.24	0.18	0.30
Boys	3rd	0.25	0.19	0.30
>10-min bouts (log(bouts/h + 1)) [a,b] adjusted for grade level and gender				
Classroom type		***Estimated marginal mean***	***Lower CI95%***	***Upper CI95%***
Open		0.21	0.16	0.27
Conventional		0.37	0.33	0.40
Sit-to-Stand-transitions (transitions/h) [b] adjusted for grade level and gender				
Classroom type		***Estimated marginal mean***	***Lower CI95%***	***Upper CI95%***
Open		6.0	5.5	6.6
Conventional		5.1	4.8	5.5

[a] log(x + 1) transformation was utilized. [b] Three-way ANOVA was conducted using the heteroskedasticity-consistent HC3 version of Huber–White's robust standard errors.

For the 5-to-9-min sedentary bouts, neither two-way interactions nor main effects were observed (Table 2). For >10-min bouts, assumptions of the normality of data and the homogeneity of variance were not met, and the number of >10-min bouts per hour was first log(x + 1)-transformed. After log(x + 1)-transformation, Levene's test still indicated a violation of the homogeneity of variances. Therefore, a robust ANOVA was conducted using the HC3-version of Huber–White's robust standard errors, which indicated that there was a significant two-way interaction between gender and grade (Table 2).

The post hoc test indicated that fifth grade girls had more >10-min bouts than third grade girls (median; interquartile range: 0.60; 0.50 vs. 0.31; 0.41 bouts/h, $p = 0.004$) when adjusted for classroom type. The main effect for classroom type was significant, and the students in open learning spaces had fewer >10-min sedentary bouts (median; interquartile range: 0.20; 0.24 vs. 0.48; 0.55 bouts/h, $p < 0.001$), when adjusted for grade level and gender (Table 3).

For sit-to-stand transitions, a robust three-way ANOVA was conducted as the assumption for the homogeneity of variance was not met. A significant main effect for classroom type was observed, as the students in conventional classrooms had fewer sit-to-stand transitions (0.9 STS/h, $p = 0.009$) compared to the students in open learning spaces when the means were adjusted for grade level and gender.

3.3. Grade-Matched Differences between Schools

A one-way ANCOVA was used to investigate differences in the sedentary behavior variables between schools controlled for gender. There were significant differences between schools ($F(2,108) = 14.816$, $p < 0.001$) in the 1-to-4-min sedentary bouts in the third grade students. The third grade students in school A had more 1-to-4-min bouts than their counterparts in schools B (mean difference 1.5 bouts/h, $p < 0.001$) and C (mean difference 1.7 bouts/h, $p < 0.001$) (Table 4). Significant differences were observed also for the fifth grade students between schools ($F(2,75) = 14.801$, $p < 0.001$). The fifth grade students in school A had more 1-to-4-min sedentary bouts than the students in schools B (mean difference 1.6 bouts/h, $p = 0.011$) and C (mean difference 2.5 bouts/h, $p < 0.001$) (Table 4).

Table 4. Grade-matched between school-estimated marginal means of sedentary behavior variables controlled for gender.

School—Classroom Type	Significant Difference between Schools	Estimated Marginal Mean	Lower CI95%	Upper CI95%
1-to-4-min sedentary bouts (Bouts/(h)				
3rd grade				
A—Open	A-B ***, A-C ***	6.8	6.4	7.3
B—Conventional		5.3	4.9	5.7
C—Conventional		5.1	4.5	5.7
5th grade				
A—Open	A-B *, A-C ***	6.8	6.1	7.5
B—Conventional		5.1	4.6	5.7
C—Conventional		4.3	3.6	4.9
5-to-9-min sedentary bouts (bouts/h)				
3rd grade				
A—Open		1.5	1.3	1.7
B—Conventional		1.4	1.2	1.5
C—Conventional		1.4	1.2	1.7
5th Grade [b]				
A—Open		1.6	1.4	1.8
B—Conventional		1.6	1.4	1.8
C—Conventional		1.5	1.3	1.7
>10-min bouts (log(bouts/h+1)) [a]				
3rd Grade [b]				
A—Open	A-B *, A-C *	0.17	0.11	0.24
B—Conventional		0.30	0.25	0.36
C—Conventional		0.33	0.25	0.41
5th Grade [b]				
A—Open	A-B *	0.25	0.16	0.35
B—Conventional		0.43	0.36	0.51
C—Conventional		0.41	0.32	0.50
Sit-to-Stand Transitions (transitions/h)				
3rd Grade				
A—Open	A-C ***	6.5	5.9	7.2
B—Conventional	B-C *	5.8	5.2	6.3
C—Conventional		3.9	3.1	4.8
5th Grade [b]				
A—Open		5.4	4.6	6.2
B—Conventional		5.3	4.7	6.0
C—Conventional		4.7	3.9	5.4

[a] $\log(x + 1)$ transformation was utilized. [b] One-way ANCOVA was using the heteroskedasticity-consistent HC3 version of Huber–White's robust standard errors. * $p < 0.05$, *** $p < 0.001$.

For the 5-to-9-min bouts, the differences between schools were not significant either for the third or fifth grade students. The estimated marginal means adjusted for gender indicated similar numbers of 5-to-9-min bouts in all three schools in both grade levels (Table 4). For log(x + 1)-transformed >10-min sedentary bouts, there were significant differences between schools in the third grade students ($F(2,108) = 8.634$, $p < 0.001$). The third grade students in school A had fewer >10-min sedentary bouts compared to schools B (median; interquartile range: 0.20; 0.20 vs. 0.36; 0.65 bouts/h, $p = 0.011$) and C (median; interquartile range: 0.42; 0.45 bouts/h, $p = 0.012$) (Table 4). In the fifth grade students, covariate gender was significantly associated with >10-min sedentary bouts ($F(1,75) = 5.598$, $p = 0.021$). However, there was an overlap between 95% confidence intervals of log(x + 1)-transformed estimated marginal means of with >10-min sedentary bouts between girls (95%CI [0.35, 0.50]) and boys (95%CI [0.23; 0.38]). There were also statistically significant differences between schools ($F(2,75) = 4.773$, $p = 0.11$). The fifth grade in school A had fewer >10-min sedentary bouts than the students in school B (median; interquartile range: 0.27; 0.33 vs. 0.67;0.22 bouts/h, $p = 0.013$), while the differences between schools A-C and B-C were not statistically significant (Table 4).

In third grade, statistically significant differences were observed for the students' sit-to-stand transitions between schools ($F(2,108) = 12.198$, $p < 0.001$). The third grade students in school A had more sit-to-stand transitions than the students in school C (mean difference 2.6 transitions/h, $p < 0.001$), and there was also a statistically significant difference between schools B and C (mean difference 1.9 transitions/h, $p = 0.011$) (Table 4). In fifth grade, statically significant differences between schools were not observed for the students' sit-to-stand transitions (Table 4).

4. Discussion

The present study investigated third and fifth grade students' accelerometry-assessed sedentary patterns and postural transitions from sitting to standing between open and conventional learning spaces and between three schools. The results indicated that the students in open learning spaces had more 1-to-4-min sedentary bouts, fewer >10-min sedentary bouts and more sit-to-stand transitions than the students in conventional learning spaces. There were no differences in 5-to-9-min bouts between the open learning spaces and conventional classrooms. In line with previous research [17,18], the current results indicate that sedentary time is accumulated in open and flexible learning spaces in shorter bouts with more frequent breaks in sedentary time and more postural transitions. Therefore, open learning spaces may provide potential benefits by breaking up the prolonged sedentary time of school-aged children and youth [6–8]. Some differences also occurred between the two schools with conventional learning spaces in the sit-to-stand transitions among third grade students, but the differences between the conventional schools were modest and statistically not significant. Although school level policies and individual teacher's pedagogical practices may influence the accumulation and breaking up of sedentary time [42], the present study suggests that classroom type seems to exert a greater influence than school on classroom-based sedentary behavior.

Gender and grade level had an interaction effect on >10-min sedentary bouts as fifth grade girls had more >10-min sedentary bouts than third grade girls. These finding are consistent with previous findings, indicating that older students, especially girls, tend to be more sedentary than younger students [11,43–46]. These findings suggest that interventions targeting classroom-based sedentary behavior need to focus on reducing sedentary behavior among older students, especially among girls. Furthermore, when examining classroom physical activity interventions, the gender and grade level or age of the participants should be considered.

Strengths of this present study include the use of accelerometry-derived measures of classroom-based sedentary behavior in authentic settings where teaching methods were not experimentally altered. This approach enabled estimation of the associations of classroom type on classroom-based sedentary behavior in real life conditions. Furthermore, our statistical approach allowed analysis of the potential associations of participants' gender and grade level on classroom-based sedentary behavior. Potential differences between schools, in addition to classroom type, were also investigated.

Limitations of this study include its cross-sectional nature, which excludes confirmation of any causal relationships between the assessed variables. Furthermore, our sample size of 15 classes and an unbalanced design including one school with open learning space and two schools with conventional classroom, reduces the statistical power and possibilities for clustering students within classes and schools with sophisticated approaches, such as hierarchical linear modeling [47]. We did not control for the possible influences of weight, body fat content or anthropometry on classroom-based sedentary behavior because such procedure is quite rare in epidemiological settings. However, we acknowledge that children who are overweight have been observed to spend significantly less time in moderate-to-vigorous intensity activities than children with normal weight [11]. For instance, one study found that while children of normal weight in the intervention group were more active than children of normal weight in the control group, similar differences were not observed among overweight and obese children [48]. Therefore, future studies are needed to examine whether associations between the type of classroom learning environment and classroom-based sedentary behavior are different in populations of normal and overweight children.

School-level physical activity policies were not assessed, but all three schools participated in the national action program, Finnish Schools on the Move, which aims to establish a physically active culture in Finnish comprehensive schools. Approximately 90% of Finnish elementary schools and 95% of pupils are involved in the program [49]. Schools and municipalities that participate in the program implement their own plans to enhance physical activity during physical education, recess and academic lessons [49,50], and, thus, there may be some differences in the activities performed during the school week that were not controlled for in this study. For example, if students participate in vigorous physical activity during physical education or recess, they may be less physically active during the classroom lessons. It is also possible that teachers feel that breaking up students' sedentary time is less necessary if students have already been physically active during the PE lesson or recess. Information is currently limited on the relation between sedentary and physical activity in different contexts, in particular, on how the extent of activity in different lessons, and during recess and lunch time, influence each other [51].

As the physical aspects of learning spaces do not influence sedentary behavior alone, but exert their influence together with factors related to the school culture and pedagogical solutions [23], future studies should investigate potential school-level policies and potential teachers' intrapersonal factors, such as their perceptions of the value of physical activity [42], which were not included in this study. Furthermore, this study did not involve assessments of students' experiences regarding open learning spaces compared to conventional classrooms. However, a recent study indicated that students studying in learning spaces with flexible furniture have reported greater satisfaction with the learning environment than students in classrooms with traditional furniture, as the former provides more opportunities for student autonomy [52]. Students' attending open and flexible learning spaces have been observed to engage more in collaborative learning activities and to incorporate mobility into their own learning activities, while developing agency by choosing how and where they will work [25]. Open and flexible classroom designs can influence social relationships by facilitating spontaneous interactions among students and teachers [25]. There is some evidence that academic results in English, Mathematics and Humanities may benefit from the utilization of flexible learning spaces in Australian children and adolescents [53]. Associations between open learning spaces and academic results have not been studied in the Finnish educational setting. Therefore, future studies should seek to investigate the potential effects of open learning spaces on the academic results of Finnish primary school-aged children.

Finally, the accelerometer data reduction methods and the accelerometers themselves used in this study are somewhat different than those in prior studies [18,38], and, therefore, the results of the different studies are not directly comparable. Currently, there is no clear consensus about the most valid operational definitions of accelerometer-based measures among researchers [39]. The MAD method used for assessing accelerometer data in this study has documented validity and reliability across different accelerometer brands [34,35]. The sit-to-stand transition algorithm has been shown to be reliable in free-living environments in community-dwelling older adults [40], but it has not been yet validated for children.

5. Conclusions

Students in open learning spaces were found to have more 1-to-4-min sedentary bouts, fewer >10-min sedentary bouts and more sit-to-stand transitions, while there were no differences in the 5-to-9-min sedentary bouts between open learning spaces and conventional classrooms. Shorter sedentary bouts and more postural transitions may induce health benefits in school-age children in the long term. Studies with longitudinal multi-level approaches are warranted.

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Informed Consent Statement: Students and their parents (or legal guardians) gave their written informed consent for the students' participation in the study.

Data Availability Statement: The data presented in this study are available upon reasonable request from the corresponding author.

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