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ORIGINAL PAPER

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

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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

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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 ≤ 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)	$9.3\pm0.3^{**/***}$	$9.5\pm0.3^{*/**}$	$9.7\pm0.3^{*/***}$
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)	$9.5\pm1.2^{\dagger\dagger/\dagger\dagger\dagger}$	$8.1\pm1.8^{\dagger\dagger\dagger}$	$8.1\pm1.6^{\dagger\dagger}$
AB (s)	$77\pm9^{\ddagger\ddagger}$	$93\pm22^{\ddagger\ddagger}$	88±21
SB (s)	$95\pm37^{\ddagger}$	$101\pm29^{\ddagger}$	101±33
5th Graders			
Participants (*n*)	21	32	23
Girls (%)	47.6	53.0	44.4
Age (years)	$11.2\pm0.3^{**(A–B)}$	$11.5\pm0.3^{**(A–B)/**(B–C)}$	$11.2\pm0.3^{**(B–C)}$
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 (%)	$67.7\pm9.1^{*}$	62.3±9.3	$60.8\pm9.6^{*}$
LPA (%)	24.0±6.7	26.9±6.8	27.3±7.4
MVPA (%)	$8.3\pm2.8^{\ddagger\ddagger}$	10.7±4.1	$11.8\pm3.8^{\ddagger\ddagger}$
BST (breaks/h)	$10.2\pm1.8^{\ddagger\ddagger/\ddagger\ddagger\ddagger}$	$8.4\pm1.7^{\ddagger/\ddagger\ddagger}$	$7.8\pm1.2^{\ddagger/\ddagger\ddagger\ddagger}$
AB (s)	$62\pm9^{\ddagger\ddagger\ddagger(A–B, A–C)}$	$83\pm22^{\ddagger\ddagger\ddagger(A–B)}$	$99\pm21^{\ddagger\ddagger\ddagger(A–C)}$
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,

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

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 ($2 \times 2 \times 2$) 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 ($\omega_p^2 = 0.04$) 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], $p < .001$, $\omega_p^2 = 0.15$) 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 ($\omega_p^2 = 0.03$) 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], $p < .001$, $\omega_p^2 = 0.21$) 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 ($\omega_p^2 = 0.03$) and between gender and classroom type on AB ($\omega_p^2 = 0.03$). 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 ($\omega_p^2 = 0.02$) 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).

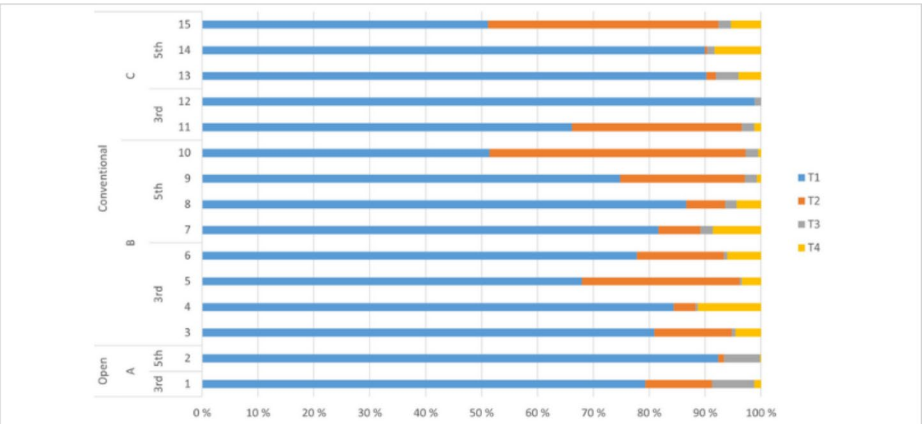

Fig. 2 Relative amounts of observed teachers' (N = 15) instructions on students' movement in each participating school (A-C) and grade. Teachers' instruction categories include T1 = Teacher(s) does not allow movement, T2 = Teacher(s) allows free movement in classroom, T3 = Teacher(s) organizes transition,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