Journal of Education and Learning; Vol. 12, No. 1; 2023
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

POE: Learning Settings and Practice Matter Exploratory Study - 9th Grade

Lennie Scott-Webber[1], Dieter Breithecker[2] & Dina Sorensen[3]

[1] INSYNC: Education Research + Design; Knoxville, TN, USA

[2] President of the Federal Institute on the Development of Posture and Exercise, Germany

[3] LEED AP BD & C; Design Director - d.studio; AIA-Committee on Architecture for Education Co-Chair Research Subcommittee 2021; Charlotte, NC, USA

Correspondence: Lennie Scott-Webber, INSYNC: Education Research + Design; Knoxville, TN, USA.

Received: August 23, 2022 Accepted: October 17, 2022 Online Published: October 25, 2022

doi:10.5539/jel.v12n1p1 URL: https://doi.org/10.5539/jel.v12n1p1

Abstract

A renovation incorporated Innovative Learning Environments' design principles. The exploratory study used a Basic Mixed Method, Convergent Parallel Research Design. Behavioral observations and photographic tracing, two surveys (pre- and post-intervention), interviews, and instrument testing. Overall findings: (a) students and educators are excited to come to school, (b) far less negative/destructive behavioral issues, and (c) a sense of pride/belonging imbued. Specifically: (a) ILE designs at the ergo-dynamic furniture level are not as intuitive as hoped, (b) teaching practices guide the use of solutions, (c) students made intuitive use of the ergo-dynamic products in seated positions at both macro and micro levels, and (d) students still had too much sedentary time. Recommendation - provide holistic understanding for all stakeholders of ILEs' positive impact.

Keywords: design for educational settings, dynamic-movement, student engagement, Innovative Learning Environments, secondary school, disaster response

1. Introduction

Brooks (2012) indicated that spatial designs have consequences aligns with Bøjer's (2021) statement, "Space shapes us; but we are also affected by the way we interact with, and act within the space" (p. 33). Research is scant regarding: (a) how the design of particular 'ergo-dynamic' (i.e., purpose-built/spatial affordances) furniture for educational places, (b) their potential spatial adaptability, and (c) options for providing spontaneous, self-organizing postural changes in ILEs impacts student wellbeing and academic engagement; particularly for secondary grade level students. Thus, the argument is made for intentionally designing space, and its spatial affordances (i.e., furniture, fixtures and equipment) (Whiteside, Brooks, & Walker, 2010; Byers, Imms, & Hartnell-Young, 2014; Imms & Byers, 2017a; Imms, Mahat, Byers, & Murphy, 2017b; Imms, Cleveland, & Fisher, 2016) with the belief that understanding the premise of why active learning, quality/dynamic movements incorporated to support student wellbeing and academic engagement are important.

A unique opportunity presented itself after the unfortunate and devastating effects of two hurricanes that swept through the US Virgin Islands, and ongoing COVID-related closures. After all of the destruction and losses, the opportunity to rebuild, renovate, and reimagine education for hundreds of teachers and students was generated throughout the US Virgin Islands. DLR Group's K12 Education Practice, (led by Pamela Loeffelman, FAIA as lead architect), began this arduous but important master planning project. One of the first schools to finish renovations was The Wheatley Modernization Center for 9th Grade Students. VS America, Inc. was selected to supply the furnishings due, in part, to their long-standing connections to applied research and understanding of active body behavior, and the ability to supply 'ergo-dynamic', or dynamic movement (items that allow for intuitive body movements based on the products' design features) furniture solutions.

Answers to our research questions may contribute to multiple audiences' decision-making abilities to 'get it right for students.' This study introduces the reader to a body of knowledge recognizing that space does make a difference. Specifically, for the: (a) physiological (Brittin, Sorensen, Trowbridge, Lee, Breithecker, Frerichs, & Huang, 2015; Brittin et al., 2017; Dave, 1970; Garcia, Huang, Trowbridge, Weltman, & Sirard, 2016), (b) psychological (Elliot & Covington, 2001; Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014), and (c) interactively engaged opportunity connections (Kilbourne, Scott-Webber, & Kapitula, 2017) for both students and educators. The work is grounded in the work of classic Environment Behavior Theorists (Altman, 1975; Sommer, 1969; Hutchison, 2015; Harrow, 1972).

The physiological items will be a focus of this study and how these behaviors (e.g., macro postural movements like walking/leaning, and micro/mindless movements like fidgeting), encourage more engagement in one's learning process. What we know is in children and adolescents daily sitting time takes over 50% of the waking day at 7 years and 75% at 15 years (Janssen et al., 2016). This high level of sedentariness, combined with the fact that about 80% of children and adolescents are inactive (i.e., not reaching the physical activity recommendations) (Farooq et al., 2018; Hallal et al., 2012), led some scientists to propose the existence of what they called a "Sedentary & Inactive" profile (Saunders et al., 2013). Thus, we are currently at a time where sedentary behaviors are a worldwide concern (Bernaards, Hildebrandt, & Hendriksen, 2016) and classroom active seating and desks (i.e., 'ergo-dynamic' furniture solutions) have been proposed as a potential key to counterbalance these adverse effects on health- wellbeing-related outcomes. It suggests the time of exposure to ergo-dynamic furniture may be an important parameter to consider. Ergo-dynamic furniture solutions appear to be promising tools in: (a) reducing sedentary behaviors in school environments, (b) increasing energy expenditure, and (c) supporting cognitive and academic performances.

Spatial situations have been measured for some time understanding how the design of classroom spaces impacts student academic engagement levels (Scott-Webber, Konyndyk, & Denison, 2019a; Scott-Webber, Konyndyk, & French, 2019b; Scott-Webber, Konyndyk, French, & French, 2018; Scott-Webber, Konyndyk, French, Lembke, & Kinney, 2017).

2. Body of Evidence

Our study builds upon others (Gracia et al., 2016; Minges, Chao, Irwin, Owen, Park, Whittemore, & Salmon, 2016; Guirado, Chambonnière, Chaput, Metz, Thivel, & Duclos, 2021) who looked at the effects of "…non-traditional (i.e., ergo-dynamic) school furniture on children's physical activity (PA), energy expenditure (EE), information retention…" (n.p.); for this study concentration levels was also studied. It is important for us to operationalize some terms:

- Accelerometer = a device, in this case worn around the waist, that measures movement of the hips and legs; accesses PA – physical activity;
- Active learning design = the intentional design of both the placement of furnishing and the inclusion of ergo-dynamic furniture solutions to support teaching modalities used to potentially increase student active movements and engagement levels;
- Cognitive performance = the ability to concentrate, is an essential prerequisite for coping with everyday work tasks. Whether in sports, school or everyday work, the focus of attention is a limiting factor for optimal performance. The positive influence of motion on the brain has already been extensively researched and confirmed;
- Energy expenditure = the amount of energy used as measured by an accelerator (EE);
- 'Ergo-dynamic' = Non-traditional school furnishings designed to physically promote quality/dynamic movements [at the micro/mindless scale = small fidgeting movements; at the macro scale (standing up, walking, lying down, etc.), and mindful body movements (i.e., postural changes from lying down to walking and standing up)];
- ILEs = Innovative Learning Environments (Imms et al., 2017a & b);
- Quality/dynamic movement = physical activity – bodies in motion at the macro and micro levels (PA); and
- Traditional school furniture = furnishings that are static and non-supportive of body movements.

2.1 Learning with the Whole Body

Learning with the whole body (i.e., body + movement) / embodied learning, is the basis for an individual to experience themselves as part of the environment, to tap into it becoming part of that individual's full experience (Moser, Körper, & Lernen, 2016). "The body then is the means and medium" (Abraham & Müller, 2010, p. 23), and through this learning medium they can perceive, experience, recognize and act. At the same time, the body is the 'house' from which we as humans come into contact with the world. In human existence, the body represents physical existence in the here and now as well as in space and time, and is characterized by its own duality: on the one hand, it separates people from the environment, on the other hand, it also provides access to, and a responsibility of being within the physical and social world (Moser et al., 2016).

Within the current state of interdisciplinary research on learning, teaching methods are recommended that see the learner as a physically active ‘discoverer’ in their own appropriation of the world. An active form of learning is based then on the fundamental importance that emotional, cognitive and physical processes function in an interactive state. Consequently, learning with movement is the most suitable approach for efficient and at the same time sustainable learning (Moser et al., 2016). This finding is by no means new. But in the context of reforming pedagogical concepts such as “learning with head, heart, and hand” or “learning with all the senses,” it has repeatedly led to a stronger integration of movement and physicality in action-oriented learning processes.

Our research questions were:

1) Do ‘ergo-dynamic/purpose-built’ furniture designs impact the students’ acts of being physically/actively and engaged in their learning process?

2) Do specific professional development sessions for teachers make a noticeable difference in encouraging dynamic movement/student engagement behaviors in a 9th grade situation?

2.2 Evidence Between Physical Movement and Learning are Inseparable

Numerous studies prove the connections between movement and the effect on learning and show that the use of specific movement activities may influence the actual ability to learn. Looking at the various study findings, however, it quickly becomes clear that these are not strictly contributing relationships, but rather causal correlations indicating significance from multidimensional fields; results from a comprehensive analysis of the dimensions of meaning of movement (Beudels, 2013).

In the favored concept of a school as a learning space, “school is viewed as an open space of experience in which the cognitive, emotional, social, aesthetic, exploratory opportunities may take place” (Klafki & Braun, 2007, p. 138). A modern and future-oriented school therefore represents a place where important knowledge can be acquired, skills may be developed and practiced and ideas may be organized with a view to preparing for life (Von Hentig, 2003). In the texts *Rethink the School* (Von Hentig, 2003) and *INSYNC: Environment behavior and the design of learning places* (Scott-Webber, 2004), authors have been demanding a consistent rethink from the school bureaucracies for over 10 years. The implementation of changed educational school concepts seems just as in need of analysis and interpretation as the learning paradigms, and the relationship between learning and teaching in school.

According to the constructivist theory (a current practiced theory) learning means actively perceiving, experiencing, acting, experiencing and communicating (Stangl, 2010). Accordingly, learning is not limited to the instrumentalization and reproduction of knowledge, but includes active, self-directed, emotionally motivating, creative and communicative processes in the active engagement with the environment (Vogelsinger, 2016, p. 42). Thus, the prior knowledge of the learner is of crucial importance in this perspective, as new knowledge is always constructed in relation to it, and the activation of prior knowledge, its order, correction, expansion, differentiation and integration in the process of gaining knowledge play the decisive roles (Stangl, 2010). Individual constructs are built up, linked, reorganized and modified through learning, always under the principle of current and future expediency.

“Movement and the body in the context of the learning paradigms within the current educational debate about pre-school and elementary school education,” Fischer (2016, p. 71) recognizes two fundamental areas of responsibility for movement: On the one hand, movement is important in order to differentiate the experience of action that the general planning ability to cope with behaviorally conditioned learning processes. On the other hand, the importance of movement lies in the transfer service for the acquisition of academic knowledge and skills, for example in cultural techniques or scientific fundamentals. “In terms of developmental logic, scientific knowledge arises from the exploration and play behavior of the child and needs a (movement) practical basis” (Fischer, 2016, p. 72). In terms of phenomenology and philosophical anthropology, it is not about the mechanical side of movement that has been stripped of the human being, but about the meaning of movement as action that opens up meaning (Hildebrandt-Stramann & Laging, 2013). Positive metabolic changes are triggered if sitting times are interrupted regularly (i.e., after 20 minutes at the latest.), Henson et al. (2013), found a positive influence of interruptions on glucose metabolism, BMI and waist circumference in people with an increased diabetes risk profile. Saunders’ (Saunders et al., 2013) working group found evidence connecting the phases of sedentary behavior and an interruption to cardiometabolic risk in children with a family risk of being overweight and obese (Altenburg et al., 2013; Bailey & Locke, 2014; van Dijk et al., 2013).

2.3 The Cognitive Connection

For their study of the attentional performance of children in three classes in the course of a school morning reported, "highly significant differences between the children whose everyday school life was more active and those who took part in conventional lessons" (Dordel & Breithecker, 2003, p. 77). Significant correlations between concentration performance and body coordination were also found in a study with 668 primary school students (Graf et al., 2003). But long-term effects of exercise on school performance have also been previously proven. With reference to the research by Castelli, Hillmann, Buck and Erwin (2007), who were able to demonstrate a positive correlation between general fitness and success in arithmetic and reading in third and fifth graders, studies by Schneider and Guardiera (2011) show that even after moderate but regular activity of 15 minutes on the bicycle ergometer, clear brain physiological changes take place in the sensory cortex and in temporal areas, which are assigned to language processing. Research into neurophysiological and neurocognitive mechanisms generally shows increased concentration performance as a result of physical activity (Hillman, Pontifex, Raine, & Kramer, 2009; Bailey & Locke, 2014) combined with school performance (Coe, Pilvernik, Womack, Reeves, & Malina, 2006; Garatachea, Torres Luque, & González, 2010). In summary, exercise supports learning in multiple ways.

"Movement leads to better levels of adaptation in the central nervous system, strengthens the synaptic connections, improves blood flow to the brain and stimulates the maintenance and regeneration of neural networks" (Hollmann, 2004, p. 7). The meta-analyzes carried out consistently come to the result that positive correlations between physical activity and cognitive performance can be assumed. The majority of the cross-sectional studies confirm a positive connection between motor and cognitive characteristics, which in addition to the neuronal changes promote the prerequisites and have a positive effect on the cognitive learning ability.

In recent years, neuroscience has found an empirically established relationship between physical activity, creativity, and learning, which are key elements for learning success and innovation. *Bodies in Motion* (Breithecker, 2009) is a concept inspired by our research on active learning and embodied learning in the classroom (Breithecker, 2005) – key phrase: *Schools in Motion*. It's about inspiring people to break away from passive behaviors and getting more physically and emotionally involved in one's learning's creative process. Static sitting leads to physical, and mental deterioration and sabotages our ability to concentrate. Sitting still, or any rigid behavior, is not an evolutionary biological state. Physical activity directly affects the cognitive processing areas of the brain, which, according to studies, helps the center for learning and memory (Hippocampus) – as well as our executive functions – participate.

"Executive functions are essentially processes that contribute to increasing the performance of:

- Our working memory, the ability to retain and process a certain (relatively small) amount of information; and
- Our flexible attention control, the ability to quickly and precisely switch focus between different requirements, or alternately observe and process different aspects of a task. Attention control also involves paying attention to the task-relevant information, ensuring the optimum level of attention for the selected aspects, and maintaining this until the end of the activity" (Diamond, 2013, n.p.).

The areas of the brain controlling the motor function (movement) are located in the frontal lobe – like the executive functions – are better supplied with blood through regular physical activity and provided with neuroplastic messengers (especially proteins and hormones), which neighboring brain areas such as the executive functions and language areas share.

2.4 The Physiological-Biochemical Connections

No matter what effects movement has on humans, it is always the muscular contractions that trigger them. One of the most important keys to our holistic performance lies in the stimulation of the muscles (600 +); our largest metabolic organ. Fibrous tissues are not just a self-contained system that mechanically propels us forward on the instruction of the brain. They also form an important organ system connected to all organs of the body, and these not only strengthens and revitalizes them, but also generates positive physical, mental, and emotional interactions. As soon as muscle fibers begin to move, a cocktail of molecular messengers is released (including proteins, enzymes, hormones) that positively affect the metabolism throughout the body. In recent years, researchers have identified nearly 3,000 different proteins that muscles release during their work – proteins that are then fed into the bloodstream (Korte, 2013). Among these proteins are hundreds of hormone-like substances that migrate into the body. This includes the brain maturation protein BDNF (Brain-Derived Neurotrophic Factor), which is known to positively stimulate the structure of neurons, promote neurogenesis (nerve cell formation in the hippocampus).

Without exaggerating, "BDNF can be called 'miracle fertilizer' for our brain cells as it also supports the release of dopamine (neurotransmitter), a hormone that supports neuroplasticity by integrating the newly formed neurons into existing circuits" (Nehls, 2014, p. 352; Melo Coelho et al., 2013; Stickgold, 2009; Lopes et al., 2013). In addition, it should be noted that dopamine not only promotes selective attention, working memory and long-term memory, but is also involved in arousing curiosity and making quick and safe decisions.

3. Research Methods & Techniques

3.1 Research Design

Understanding the impact of spatial designs is important (Whiteside, Brooks, & Walker, 2010; Byers, Imms, & Hartnell-Young, 2014). For this Exploratory (George, 2021) study, a Basic Mixed Method, Convergent Parallel Research Design (see Figure 1, Harvard Catalyst, 2022) requiring both quantitative and qualitative data gathering was used.

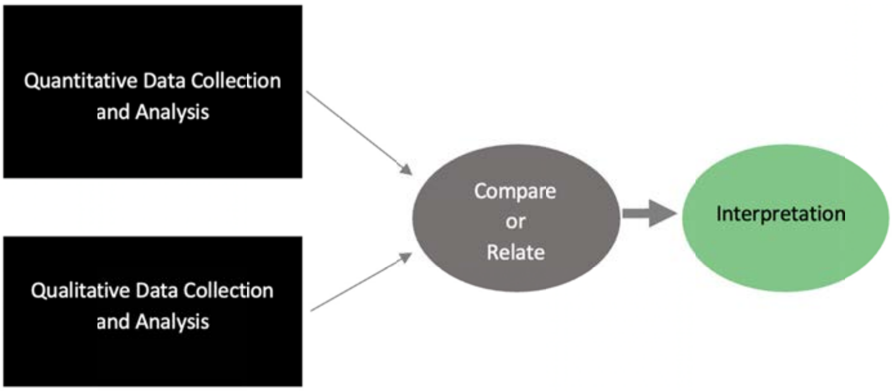

Figure 1. Basic mixed-methods research design (adapted from Harvard Catalyst, 2022)

3.2 A Multiple Techniques Exploratory Study / POE

Qualitative and quantitative data were collected using multiple techniques: (a) observational mapping – behaviors and photographic traces, (b) online surveys, (c) d2 concentration test, and (d) an accelerometric measurement method to record physical behavior in onsite conditions. Two profession development sessions were administered (the intervention) after the first two-day observation period – introducing the science behind physical movement, engagement practices, and purpose-built/ergonomic designs for learning places. Content from each technique was analyzed independently, then compared in order to generated interpretive findings. Information on the techniques is next.

The Condition

This research team observed as a Post Occupancy Evaluation (POE). The room and its furnishings were set up in a manner to support an active learning experience (i.e., ILE) with as much ergo-dynamic furniture as both time and budget would allow (see Figure 2).

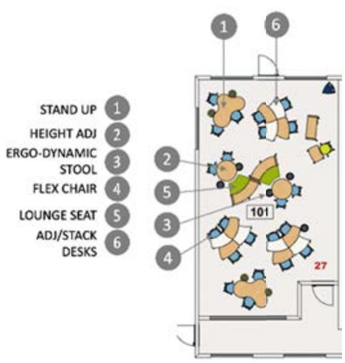

Figure 2. Typical Ergo-dynamic Furniture Solutions

Behavioral Mapping

Mapping behaviors takes its procedures from anthropological ethnography (Zeisel, 1984; Bectel, Marans, & Michelson, 1987), recording for understanding particular in-situ behavior(s). What researchers want to discern is how people actually behave in certain situations as opposed to what they think they do (e.g., surveys). Thus, time on site viewing behaviors with a particular ‘lens’ and recoding them with a short hand of agreed upon note taking codes, along with written descriptions generates the data. The codes were developed to capture the essence of the research questions, and each researcher was trained on how to use all data gathering techniques in order to be consistent across researchers. See Figure 3 for this research’s behavioral method’s code, and recorded data spreadsheet is shown in an example in Figure 4. These data points can be graphically illustrated for quantifying the data (Tufte, 1983, see Figures 2–3).

The behavioral mapping short hand codes for this study included: # of Students; Movement = / for leaning on something, W for walking, L for sitting, ^ for standing, > for a prone position, ~ for fidgeting. The Engagement (i.e., Interaction) included: S/C for Student-to-Content, S/S for Student-to-Student, S/F for Student-to-Faculty, S/E for Student-to Environment/or Environmental Object (e.g., a computer or whiteboard), F/S for Faculty-to-Student. The Practice included the teaching practices of: WG for Whole Group, SG for Small Group, and Ind for Independent work. The tallies below each column are the number of observables in-situ conditions (tallies n= 5008).

#	DESCRIPTION																
S	MOVEMENT						M.sum	ENGAGEMENT					E.sum	PRACTICE			P.sum
	/	W	L	^	>	~		S/C	S/S	S/F	S/E	F/S		WG	SG	Ind	

KEY:	KEY:	KEY:
S = Student / = Macro leaning W = Walking L = Sitting ^ = Standing > = Lying on surface ~ = Wiggling	S/C = Student-to-content S/S = Student-to-student S/F = Student-to-faculty S/E = Student-to-environment F/S = Faculty–to-student	WG = Whole group SG = Small group IND = independent

Figure 3. Behavioral mapping code

ROOM							DAY				TIME				#	DESCRIPTION																	NOTES
A	B	C	E	F	G	H	M	T	W	TH	BLK	Clock	AM	PM	S	MOVEMENT						M.sum	ENGAGEMENT					E.sum	PRACTICE			P.sum	
																/	W	L	^	>	~		S/C	S/S	S/F	S/E	F/S		WG	SG	Ind		
												3:07					1		1							1					1		s = walks out
												3:08					5	10	5				1	1	1	1				1	1		s = waks, stands, sits back down
																	1		1							1					1		t = walks out
																			2				1			1					1		s = works on white board
												3:09					1		1							1					1		s = walks around room
																			2							1					1		s = stands up/sits down
																					1					1					1		s = twisting in chair
												3:10						10	5				1	1		1				1	1		s = game against teams
												3:12					1		1							1					1		s = walks back in

Figure 4. Mapping data input

Photographic Traces

Photographic traces (Zeisel, 1984) are another important mapping technique providing artifact analysis. Where the maps using analogue, or a written dialogue and graphing, and give an ongoing sequence of events as a written record by the researchers, photographs provide visual traces of these same events capturing specific points in time (Zeisel, 1984). By providing a ‘trace’ in a photographic record, that is time sequenced (in this case every 15 minutes by each observer’s camera) these records can be compared individually, and then cross referenced with other data collection techniques to add clarity and consistency, begin defining categories of situational types, and reduce bias during the analysis phase (see Figures 4 & 6).

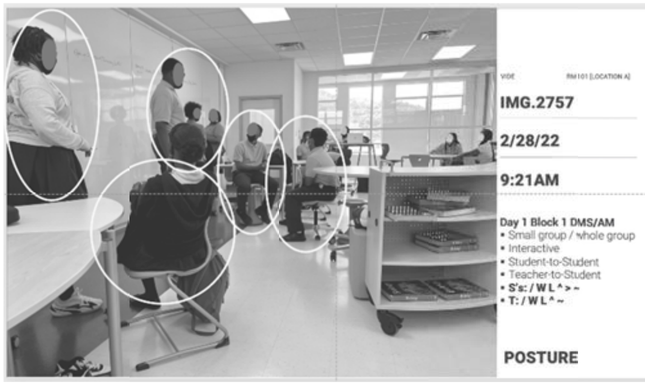

Figure 5. Photographic trace mapping / a (one photograph)

Figure 6. Photographic trace mapping / b (two photographs)

Comprehension Testing

> The d2 test, d2 for short, is a standardized, neuropsychological test for recording attention and concentration. The test can be used on people aged 9 to 60 years. Individual and group test for the age range from 9 to 60 years. Is used in almost all psychological work areas, including in the areas of clinical and medical, neuro-, educational, traffic, as well as industrial and organizational psychology. The d2 test is timed for 10 minutes, and consists of 14 lines in which a large number of the letters 'd' and 'p' appear next to each other. These two letters have one or two dashes above and / or below them. The test person's task is to cross out all 'd' with two lines (target object). All other stimulus constellations, that is, all 'p' and all 'd' with fewer or more than two lines, are referred to as distractors. The test person has exactly 20 seconds to complete for each row (Brickenkamp, Schmidt-Atzert, & Liepmann, 2002, n.p.).

The d2-R is a revised and newly standardized version of the attention test d2 (Brickenkamp et al, 2002). It records the concentrated attention in the age range from 9 to 60 years in the form of the concentration performance (KL), in which the speed (BZO) and accuracy (F%) of the machining are included. Central changes compared to the d2 are written instructions for the participants, copy sheets for the evaluation, an increased number of items and revised parameters. Areas of application are in assessing the suitability of employees in occupations that require concentrated work, as well as identifying performance restrictions in educational, clinical and neuropsychological contexts. For our purposes, two classrooms of students took this test at the same time period.

'Wearable' / The Accelerometer

"The International Children's Accelerometry Database (ICAD) (Sherar, Griew, Esliger, Cooper, Ekelund, Judge & Riddoch, 2011), has developed standardized methods to create comparable physical activity variables from more than 20 studies including more than 32,000 participants (Cooper et al., 2015), and used this database to describe variations in physical activity and sedentary time between seven European countries" (Steene-Johannessen et al., 2020, p. 2).

Accelerometers are acceleration sensors that measure the duration, frequency and intensity of human activity or inactivity. Depending on the positioning, accelerometers allow conclusions to be drawn about some of the relevant movements, but not about all physical activities equally well. Since the accelerometer does not measure movements that only the upper body makes if it is worn on the hip, the device sometimes underestimates the energy expenditure.

For this study, physical activity was measured using an ActiGraph accelerometer (model GTX3). The ActiGraph is the most intensively studied device for accelerometric measurement of physical activity in international specialist literature, and provides proven valid and reliable measurement data (Santos-Lozano et al., 2012; Kelly et al., 2013; Hänggi, Phillips, & Rowlands, 2013). Accelerometers not only allow the intensity of an activity to be measured, but also a high-resolution (second-precise) representation of the activity profile over the wearing period. The device is worn on the side of the hip with an elastic belt (see Figure 7). When positioned near the center of the body, a high correlation of the accelerometer signal with physical activity and energy expenditure may be observed (Garatachea et al., 2010).

Figure 7. An example of a person wearing the 'wearable' – the accelerometer

We used accelerometers to record the students' physical behavior during the lessons in two scheduled blocks. The aim was to find out to what extent classroom conditions (i.e., pedagogical and facility design features) were weighted with an increased focus on changing postures such as active-dynamic sitting, standing and movement in the room, were also reflected in better metabolic-physiological values in the students (Altenburg, Rotteveel, Dunstan, Salmon, & Chinapaw, 2013). In the present study, an epoch length of 30 seconds was chosen for storing the activity units.

Professional Development

The Professional Development (PD) sessions for the educators consisted of two, synchronously delivered online sessions. The first was delivered by the Co-PI on quality/ergo-dynamic movement. The second was delivered by the PI on engagement factors and active learning. Both delivered after school via live zoom meeting.

Surveys

Two surveys were sent online to both the educators (n=8), and the students (n=90); one was pre-intervention. The other was post.

4. Interpretive Findings

4.1 Behavioral Mapping

Observations reflected students were seated 72% of their class time overall (see Figure 8). The macro movements (i.e., major body leaning – forward or backward; walking; standing) these segments of physical postural changes reflected 42% leaning, 36% walking, and 21% standing (students stood to walk in or out of class) (see Figure 9). For the overall micro movements, these were split between lying down on the desk (70%) or wiggling (30%) (see Figure 10).

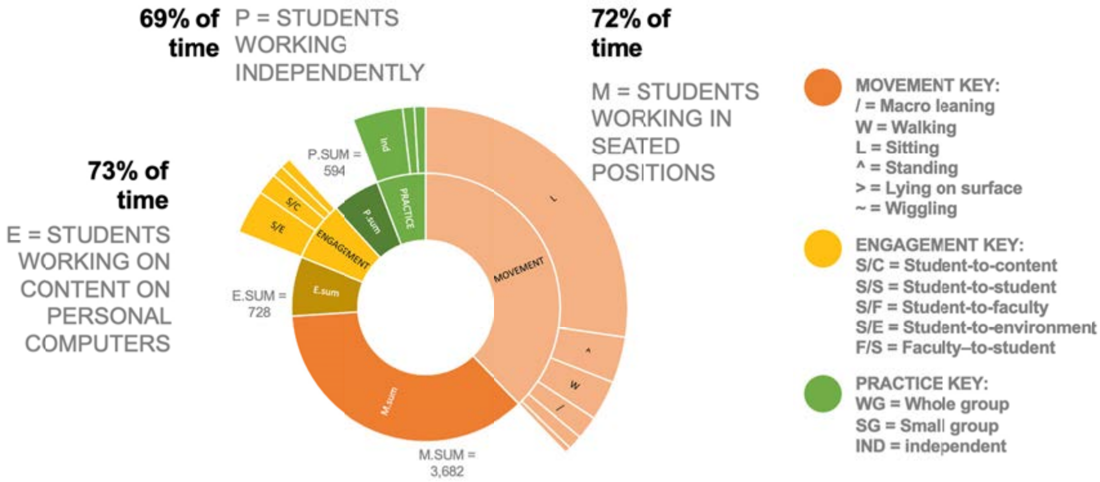

Figure 8. Mapping summary – overall / students

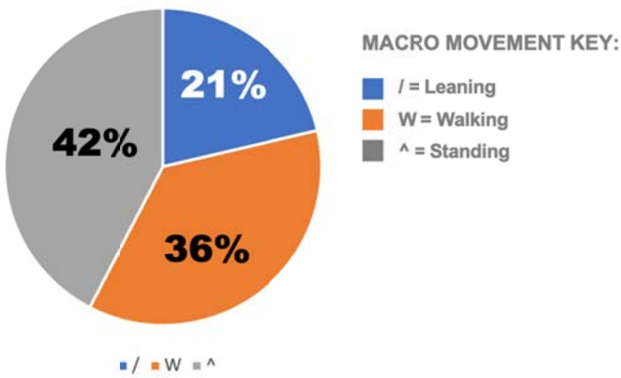

Figure 9. Macro movements / students

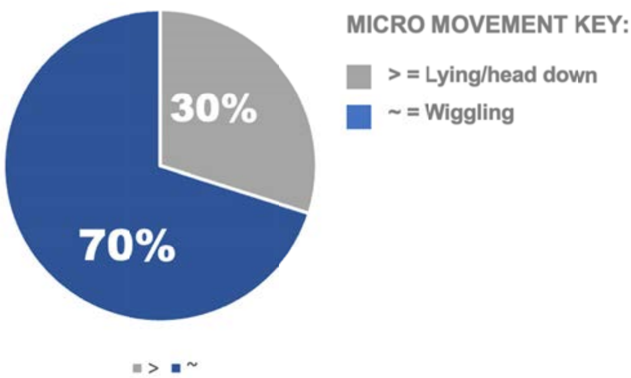

Figure 10. Micro movements / students

Students were engaged primarily with their environment (dominantly on the computer, but some on notebooks, or on some occasions on the vertical white board). 12% was student-to-student in interactive discussions. Only 2% of the time students went directly to the faculty member for one-on-one (see Figure 11).

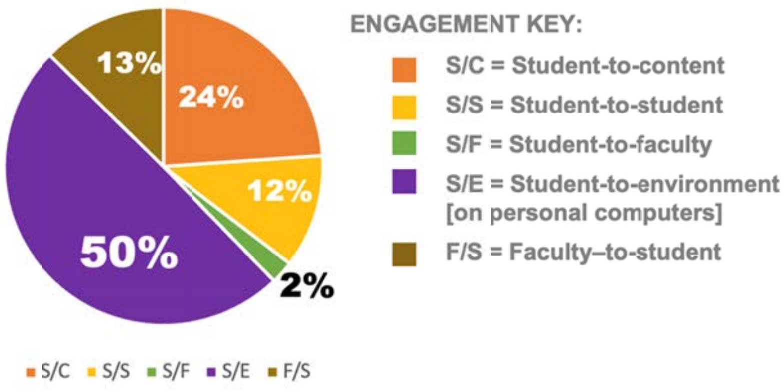

Figure 11. Interactive engagement overall / students

The teaching practices revealed a dominant whole group strategy (69%), with 16% for both small group or individual instruction (see Figure 12). the photographic traces.

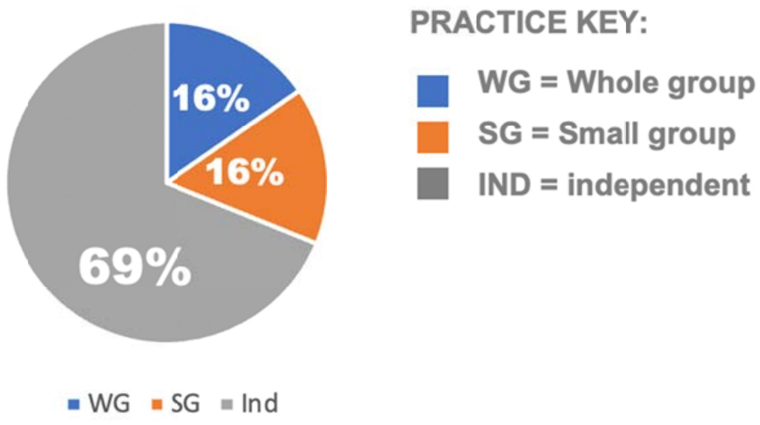

Figure 12. Teaching practices overall / students

4.2 Comprehensive Testing

Objectivity Implementation

Evaluation and interpretation of the d2-R are described in detail in the text (Brickenkamp et al., 2002). The d2-R is an established and extensively analyzed test method for recording attentional performance that can be used on children and adults. With an implementation and evaluation time of around 15 minutes, the test enables an economical, objective, and reliable recording of concentration performance and work speed. The accuracy value (F%) should not be interpreted because of its limited reliability and the inconsistent findings on convergent validity. Predictive decisions should therefore primarily be based on (KL) or (BZO).

Test Evaluation

The following measured values are included in the evaluation of the present study the:

- Total number of all processed characters (GZ) as a criterion for processing speed;
- Raw error score (F), the sum of all errors (both omissions and mistakes of confusion) as a criterion for the accuracy of the work;
- Total number of all processed characters (GZ-F) reduced by the number of errors as a total performance; here the quantitative part is weighted more heavily than the qualitative aspect of the service; and
- Concentration performance value (KL), which consists of the number of correctly crossed out relevant

characters reduced by the number of mistakes made for confusion; the qualitative aspect of performance plays a greater role here than in the case of overall performance.

The recorded raw values are converted to standard values using the standard tables. Norms are available for children from 9-years of age and up (Hänggi, Phillips, & Rowlands, 2013). The norms that are currently proposed as a standard are presented in detailed tabular form and serve as an optimal basis for comparison. They contain almost all expected raw values of GZ, GZ-F and KL. In the current edition of the attention stress test, the test refers to German norms based on different samples, since no US American norms were available for the corresponding age group. Results of concentration tests are listed and compared here in tabular form. The performance or changes of all students are compared, and performances or changes after the two classes are compared (see Tables 1 & 2).

Table 1. Two classrooms - d2 test findings / students

Parameter [Room 1] N = 10	Average Value	Standard Deviation	Parameter [Room 2] N = 6	Average Value	Standard Deviation
GZ	481,80	64,65	GZ	345,33	73,86
F in Total	34,70	18,48	F in Total	30,67	14,02
GZ-F	447,30	46,78	GZ-F	276,83	64,13
KL	173,70	21,39	KL	118,83	28,47

Note. GZ = all marks; GZ-F = correct marks; F = wrong marks; KL = concentration performance.

Results of d2 test indicate the two classrooms had very different levels of engagement. With 14 lines of the test; one class had every line completed. The other class 3-4 students did not complete the lines. The results should not be overestimated, since the sample is relatively small and the survey was only carried out on one day only in two classrooms at the same time period. Both classes show a slightly above-average number of processed characters, as a criterion for processing speed. At the same time, both classes also have a high number of errors, which includes omissions, mistakes, or confusion. These are all signs that the qualitative aspect, the concentration (accuracy) on the relevant signs for both classes was only average (about 50% of the age group). If one looks at both classes separately, there are clear differences. Room GN has a slightly above average processing speed, yet an average focus on crossing out the relevant characters. Their attention span is therefore average (about 50% of the age group). Room 103 not only has a processing speed that is well below average, but their attentional performance is also well below average (about 10% of the age group).

Table 2. Combined results for d2 test / students

Parameter	Both Classrooms	Average Value	Standard Deviation
GZ	N = 16	430,63	50,08
F in Total		33,18	26,91
GZ-F		383,25	50,80
KL		153,13	30,71

Note. GZ = all marks; GZ-F = correct marks; F = wrong marks; KL = concentration performance.

Wearables / Accelerometer

The ActiGraph weighs 27g and measures 4.6×3.3×1.5cm; 19g. It measures accelerations of the vertical axis. Physical activity is described in units (so-called "activity counts"). In the accelerometry, limit values (cut points) are then defined, which classify the activity of the subject into corresponding intensity categories based on the measured activity counts. The following applies here: the higher the intensity of the activity, the higher the resulting activity counts. Based on this classification, it can consequently be determined how much time or what proportion of time the participant spends in individual intensity ranges. With regard to the intensity categories, we refer here to the work of Troiano et al. (2008), who for their part used the criteria of four different studies as a basis for establishing the limit values:

- Light to low intensity (light): < 2020 counts per minute cpm (corresponds to approx. 1.5–2.99 MET);
- Moderate intensity (moderate): ⩾ 2020 cpm (corresponds to approx. 3 METs–5.99 METs); and
- Intense intensity (vigorous): ⩾ 5999 cpm (equivalent to 6 METs–9 METs).

The definition of inactive behavior as < 100 cpm is now also generally accepted (Hagströmer et al., 2015; Trost et al., 2011).

Evaluation

The data collection has been done during two morning classroom blocks. It has been prepared with detailed instructions on how to use the ActiGraph, and a written request for some personal information (e.g., age, gender). Subsequently, a total of 6 randomly selected subjects (4 female / two male in the age 15 and 16) were each given an accelerometer with the request to keep them on for the morning (i.a., 8:30–12:30). The initialization and evaluation of the data was carried out with the ActiLife Lifestyle Software.

We knew that to collect reliable data, the accelerometers should be worn for at least 7 days. However, for technical, COVID-related, and organizational reasons, data collection was only possible on one school morning. The knowledge gained in this regard has limited but no representative significance. The following Figure 13 (see Figure 13) shows physical activity based on cpm values during lessons over the course of the school morning. Since the accelerometer does not measure movements that only the upper body makes if it is worn on the hip, the device sometimes underestimates the energy expenditure. The Activity Level in cpm during Block 1 (8:50–10:10 am) and Block 2 (10:20–11:40 am) = blue: a student's highest measured cpm score; orange: a student's lowest measured cpm score; grey the average cpm of all students.

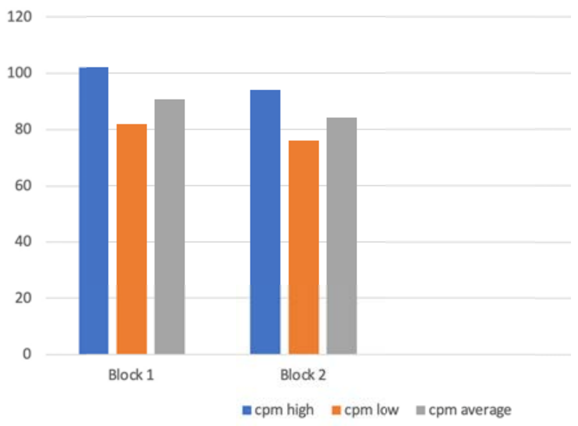

Figure 13. Measured activity levels / cpm

From this data it can be inferred – as was already shown in the behavior observations – that these students were maintaining a sitting, mostly inactive behavior almost exclusively during the lessons (inactive behavior < 100 cpm). On the basis of metabolic-physiological consequences, this data suggests that the subjects were exposed to an unphysiological metabolism over an extended period of time.

It can be stated that evidence from intervention studies provide indications of the positive effects of active interruptions on glucose metabolism during sedentary behavior. The levels of 'interruptions' here need to be improved.

Surveys & Interviews

What we think we do (i.e., surveys) and what we actually do (i.e., observations of actual behavior) are often somewhat different. Affirmation was attained with interviews. Notably, both students and educators were: excited (and remained so throughout the term) to be in this newly designed place with special furniture. Across the term, there was: (a) a significant lack of disruptive, and destructive behaviors, (b) more motivation to come to school and be there early, (c) new senses of pride and belonging, and (d) a report of more motivation to achieve higher grade levels and be more engaged in their learning process.

After the interventions, educators indicated they were working to include more interactive engagement practices, allowing students to move at will, and allowing them to use the ergo-dynamic furniture as intended more. The most favored furniture feature was the ability to encourage movement (i.e., standing desks, chairs with wheels, height adjustable tables). In their own words, educators indicated, "They felt empowered to allow students to become independent in navigating the classroom.

4.3 Limitations

As in any exploratory study, there are always limitations; factors not under our control as researchers. Multiple factors complicated this study. The primary one was the shutdown of classes due to COVID resulting in the second observation and test opportunities being lost. The two PD session were held virtually, and that situation is not always the best for helping attendees practice, and be observed in that practice to help them retain their new knowledge. These closures meant that the comparative analysis was not as robust as hoped.

4.4 Insights

The data indicates that the ergo-dynamic furnishings are providing the much-needed interruption with seated postures allowing for the micro movements and some macro-ones all humans need. It is also recognized that teaching practices (e.g., what teachers allow/ask of students) is a critical component of student behavior, and behavioral possibilities. Concentration levels are affected when seated situations are the norm. Some behavioral changes, relative to the amount of student movements were noted after the professional development sessions were administered.

The gap is clear…intentional research-informed designs must connect with pedagogical practices. Therefore, it is important to understand that:

- Ergo-dynamic furniture is intuitively used by students – at least at the micro levels, and some seated macro-ones; it seems to be one of their only opportunities to physically change postures and support the human body's mechanistic needs when teaching practices are not fully implementing an ILE condition;
- No matter the design, or the designs of ergo-dynamic furniture designs, if teachers are uniformed of these new designs (i.e., technologically enhanced and research-informed design solutions) practices do not connect with the opportunity the solution provides. Thus, the maximum advantages of the intentional designs for learning are not being reaped; and
- The message that individuals must move to learn is not yet integrated into the classroom.

4.5 Conclusion

- Embed into teaching practices the research evidence for how the human brain learns through movement (see Figure 14);

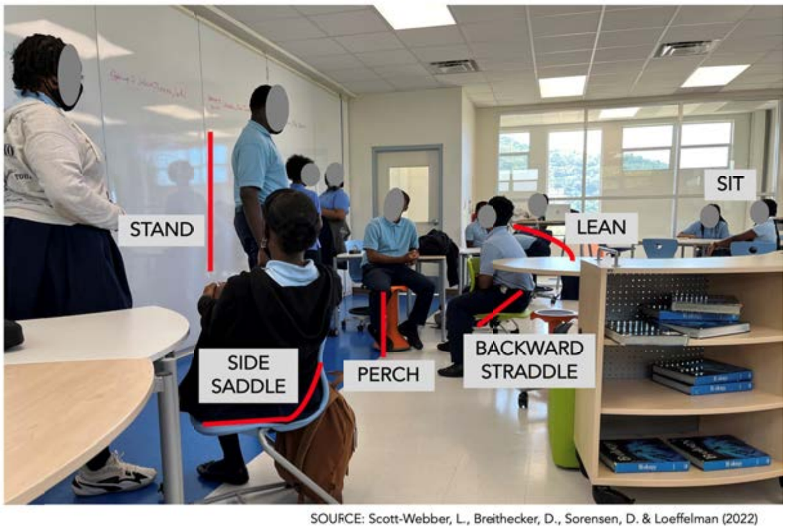

Figure 14. Magic happens when pedagogy embraces design solutions

- Provide robust Professional Development 'Spatial Orientation' courses (preferably starting at the college level educators' degree path); at the very least, whenever new design solutions are being introduced for a solution orientation to the 'why learners must move to learn' must be part of any real transition into the full use, and knowledge of space and its solutions as a tool for active learning;
- Recognize that research evidence brings the responsibility to provide for appropriate design solutions, BUT must help the educational community change their mind sets and use these designs to support students' ability to learn; and

- Have a global picture on the role of classroom active desks on improving health-related outcomes of children and adolescents is needed to inform policy and practice.

Acknowledgements

This research study was funded by VS America, Inc. We want to thank them along with the principle, educators and students of Wheatley 9th Grade Center for supporting this important research study.

References

Abraham, A., & Müller, B. (2010). *Body action and body experience - Introduction to an explosive field*. Transcript, Bielefeld.

Altenburg, T. M., Rotteveel, J., Dunstan, D. W., Salmon, J., & Chinapaw, M. J. (2013). The effect of interrupting prolonged sitting time with short, hourly, moderate-intensity cycling bouts on cardiometabolic risk factors in healthy, young adults. *Journal of Applied Physiology*, *115*(12), 1751–1756. https://doi.org/10.1152/japplphysiol.00662.2013

Altman, I. (1975). *The environment and social behavior: Privacy, personal space, territory, crowding*. Monterey, CA: Brooks/Cole Pub. Co.

Bailey, D. P., & Locke, C. D. (2014). Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. *Journal of Science Medicine and Sports*, *18*(3), 294–298. https://doi.org/10.1016/j.jsams.2014.03.008

Bechtel, R. B., Marans, R. W., & Michelson, W. (1987). *Methods in Environmental and Behavioral Research*. New York: Van Nostrand.

Bernaards, C. M., Hildebrandt, V. H., & Hendriksen, J. M. (2016). Correlates of sedentary time in different age groups: results from a large cross sectional Dutch survey. *BMC Public Health*, *16*(1), 1121. https://doi.org/10.1186/s12889-016-3769-3

Beudels, W. (2013). Movement as a medium of learning. In A. Krus & C. Jasmund (Eds.), *Movement in early childhood* (pp. 73–78). BMBF Research Project. Niederrhein University of Applied Sciences.

Bøjer, B. (2021). Learning: The importance of engaging the users in the design process. In W. Imms & T. Kvans (Eds.), *Teacher transition into innovative learning environments*. https://doi.org/10.1007/978-981-15-7497-9_4

Breithecker, D. (2005). Workplace school. The impact of situational and behavioral prevention measures on the development of attitudes in elementary school students. *Posture and Movement*, *25*(3), 17–22.

Breithecker, D. (2009). *Bodies in motion. How adequate movement promotes both physical development and academic progress*. Federal Institute on the Development of Posture and Exercise Wiesbaden, Germany. Retrieved from file:///C:/Users/Breithecker/Documents/Dieter%20Breithecker/Word%20Dokumente/VS%20USA/Bodies%20in%20Motion%20-%20Brains%20in%20Motion.pdf

Brickenkamp, R., Schmidt-Atzert, L., & Liepmann, D. (2002). *d2 test of attention* (revised). UK. Hogrefe Ltd, Hogrefe House. Retrieved from https://www.hofmann-verlag.de/pdf/archiv/sportunterricht/2008/sportunterricht-Ausgabe-August-2008.pdf#page=12

Brittin, J., Frerichs, L., Sirard, J. R., Wells, N. M., Myers, B. M., Garcia, J., … Huang, T. (2017). Impacts of active school design on school-time sedentary behavior and physical activity: A pilot natural experiment. *PLoS ONE*, *12*(12), e0189236. https://doi.org/10.1371/journal.pone.0189236

Brittin, J., Sorensen, D., Trowbridge, M., Lee, K. K., Breithecker, D., Frerichs, L., & Huang, T. (2015). Physical activity design guidelines for school architecture. *PLoS ONE*, *10*(7), e0132597. https://doi.org/10.1371/journal.pone.0132597

Brooks, C. D. (2012). Space and consequences: The impact of different formal learning spaces on instructor and student behavior. *Journal of Learning Spaces*, *1*(2), ISSN 21586195. Retrieved from http://libjournal.uncg.edu/jls/article/view/285/275

Byers, T., Imms, W., & Hartnell-Young, E. (2014). Making the case for space: The effect of learning spaces on teaching and learning. *Curriculum and Teaching*, *29*(1), 5–19. https://doi.org/10.7459/ct/29.1.02

Castelli, D. M., Hillmann, C. H., Buck, S. M., & Erwin, H. E. (2007). Physical fitness and academic achievement in third- and fifth-grade students. *Journal of Sport and Exercise Psychology*, *29*(2), 239–252. https://doi.org/10.1123/jsep.29.2.239

Coe, D. P., Pilvernik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effects of physical education and activity levels on academic achievement of children. *Medicine and Science in Sports & Exercise*, *38*(8), 1515–1519. https://doi.org/10.1249/01.mss.0000227537.13175.1b

Cooper, A. R., Goodman, A., Page, A. S., Sherar, L. B., Esliger, D. W., van Sluijs, E. M., … Ekelund, U. (2015). Objectively measured physical activity and sedentary time in youth: The International children's accelerometry database (ICAD). *International Journal of Behavioral Nutrition and Physical Activity*, *12*, 113. https://doi.org/10.1186/s12966-015-0274-5

Dave, R. H. (1970). Psychomotor levels. In R. J. Armstrong (Ed.), *Developing and writing behavioral objectives*. Tucson, Arizona: Educational Innovators Press. https://doi.org/10.1016/j.ultrasmedbio.2019.07.508

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dordel, S., & Breithecker, D. (2003). Active school as an opportunity to promote learning and performance. *Posture and Movement*, *23*(2), 5–15.

Elliot, A. J., & Covington, M. V. (2001). Approach and avoidance motivation. *Educational Psychology Review*, *13*(2), 73–92. https://doi.org/10.1023/A:1009009018235

Farooq, M. A., Parkinson, K. N., Adamson, A. J., Pearce, M. S., Reilly, J. K., Hughes, A. R., … Reilly, J. J. (2018). Timing of the Decline in Physical Activity in Childhood and Adolescence: Gateshead Millennium Cohort Study. *Br. J. Sports Med.*, *52*, 1002–1006. https://doi.org/10.1136/bjsports-2016-096933

Fischer, K. (2016). Learning as an exploratory activity in childhood. In O. Weiß, J. Voglsinger & N. Stuppacher (Eds.), *Efficient learning through movement* (pp. 65–84). Waxmann, Munster/New York. https://doi.org/10.1093/acprof:oso/9780198769873.003.0003

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). *Active learning increases student performance in science, engineering, and mathematics*. PNAS 2014, https://doi.org/10.1073/pnas.1319030111

Garatachea, N., Torres Luque, G., & González-Gallego, J. (2010). Physical activity and energy expenditure measurements using accelerometers in older adults. *Nutrition Hospitality*, *25*(2), 224–230.

Garcia, J. M., Huang, T. T., Trowbridge, M., Weltman, A., & Sirard, J. R. (2016). Comparison of the effects of stable and dynamic furniture on physical activity and learning in children. *Journal of Primary Prevention*, *37*, 555–560. https://doi.org/10.1007/s10935-016-0451-6

George, T. (2021). *Exploratory research | definition, guide, & examples*. Scribbr. Retrieved from https://www.scribbr.com/methodology/exploratory-research/

Graf, C., Dordel, S., & Koch, B. (2003). Physical activity and concentration – is there a connection? *Physical Education*, *52*(5), 142–146.

Guirado, T., Chambonnière, C., Chaput, J. P., Metz, L., Thivel, D., & Duclos, M. (2021). Effects of classroom active desks on children and adolescents' physical activity, sedentary behavior, academic achievements and overall health: a systematic review. *International Journal of Environment Research and Public Health*, *18*(6), 2828. https://doi.org/10.3390/ijerph18062828

Hagströmer, M., Kwak, L., Oja, P., & Sjöström, M. (2015). A 6-year longitudinal study of accelerometer measured physical activity and sedentary time in Swedish adults. *Journal of Science and Medicine in Sport*, *18*(5), 553–557. https://doi.org/10.1016/j.jsams.2014.07.012

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global Physical Activity Levels: Surveillance Progress, Pitfalls, and Prospects. *Lancet*, *380*, 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Hänggi, J. M., Phillips, L. R. S., & Rowlands, A. V. (2013). Validation of the GT3X ActiGraph in children and comparison with the GT1M ActiGraph. *Journal of Science and Medicine in Sport*, *16*(1), 40–44. https://doi.org/10.1016/j.jsams.2012.05.012

Harrow, A. (1972). *A taxonomy of the psychomotor domain: A guide for developing behavioral objectives*. New York: David McKay.

Harvard Catalyst. (2022). *Community Engagement Program. Innovation and improvement in public health via community engagement and research*. Retrieved from https://catalyst.harvard.edu/community-engagement/mmr/

Henson, J., Yates, T., Biddle, S. J. H., Edwardson, C. L., Khunti, K., & Wilmot, E. G. (2013). Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health. *Diabetes*, *56*(5), 1012–1020. https://doi.org/10.1007/s00125-013-2845-9

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience*, *159*(3), 1044–1054. https://doi.org/10.1016/j.neuroscience.2009.01.057

Hollmann, W. (2004). *Movement and physicality as the elixir of life*. Retrieved March 22, 2010, from http://www.clubofrome.de/schulen/schulen/Hollmann_bewegung_Körperaktivitaet_Lebenselexier.pdf

Hutchison, E. D. (2015). *Dimensions of human behavior: Person and environment* (5th ed.). NY: Sage Publications. ISBN: 978-1483303918

Imms, W., & Byers, T. (2017). Impact of classroom design on teacher pedagogy and student engagement and performance in mathematics. *Learning Environments Research*, *20*(1), 139–152. https://doi.org/10.1007/s10984-016-9210-0

Imms, W., Cleveland, B., & Fisher, K. (2016). Pursuing that elusive knowledge about what works in learning environment design. In W. Imms, B. Cleveland & K. Fisher (Eds.), *Evaluating learning environments: Snapshots of emerging issues, methods and knowledge* (pp. 3–16). Rotterdam, Netherlands: Sense Publishing. https://doi.org/10.1007/978-94-6300-537-1_1

Imms, W., Mahat, M., Byers, T., & Murphy, D. (2017). *Type and use of innovative learning environ- ments in Australasian schools*. ILETC Survey 1 (0734053819). Retrieved from https://minerva-access.unimelb.edu.au/handle/11343/219467

Janssen, I., & Leblanc, A. G. (2016). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavior Nutrition Physical Activity*, *2010*(7), 40. https://doi.org/10.1186/1479-5868-7-40

Kelly, L. A., McMillan, D. G., Anderson, A., Fippinger, M., Fillerup, G., & Rider, J. (2013). Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC Medical Physics*, *13*(1), 5. https://doi.org/10.1186/1756-6649-13-5

Kilbourne, J., Scott-Webber, L., & Kapitula, L. R. (2017). An activity-permissible classroom: Impacts of an evidence-based design solution on student engagement and movement in an elementary school classroom. *Children, Youth and Environments*, *27*(1), 112–134. https://doi.org/10.7721/chilyoutenvi.27.1.0112

Klafki, W., & Braun, K. H. (2007). *Ways of pedagogical thinking*. Ernst Reinhardt, Munich/Basel.

Korte, M. (2013). *Young at heart. Amazing insights from brain research into aging*. German publishing house in Munich.

Lopes, L., Santos, R., Pereira, B., & Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. *Human Movement and Science*, *32*(1), 9–20. https://doi.org/10.1016/j.humov.2012.05.005

Melo Coelho, F. G., Gobbi, S., Andreatto, C. A. A., Corazza, D. I., Pedroso, R. V., & Santos-Galduróz, R. F. (2013). Physical exercise modulates peripheral levels of brain-derived neurotrophic factor (BDNF): a systematic review of experimental studies in the elderly. ELSEVIER. *Archives of Gerontology and Geriatrics*, *56*(1), 10–15. https://doi.org/10.1016/j.archger.2012.06.003

Minges, K. E., Chao, A. M., Irwin, M. L., Owen, N., Park, C., Whittemore, R., & Salmon, J. (2016). Classroom standing desks and sedentary behavior: A systematic review. *Pediatrics*, *137*(2), e20153087. https://doi.org/10.1542/peds.2015-3087

Moser, T. (2016). Body and learning. In O. Weiß, J. Voglsinger & N. Stuppacher (Eds.), *Efficient learning through movement* (pp. 15–40). Waxmann, Munster. New York.

Nehls, M. (2014). *The Alzheimer's Lie*. Wilhelm Heine Verlag, Munich.

Saunders, T. J., Tremblay, M. S., Mathieu, M.-È., Henderson, M., O'Loughlin, J., & Tremblay, A. (2013). Associations of Sedentary Behavior, Sedentary Bouts and Breaks in Sedentary Time with Cardiometabolic

Risk in Children with a Family History of Obesity. *PLoS ONE*, *8*(11), e79143. https://doi.org/10.1371/journal.pone.0079143

Schneider, S., & Guardiera, P. (2011). Education needs movement – neurophysiological connections between physical activity and learning performance in school. *Physical Education*, *60*, 317–321.

Schulkultur. (n.d.). In R. Hildebrandt-Stramann, R. Laging & K. Moegling (Eds.), *Körper, Bewegung und Schule* (Teil 1: Theorie, Forschung und Diskussion Prolog, Immenhausen, pp. 54–75).

Scott-Webber, L. (2004). *INSYNC: Environment behavior and the design of learning places*. MI: The Society of University Planning.

Scott-Webber, L. (2021). Row-by-column, plexiglass & zoom, oh my! A K-12 COVID-19 storm / A pilot. *Journal of Education and Learning*, *10*(2), 9. https://doi.org/10.5539/jel.v10n2p9

Scott-Webber, L., Konyndyk, R., & Denison, M. (2019). POE: Understanding innovative learning places and their impact on student academic engagement – index 6–8 'alpha' survey developments. *Journal of Education and Learning*, *8*(5), 31–56. https://doi.org/10.5539/jel.v8n5p31

Scott-Webber, L., Konyndyk, R., & French, R. (2019). Developing instruments: Student academic engagement levels and satisfaction with school design. *European Scientific Journal*, *15*(1), 325–347. https://doi.org/10.19044/esj.2019.v15n1p325

Scott-Webber, L., Konyndyk, R., French, R., & French, J. (2018). Significant results: Space makes a difference for student academic engagement levels. *European Scientific Journal*, *14*(16), 61. https://doi.org/10.19044/esj.2018.v14n16p61

Scott-Webber, L., Konyndyk, R., French, R., Lembke, J., & Kinney, T. (2017). Spatial design makes a difference in student academic engagement levels: A pilot study for grades 9–12. *European Scientific Journal*, *13*(16), 5. https://doi.org/10.19044/esj.2017.v13n16p5

Sherar, L. B., Griew, P., Esliger, D. W., Cooper, A. R., Ekelund, U., Judge, K., & Riddoch, C. (2011). International children's accelerometry database (ICAD): Design and methods. *BMC Public Health*, *11*, 485. https://doi.org/10.1186/1471-2458-11-485

Sommer, R. (1969). *Personal space. The behavioral basis of design*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Stangel, W. (2010). *Learning definition's worksheets*. Retrieved March 28, 2017, from http://www.arbeitsblaetter.stangl-taller.at/LERNEN/ Lerndefinitionen.shtml

Steene-Johannessen, J., Hansen, B. H., Dalene, K. E., Kolle, E., Northstone, K., Møller, N., … Ekelund, U. (2020). Variations in accelerometry measured physical activity and sedentary time across Europe – harmonized analyses of 47,497 children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(38), 1–14. https://doi.org/10.1186/s12966-020-00930-x

Stickgold, R. (2009). How do I remember? Let me count the ways. *Sleep Med. Rev.*, *13*, 305–308. https://doi.org/10.1016/j.smrv.2009.05.004

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine, Science and Sports Exercise*, *40*(1), 181–188. https://doi.org/10.1249/mss.0b013e31815a51b3

Trost, S. G., Loprinzi, P. D., Moore, R., & Pfeiffer, K. A. (2011). Comparison of accelerometer cut points for predicting activity intensity in youth. *Medicine and Science in Sports and Exercise*, *43*(7), 1360–1368. https://doi.org/10.1249/MSS.0b013e318206476e

Van Dijk, J. W., Venema, M., Van Mechelen, W., Stehouwer, C., Hartgens, F., & Van Loon, L. (2013). Effect of moderate-intensity exercise versus activities of daily living on 24-hour blood glucose homeostasis in male patients with type 2 diabetes. *Diabetes Care*, *36*(11), 3448–3453. https://doi.org/10.2337/dc12-2620

Vogelsinger, J. (2016). Active learning – active thinking. In O. Weiß, J. Voglsinger & N. Stuppacher (Eds.), *Efficient learning through movement* (pp. 41–64). Waxmann, Munster/New York.

Von Hentig, H. (2003). *Rethink school*. Beltz, Weinheim/Basel.

Whiteside, A. L., Brooks, D. C., & Walker, J. D. (2010). Making the case for space: Three years of empirical research on learning environments. *EDUCAUSE Quarterly*, *33*(3), 1–23. Retrieved April 18, 2017, from http://www.educause.edu/ero/article/making-case-space-three-years-

Zeisel, J. (1984). *Inquiry by design: tools for environment-behavior research*. Brooks/Cole Publishing Company.