

## Detecting pupils' opinions on learning physics bodily by unsupervised machine learning

Hannu Moilanen

Sami Äyrämö

Marja Kankaanranta

Faculty of Information Technology, University of Jyväskylä  
Finland

[hannu.moilanen@jyu.fi](mailto:hannu.moilanen@jyu.fi)

[sami.ayramo@jyu.fi](mailto:sami.ayramo@jyu.fi)

[marja.kankaanranta@jyu.fi](mailto:marja.kankaanranta@jyu.fi)

**Abstract:** The purpose of this study is to explore the added value that bodily learning brings to the study of physics at lower secondary school and how pupils experience a new way of studying physics. The study compares how pupils who liked and disliked physics experienced the new teaching methods. Here we use unsupervised machine learning in order to discover new information from the inquiry, that was held after the workshop, where pupils were experimenting with new ways of studying physics. We find that unsupervised machine learning can be a helpful tool for teachers to detect students preferred learning styles and different types of personalities in the classroom.

### Introduction

In recent years there has been increased attention to study the potential of bodily activity to strengthen memories and enhance learning in math and science (e.g. Goldin-Meadow, Cook, & Mitchell 2009; Han&Black 2011; Kontra, Lyons, Fischer, & Beilock 2015). Bodily learning is an emerging multidimensional conception of learning, according to which learning occurs within one's entire body and in the social and physical reality between people. In bodily learning, physical activity is an essential part of the learning process, and attention focuses on bodily experiences and sensations as well as reflecting on them (Anttila 2013; Katz 2013). Kontra, Lyons, Discher and Beilock (2015) state that the idea of the body as an integral part of human thinking is also gradually taken into account in the research that focuses on learning in the natural sciences, and that people are starting to understand that physical activity can promote learning (Han&Black 2011; Kontra, Lyons, Fischer, & Beilock 2015). In this article, we use the term *bodily methods* as an umbrella concept. It encompasses a number of working and teaching methods based on physical activity and action, in which body movement and physical activity are utilised in learning. Besides adding a physically active element to instruction, the aim is for the bodily experience and emotion involved in the learning process to reinforce the emerging memory trace (Moilanen & Salakka 2016).

The development of bodily pedagogical methods is connected to various challenges present in young people's daily lives. First, recent research has highlighted concerns about the physically inactive lifestyle of Finnish school-aged adolescents (Kannas 2015; Tammelin, Kallio, Rajala, Hakonen & Laine 2013; THL 2017). Second, according to the results of education evaluation surveys (e.g. PISA 2015), Finnish pupils' attitudes towards school have become more negative, and many of them experience a lack of school motivation (OECD 2017). The amount of pupils who like going to school has decreased by 3.6 percent from 2015 to 2017, and a larger part of them currently have difficulties in following instruction (THL 2017). Even though Finnish children continue to perform well in PISA (Programme for International Student Assessment) tests, their school enjoyment is low compared with several other countries (PISA 2015). Third, especially Finnish boys' lowered performance in science in the 2015 PISA tests raises the question of whether the prevailing teaching methods are suitable for stimulating, in particular, boys' motivation and interest in studying natural sciences. The still relatively commonly used teaching methods often make pupils passive, sedentary recipients of instruction. This role does not necessarily promote pupils' interest in the subject or help them acquire the knowledge and skills they need in the future world of work – in particular, creativity, empathy, teamwork and ICT skills (Griffin et al. 2012). Finland's new national core curriculum actually aims at responding to the challenges that have been faced in teaching, such as the lack of connections between subjects and the fragmented nature of the content.

Shams and Seitz (2008) emphasise that the use of different sensory channels as well as physical activity could make learning more experiential, enhance learning motivation and increase deep learning (see also Finnish National Board of Education FNBE 2014). The aim of the new national core curriculum for basic education is also to increase experiential and activity-based working methods (FNBE 2014). New kinds of learning experiences can be offered by taking instruction out of the classroom to so-called extended learning environments, in which new ICT solutions are also utilised in order to promote and support learning. In the core curriculum for basic education (FNBE 2014, 27–30), the aim is also to integrate the knowledge of different subjects into larger entities. For instance, physical activity, dance and the methods of drama could be integrated into school days as natural parts of any subject.

Tammelin et al. (2013) find that schools have optimal opportunities to promote physical activity in all adolescents because they reach all school-aged young people. One of the objectives of the Ministry of Education and Culture in its 'Finnish Schools on the Move' action programme is to convince secondary school subject teachers about the benefits of increasing physical activity during classes (Prime Minister's Office 2015). The programme has already achieved positive changes in pupils' physical activity through, for example, physically active breaks and commuting (Tammelin et al. 2015). In past years, various research results have been published on the benefits of physical activity for learning (Mullender-Wijnsma et al. 2016; Kibbe et al. 2016; Watson et al. 2017). However, the use of physical activity or bodily learning in subject teaching has been studied less (Kantomaa, Syväoja & Tammelin 2013). No research has been conducted in Finland on the added value of bodily teaching methods for learning in science classes.

This article examines the results of a physics teaching experiment implemented with year seven pupils at a comprehensive school in Central Finland from 2016 to 2017. Comprehensive school physics and particularly mechanics phenomena were taught in the experiment through a bodily approach, dance. In lower secondary school physics, the mechanics section deals with phenomena such as motion, acceleration, force, friction, centre of gravity and equilibrium. These phenomena can be taught so that pupils experience them personally through their own body. Our aim was to develop new bodily learning methods to study physics and to explore how pupils experience a new way of studying physics. The study compared how pupils who liked physics and those who disliked it experienced the workshop and the bodily teaching methods. Furthermore, a methodological objective was to examine how pupils can be grouped into different subcategories by unsupervised machine learning based on their answers regarding the things learned in the workshop and the attitudes they expressed towards the workshop.

## **The benefits of bodily learning**

A clear connection has been observed between the use of our body and cognitive brain function (e.g. Schmahmann 1997; Desmond, Gabrielli, Wagner, Ginier, & Glover, G 1997; Mehta, Shortz, & Benden 2015; Opezzo, M, & Schwartz 2014). Increased physical activity in class is considered to improve pupils' learning outcomes, and it is also seen as promoting attention and cognitive control, which contribute to learning (e.g. Watson, Timperio, Brown, Best & Hesketh 2017; Hillman, Pontifex, Raine, Castelli, Hall, & Kramer 2009; Ma, Le Mare, & Gurd 2014). Kantomaa et al. (2013) emphasise that physical activity has positive effects on brain structure and function, which means that a physically active child has better readiness for learning. To some extent, the effects of physical activity on self-esteem, school enjoyment and social interaction may also explain its positive impact on learning (Kantomaa et al. 2013).

When our body or body memory is involved in the learning process, we can also talk about a kinaesthetic learning style (Kuzcala 2013). The use of the body has been observed to have various benefits for learning. In earlier studies, dance has been integrated into mathematics, physics and language instruction, among other subjects (e.g. Posner & Patoine 2009; Paulson 2012; Moore & Linder 2012, Westreich 1999). Posner and Patoine (2009) demonstrated that through dance pupils were able to form new kinds of connections between the things to be learned, which typically improves pupils' motivation and attention towards the studied phenomenon. In addition, dance activates pupils' brains in various ways, and the emotions involved in the bodily learning process facilitate learning (Paulson 2012). Leonard (2012) investigated how pupils created meanings for bodily experiences and observed that dance has a positive impact on the development of higher-level reasoning skills.

The benefits of bodily methods have also been perceived in mathematics and science. Integrating dance into mathematics teaching increased interaction between pupils and their commitment to studying as well as deepened their understanding of geometric concepts (Moore & Linder 2012). According to Westreich (1999), a kinaesthetic activity such as dance helps kinaesthetic learners, in particular, to understand abstract mathematical concepts and to translate the mathematical reasoning process into words and text. Faber (2011) observed that the group of pupils whose science instruction was supported by a bodily approach achieved better learning outcomes than the control group in which no bodily methods were used. The group that had had bodily learning experiences remembered the studied content better 30 days later. When Burke (2009) integrated dance into chemistry teaching, pupils found that it helped them recall chemical reactions in an exam situation. Moreover, even pupils who were unable to verbalise abstract chemistry concepts in normal class discussions managed to demonstrate their competence through the bodily methods. Kontra et al. (2015) examined the learning of a physics concept, angular acceleration, and observed that the group using a bodily approach performed better than the control group in the test measuring the learning of this concept. According to Kontra

et al. (2015), because of bodily activity the activation of the brain sensorimotor area contributed to better reasoning and learning of the phenomenon. It can therefore be concluded that offering bodily experiences closely related to the studied phenomenon, particularly at an early stage of studies, supports pupils' reasoning related to physics phenomena.

## **Educational data mining**

Recently, Educational Data Mining (EDM) has become an emerging research field used to understand learning and learner individual differences and choices better. EDM typically uses educational data and apply data mining techniques such as prediction (including classification), discovery of latent structure (such as clustering and q-matrix discovery), relationship mining (such as association rule mining and sequential pattern mining) to process new information from traditional student survey data (Baker & Yacef 2009). For example, cluster analysis finds the structure that emerges naturally from data, allowing researchers to search for patterns in student behavior that commonly occur in data, but which did not initially occur to the researcher which could provide new interesting information compared to using traditional quantitative research methods. Machine learning methods have been used very little in education research in Finland so far and this article could provide some ideas to enrich quantitative research methods.

There are many different personalities in the classroom. Different pupils like different teaching methods more than others. Personalization of school experience is a key need to improve pupils' motivation (Williams and Williams, 2011). Unsupervised machine learning could help teacher to detect different learners from each class and to optimize teaching methods suitable for different classes. With help of artificial intelligence it could be possible to deepen personalized learning experiences for people of all ages and stages. Here we used unsupervised machine learning in order to discover new information from the inquiry, that was held after the workshop, where pupils were experimenting with new ways of studying physics.

## **Implementation of the study**

The study was conducted at a lower secondary school of about 400 pupils in Central Finland. During the 2016–2017 school year, a visiting researcher-teacher delivered a two-hour workshop, *Physics by Dancing*, for pupils in year seven. Seventeen pupil groups participated in the study.

## **The workshop**

The workshop consisted of three sections: motion, equilibrium and rotation (see Moilanen & Salakka 2016). Three short videos were watched during the 90-minute workshop, but its main emphasis was on physical activity and subsequent reflection. Immediately after the physical activity, pupils discussed in groups or led by the teacher how the bodily activity was linked to the physics phenomenon to be learned. In the motion section, pupils sought different ways of moving in time with music (accelerated, steady, slow, fast, curvilinear or rectilinear) and different body parts that can be used for oscillating motion. Pupils also competed in a line run using different socks and reflected on the factors that affect friction. In the equilibrium sections, pupils tested supporting surfaces of different sizes with their body. They discussed how the supporting surface influenced the fact that one manages to remain standing and looked for the centre of gravity in different objects and their own body. In addition, they reflected on how the supporting surface and centre of gravity are related to the falling of an object and experimented with picking up an object from close to the wall while keeping their heels and backsides against the wall. In the rotation section, pupils tested spinning by putting weight on different body parts, both on a chair and in different positions. Furthermore, the class reflected on how spinning becomes fastest and how the conservation law of angular momentum is related to rotation. At the end of the workshop, the pupils designed a short dance with six movements or a routine that included two positions of equilibrium, in other words, 'freezes', two rotary movements and two translational motions in space. The dances were finally performed for the others.

## **Research data and analysis**

At the end of the workshop, the pupils responded to a questionnaire using iPads. The questionnaire was answered by 224 pupils, 48.2 percent of whom were boys and 51.8 percent girls. The researcher-teacher recorded his observations of the workshop in a notebook, and one of the workshops was recorded on video. The questionnaire for pupils was divided according to main research questions as shown in Table 1.

Main research question	Question in questionnaire	Reply Scale / format
------------------------	---------------------------	----------------------

<p>1. Was there any differences between pupils who liked and disliked physics in experiencing the new bodily teaching methods</p>	<p>In my opinoin Physics as a subject is</p> <ol style="list-style-type: none"> <li>1. More bodily methods are needed in physics and chemistry teaching'</li> <li>2. Using own body for assignments makes learning more effective'</li> <li>3. Workshop assignments felt more pleasant than traditional assignments in classroom</li> <li>4. Studying physics is more enjoyable outside of the classroom'</li> <li>5. Would you like to use bodily learning methods in other subjects also?</li> <li>6. Physical exercise diverted the attention from phenomena of physics</li> </ol>	<p>1=Nothing meaningful 5=Really meaningful Likert (5 totally agree, 1 totally disagree) Likert (5 totally agree, 1 totally disagree)</p>
<p>2. What kind of sub-categories of pupils can be detected by unsupervised machine learning?</p>	<ol style="list-style-type: none"> <li>1. What are the most important things you learned in the workshop?</li> <li>2. Why do you think that exercise-based workshops should be more</li> <li>3. What was your most memorable moment in the workshop</li> </ol>	<p>Open-ended  Open-ended  Open-ended</p>

**Table 1.** Main research questions and related question in questionnaire

The data were analysed using statistical hypothesis tests and cluster analysis. Before the statistical analysis, the answers to the open-ended questions were tabulated, simplified and divided into groups for cluster analysis according to different umbrella concepts and subconcepts. The groups of answers are presented in Figures 2, 3 and 4. For example, when pupils were asked about the most important things they had learned in the workshop, a pupil's answer 'friction is needed for moving' was placed in the 'friction' group under the 'physics' umbrella concept. For example, unclear or slang answers were placed in the 'something else' group. The aim of the descriptive methods was to produce new perspectives on the data and potentially new interesting data-based hypotheses for further research.

The statistical hypothesis tests focused on the question *I think physics as a subject is* and on the pupils who had given the most negative (R1: answer 1, 2 or 'blank'; N = 55) and positive (R2: answer 4 or 5; N = 96) answers to the question. The applied method was Wilcoxon two-sample rank-sum test, whose p-values were corrected using the Bonferroni method in relation to the number of hypotheses. The difference between the groups was observed as statistically significant when  $p \leq 0.05$ .

Cluster analysis is a statistical method of unsupervised machine learning (Hastie et al. 2001; Bishop, 2006). Robust clustering is able to produce meaningful patterns from contaminated and incomplete data sets (Ayrämö, 2006). The aim of cluster analysis in this study was to identify identical pupil groups in the sample, in other words, more individual pupil profiles than the whole data. The cluster prototypes identified with the method represent typical behaviour in each group. The input variables were preprocessed with linear scaling by converting dichotomous 0/1 variables to the range [1/4, 3/4], discrete (1,2,3) scale variables to the range [1/6, 5/6] and Likert scale 1–5 variables to the range [1/10, 9/10]. The cluster model was formed with the multivariate k-spatialmedians method which is independent of assumptions on the normal distributions (Äyrämö 2006). The number of clusters, K = 3, was chosen by interpreting the different options visually. The applied K-spatialmedians algorithms is based on the available case strategy on incomplete data which is why no imputation or preprocessing of missing values is needed. . The groups produced by the cluster model were interpreted visually with a bar chart.

In this study, the purpose of cluster analysis was to produce novel unsuspected insights into the multivariate target data and generate data-based hypotheses. More precisely, to detect clusters in which pupils express similar attitude within clusters and dissimilar attitude between clusters towards exercise-based learning.

Classical machine learning methods, such as the ordinary least-squares regression and K-means clustering, are sensitive to noise and outlying, especially when the amount of training data is limited. The sensitivity ensues from the least-square type of estimation of the training/fitting error. The spatial median is the point that minimizes the sum of Euclidean distances to n data points. The use of non-squared Euclidean norm provides a higher breakdown point (0. 5) than classical estimators (0. 0) (Huber, 1981). Due to the high breakdown point at least 50 % of the data points must be shifted in order to cause infinite change on the estimate (Lopuhaä and Rousseeuw, 1991). The spatial median is also location and orthogonal equivariant, but not affine equivariant estimator of location.

Let us now consider a training data set where . In order to follow the available case strategy for missing data treatment, that is some of the values in are missing, the operations must be projected to the available values, which can

be performed by defining a diagonal matrix for each data point. Diagonal element if element of data vector is missing and otherwise = 1. By applying the available case strategy and the spatial median for estimating the cluster centers, the score function for the nan-K-spatmed clustering model is defined as:

where is the spatial median point of the cluster and is determined by:

The score function (1) is minimized by applying the following K-means-like steps until the partition does not change:

1. Assign each data points to its closest cluster.
2. Update the center for each by computing the spatial mean of the assigned points.

Since the problem is non-convex, i.e., multiple local minima exist, multiple restarts must be taken or some sort of initialization strategy applied, or otherwise the algorithm may converge to a suboptimal local minimum solution (Pena et al., 1999; Arthur and Vassilvitskii, 2007; Ayrämö et al., 2007).

Each cluster center is obtained (the second step of the Algorithm 2) by finding the minimizing point for the problem of the spatial median on incomplete data sample (data points assigned to the cluster):

The problem (3) has a unique solution provided that the data points are not collinear (Milasevic and Ducharme, 1987). Because there exist, however, no closed-formed solution to the problem (3), an iterative successive over-relaxation variant of the Weiszfeld algorithm (SOR-Weiszfeld) can be applied (see details in (Äyrämö, 2006)).

## Results

The study examined the connection between pupils' attitude towards physics as a subject and their experiences of the workshop (Table 2). The views of pupils with the most positive attitude towards physics (Group 2) and those with the most negative attitude (Group 1) on whether there should be more bodily learning methods in science teaching were statistically significantly different ( $p = 0.001$ ). In Group 1 the median of the answers was 4/5, and in Group 2 more than half of the pupils (53.3%) answered 5/5. Despite the statistically significant difference, pupils in both groups found the workshops mainly necessary. The statistical difference in the answer distributions is explained by the share of those who gave a maximum of 3/5 answer or a blank answer; in Group 1 their share was 30.9% and in Group 2 only 12.5%.

In addition to the aforementioned difference, we observed a statistically significant difference based on the rank-sum test in the question 'Have you had bodily learning methods in physics/chemistry classes?'; however, the medians of the groups do not differ. When examining the group-specific distributions of the answers, we observed that in both groups the share of those who answered 3/3 to this question was minimal (Group 1: 0%, Group 2: 0.01%). However, the distributions of the groups differ clearly: in Group 1 only 18.8% answered 2/3, whereas in Group 2 the corresponding share was more than twice as large, 42.7%.

No statistically significant differences were observed in the Likert scale questions 2–5 measuring the meaningfulness of the workshop and the work methods. Both groups thus found the bodily learning methods of the workshops equally positive in light of these questions.

Question	Group 1	Group 2	<i>p</i>
<b>'More bodily methods are needed in physics and chemistry teaching'</b>	<b>4</b>	<b>5</b>	<b>0,001</b>
<b>'Have you had bodily learning methods in physics and chemistry?'</b>	<b>1</b>	<b>1</b>	<b>0,012</b>
'Workshop assignments felt more pleasant than traditional assignments in classroom'	4	5	0,122
'Would you like to use bodily learning methods in other subjects also?'	3	3	0,171
'Using own body for assignments makes learning more effective'	4	4	0,561
'Studying physics is more enjoyable outside of the classroom'	5	5	0,692
'Physical exercise diverted the attention from phenomena of physics'	3	3	1,000

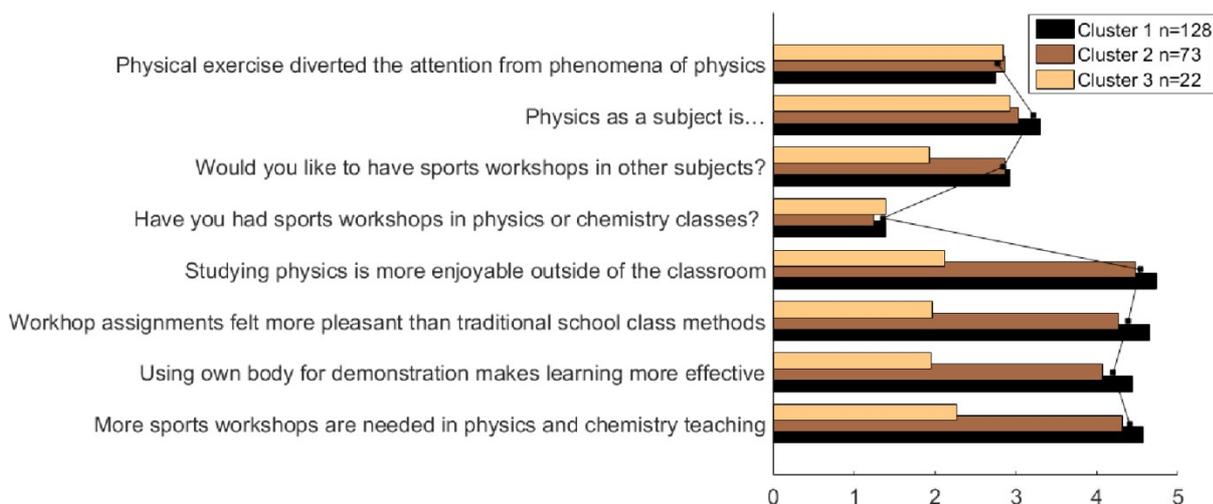
**Table 2.** The median and statistical significance of pupils' answers. Group 1=Dislike physics as a subject. Group 2= Like physics as a subject.

The study also had a methodological development task with the aim of identifying different pupil profiles. In cluster analysis, we observed three groups that can be distinguished based on their response profiles. The cluster algorithm models were interpreted qualitatively by paying attention to those variables in which, in an answer typical of the cluster, we noticed a trend that differed from a typical answer in the entire data.

Cluster 1 (n = 128) constituted the largest group, whose answers to the Likert scale questions were higher than typical of the entire data, except for the statement ‘Physical activity shifted attention away from the actual physics phenomena’ (Figure 1). Pupils in this cluster answered actively and left questions unanswered clearly less seldom than those in the other clusters did. More often than the others, they found that equilibrium and the centre of gravity were the most important things they had learned (Figure 2). In relation to the entire data, the pupils in this cluster also had more views on why more workshops should be provided. Some important reasons for them were a better retention of the studied content, emotion, variation and the benefits of physical activity (Figure 3). More often than the entire sample, these pupils thought that, in addition to spinning and the centre of gravity, the most memorable things were their own dancing and the chance to win 10,000 euro by picking up the teacher’s mobile phone from the floor without falling down. The issues were related to the moments in which the bodily method was strongly present in learning the phenomenon (Figure 4).

Cluster 2 (N = 73) is the second largest of the groups. Its answers to the Likert scale questions mainly follow the profile typical of Cluster 1 and the entire data, but the scores given by the pupils are overall slightly lower (Figure 1). The clearest difference from the entire data was that these pupils mostly left three open-ended questions unanswered (Figure 2, Figure 3, Figure 4).

Cluster 3 (N = 22) most distinctly differed from the other groups in its Likert scale questions: in five of eight questions, the answers by pupils in this cluster were clearly different from the profile of the other two groups (Figure 2). Typical answers in this cluster to the five questions were more negative (i.e. level 2, on the Likert scale ‘disagree’), while the answers to these questions in the other groups were at levels 3/3 and 4-5/5. Only ‘friction’ was highlighted as one of the most important things learned in the workshop (Figure 3). Compared with the entire sample, pupils in this cluster more often answered ‘Nothing’, ‘I don’t know’ or ‘Something else’, and about half of them did not answer the question at all. When asked ‘Why do you think there should be more bodily learning workshops?’, the pupils in Cluster 3 chose the options ‘Benefits to physical activity’, ‘There should not be more of them’, ‘I don’t know’, ‘Other’, and nearly half of them did not answer at all (Figure 3). A small part of the cluster found that their own dancing was the most memorable moment of the workshop, but a typical answer was ‘Relates to something else’ or the question was left unanswered (Figure 4). Compared with the entire sample, the cluster can be regarded as a small, atypical observation group, whose answers demonstrate an emphasis on options associated with uncertainty.



**Figure 1.** Answer profiles to the Likert-scale questions. Each cluster is represented by its spatial median. The line with square markers represents the spatial median for all the pupils.”

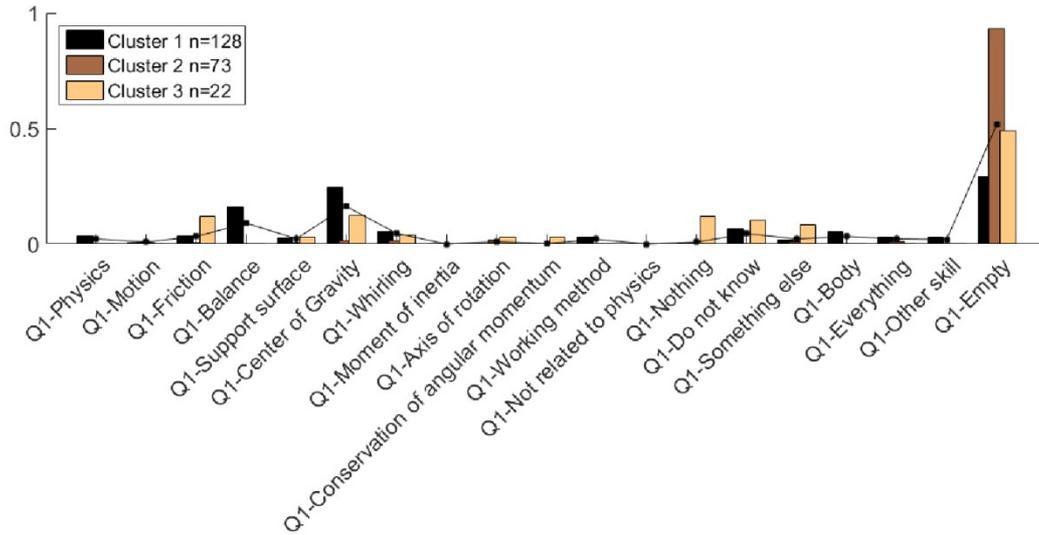


Figure 2. Answer profiles to the question "What are the most important things you learned in the workshop?"

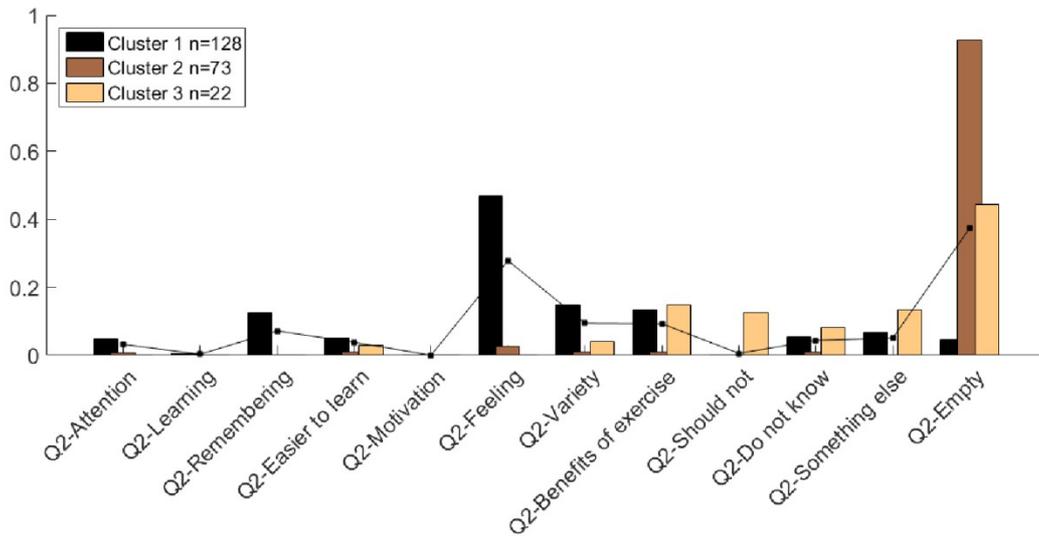


Figure 3. Answer profiles to the question "Why do you think that sports workshops should be more?"

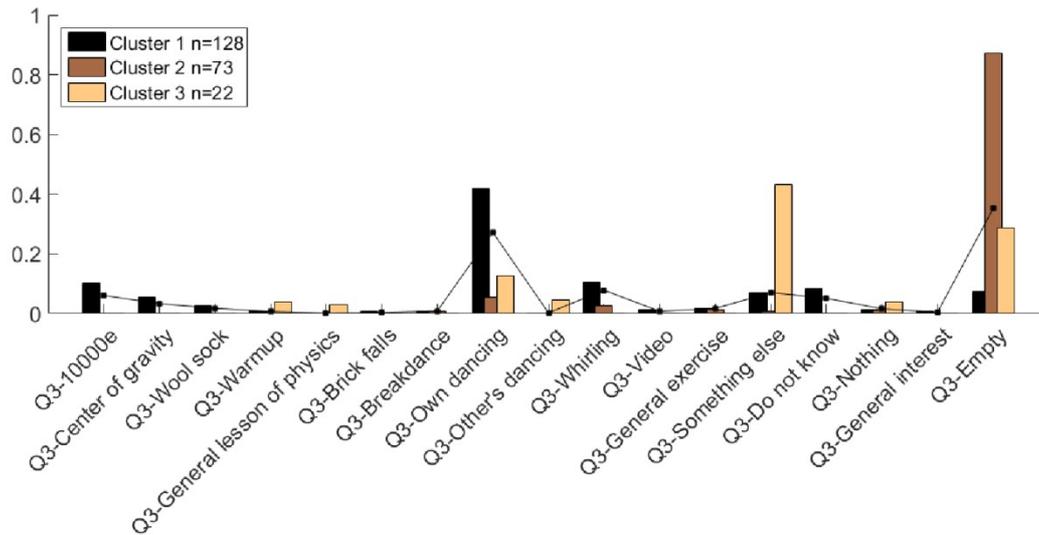


Figure 4. Answer profiles to the question: "What was your most memorable moment in the workshop?"

## Discussion and conclusions

The focus of the pilot study was to explore how pupils experience the use of physical activity as a pedagogical method. Because research was restricted to one school, the results can be generalised only after further studies in other environments. However, the findings provide measured data that can be utilised in developing teaching practices in compliance with the new national core curriculum in Finnish schools.

The results show that pupils had a positive experience of bodily learning and the use of physical activity in teaching. Based on the video material from the workshop and notes made by the researcher-teacher, it can be observed that particularly boys were motivated by the competitive sections of the workshop, such as picking up the wallet from the floor and spinning on one's bottom. Boys' motivation to study physics phenomena is significant because, for example, the PISA 2015 results highlighted that Finnish boys' interest in science had lessened and their science performance was lower than that of girls. It may thus be that traditional science teaching methods do not stimulate boys' interest in the studied content. Further research should be conducted to find out whether girls and boys experience bodily learning methods in different ways, and whether especially boys could benefit from the bodily approach in physics classes.

Several researchers emphasise the significance of emotions in the learning process (Pekrun 2006; Pekrun, Goetz, Titz & Perry 2002; Mayer, Salovey & Caruso 2000). A positive feeling strengthens the learning experience and enhances learning (Walker et al. 2003; D'Argenbaum et al. 2002; Lyubomirsky, King & Diener 2005). Emotions affect the amount of stress hormone, cortisol, which reinforces the memory trace that emerges through the learning process in the hippocampus (Joëls et al. 2006). On the other hand, excessive stress can prevent the effective functioning of prefrontal brain areas important for learning and have a negative effect on learning (LeDoux, 1998; Dalgleish et al., 1999). Moreover, the teacher's emotional state has a great impact on pupils' learning (Becker et al. 2014). An overall starting point in planning the workshop model described in this article was the creation of a positive learning atmosphere and positive learning experiences. In light of the results, the workshop model functioned as expected.

Breaking the routine regarding teaching methods, learning environments or tools increases pupils' attention and contributes to a memorable learning experience (Moilanen & Salakka 2016; Smeds et al. 2015). The Physics by Dancing workshop featured various elements that differed from the elements of regular physics classes, for instance, the bodily approach, a learning environment outside of the classroom, and a visiting teacher. In the school where the study was conducted, approaches based on physical activity had been used only a little. It can be hypothesised that pupils tend to find a change in working methods positive, so the positive findings of the study are no surprise in this respect. Therefore, further research should be conducted in a school where the bodily approach in science teaching has already been put into practice before starting the study, so that the workshop could be led by the pupils' own teacher. It is also essential to implement longer teaching periods in which physical activity plays a key role in learning and teaching.

One of the aims in this study was to examine whether pupils with either a positive or a negative attitude towards physics as a subject had different experiences of the bodily workshop. The results did not demonstrate any statistically significant differences in the questions related to meaningfulness. This suggests that the bodily learning methods increase meaningfulness in learning physics in both of these pupil groups. This supports the view that most pupils benefit from bodily learning and the use of several sensory channels in instruction (Kuzcala 2013; Shams & Seitz

2008). According to Kujala et al. (2012), particularly hyperactive, poor-performing pupils benefit from the integration of physical activity into lessons. In Finland, however, no research has so far been conducted on how bodily learning methods affect poor-performing pupils' physics learning.

Even though most pupils had a positive attitude towards the workshop, the cluster analysis highlighted some negative observations that need attention. The questionnaire was implemented at the end of the workshop, and unanswered open-ended questions were common in the second largest group ( $n = 73$ ). According to the researcher-teacher's observations, some of the pupils were clearly hurrying to the break and therefore answered hastily. This naturally may affect the results of the study as well. It might consequently be better to hand out the questionnaire, for example, at the beginning of the lesson following the workshop, or to integrate it more closely into the workshop.

Another group ( $n = 22$ ) distinguished from the sample by cluster analysis is the one whose open-ended answers are more commonly related to other topics than physics. Moreover, a negative attitude towards the workshop's methods was highlighted in this group. To some extent, the response profile of this group may be explained by the fact that some of the pupils did not participate in the bodily tasks of the workshop because of, for instance, religious reasons or physical disabilities and stayed in the audience instead. On the other hand, according to the researcher-teacher's observations, the group also included pupils with a negative or 'nothing interests me' attitude towards the workshop, and their responses are probably visible in this cluster.

From the viewpoint of cluster analysis, the small sample size can be regarded as a limitation of the study. The primary purpose of utilising cluster analysis in this study was methodological development, and the findings are suggestive. The aim in later research will be further data collection. The cluster method used in the study can produce new hypotheses, but their validity must be examined more closely through further research.

From the perspective of teachers, the cluster method can provide useful information on pupil groups and their attitudes towards learning and teaching. Teachers can identify different pupil profiles in their groups, based on whose distributions they can choose pedagogical methods suitable for the respective groups. Methods and tools could be developed also at the individual level to provide each pupil with more individualised teaching.

Many class teachers and teacher trainees are already aware of the benefits of bodily learning. The main challenge remains how to put these methods into practice as a natural part of subject teachers' work as well. Many teachers may feel that they do not have the skills needed to integrate, for example, dance into their own subject. One of the aims of Finland's national core curriculum for basic education (OPS 2014) is actually to increase cooperation between the teachers of different subjects as well as to plan and implement multidisciplinary learning modules that integrate subjects and constitute harmonious entities of the studied phenomena. Excellent examples are the teaching experiments that integrate various subjects and offer pupils – in addition to 21st century skills – meaningful learning experiences and permanent memory traces necessary for deep learning. Changing the practices, however, requires from teachers the courage to experiment and potentially fail. It is essential to understand that moving and action in the lesson are not an end in themselves but an effective means to promote learning (Moilanen & Salakka 2016).

## References

- Anttila, E. 2013. Koko koulu tanssii! Kehollisen oppimisen mahdollisuuksia kouluyhteisössä. *Possibilities of bodily learning in schools (In Finnish) Acta Scenica 37*. Helsinki: Teatterikorkeakoulu, esittävien taiteiden tutkimuskeskus.
- Agrawal, R., & Srikant, R. (1994). Fast algorithms for mining association rules. *In Proc. 20th int. conf. very large data bases, VLDB (Vol. 1215, pp. 487–499)*.
- Arthur, D., Vassilvitskii, S., 2007. k-means++: The advantages of careful seeding. In: Proceedings of the eighteenth annual ACM-SIAM symposium on Discrete algorithms. *Society for Industrial and Applied Mathematics*, pp. 1027–1035.
- Baker, R., & Yacef, K. (2009). The state of educational data mining in 2009: A review and future visions. *Journal of Educational Data Mining, 1*(1), 3–17.
- Bishop, C. M., 2006. *Pattern recognition and machine learning*. springer.
- Becker, E.S., Goetz, T., Morger, V. & Ranellucci J. (2014). The importance of teachers' emotions and instructional behavior for their students' emotions: An experience sampling analysis. *Teaching and Teacher Education, 43*, 15–26.
- Burke, J. S. (2009). Chemistry meets choreography to enhance student comprehension. Retrieved from <http://www.edutopia.org/arts-education-chemistry-dance-visualization> (27.9.2017).
- Cook, S. W., Mitchell, Z., & Goldin-Meadow, S. (2008). Gesturing makes learning last. *Cognition, 106*(2), 1047-1058.
- Dalgleish, T. & Power M. (1999). *Handbook of cognition and emotion*. John Wiley & Sons Ltd, Sussex, UK.

- D'Argenbaum, A., Comblain, C. & van der Linden, M. (2002). Phenomenal characteristics of autobiographical memories for positive, negative, and neutral events. *Applied Cognitive Psychology*, 17(3), 281–294.
- Desmond, J., Gabrielli, J., Wagner, A., Ginier, B., & Glover, G. (1997). Lobular patterns of cerebellar activation in verbal working-memory and finger tapping tasks as revealed by functional MRI. *Journal of Neuroscience*, 17(24), 9675–9685
- Faber, R. (2011). Science with dance in mind: A collaboration with primary movers and Baltimore County public schools 2009-2011. *National Dance Education Organization Conference*, Minneapolis.
- Finnish National Board of Education (FNBE). (2014). Perusopetuksen opetussuunnitelman perusteluonnos. A draft of the national core curriculum for basic education. Helsinki: National Board of Education. Retrieved from <http://www.oph.fi/ops2016/perusteet> (27.12.2017)
- Gibbs, R. W. (2005). *Embodiment and cognitive science*. New York, NY: Cambridge University Press.
- Goldin-Meadow, S. (2009). How gesture promotes learning throughout childhood. *Child development perspectives*, 3(2),
- Griffin, P. McGaw, B., & Care, E. (eds.) 2012. *Assessment and teaching of 21st century skills*. Springer Science+Business Media B.V 106-111
- Han, I., & Black, J. B. (2011). Incorporating haptic feedback in simulation for learning physics. *Computers & Education*, 57(4), 2281-2290.
- Hand, D. J., Mannila, H., & Smyth, P. (2001). *Principles of data mining*. MIT press.
- Hastie, T., Tibshirani, R., & Friedman, J. H. (2009). *The elements of statistical learning: Data mining, inference, and prediction*. New York: Springer.
- 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.
- Joëls, M., Pu, Z., Wiegert, O., Oitzl, M., & Krugers H. (2006). Learning under stress: how does it work? *Trends in Cognitive Sciences*, 10(4), 152–158.
- Kannas, L. (2015). Liikunta-aktiivisuus ja ruutu-aika. [Physical Activity and screen time of School-aged children] (In Finnish). In Kokko, S. & Hämylä, R. (eds.) *Lasten ja nuorten liikuntakäyttäytyminen Suomessa. LIITU- tutkimuksen tuloksia 2014*. Valtion liikuntaneuvoston julkaisuja 2015:2, 13–20.
- Kantomaa, M., Syväoja, H. & Tammelin, T. (2013). Liikunta – hyödyntämätön voimavara oppimisessa ja opettamisessa? [Sport-an untapped resource in learning and teaching] (In Finnish, abstract in English). *Liikunta & Tiede*, 50 (4), 12–16.
- Katz, M. L. (Ed.). (2013). *Moving ideas: Multimodality and embodied learning in communities and schools*. Peter Lang.
- Kibbe, D., Hackett, J., Hurley, M., McFarland, A., Godburn Schubert, K., Schultz, A. & Harris, S. (2011). Ten years TAKE 10!: Integrating physical activity with academic concepts in elementary school classrooms. *Preventive Medicine*, 52, 43–50.
- Kontra, C., Lyons, D. J., Fischer, S. M., & Beilock, S. L. (2015). Physical experience enhances science learning. *Psychological Science*, 26(6), 737–749.
- Kujala, T., Krause, C-M., Sajaniemi, N., Silvén M., Jaakkola T. & Nyyssölä, K. (eds.) (2012). Aivot, oppimisen valmiudet ja koulunkäynti. Neuro- ja kognitiotieteellinen näkökulma (in Finnish). OPH:n julkaisuja 2012. Retrieved from [http://www.oph.fi/download/138958\\_Aivot\\_oppimisen\\_valmiudet\\_ja\\_koulunkaynti.PDF](http://www.oph.fi/download/138958_Aivot_oppimisen_valmiudet_ja_koulunkaynti.PDF)
- Kuczala, M. (2013). The kinesthetic classroom: teaching and learning through movement. presentation. *Special Education and CCLC Fall Conference*, Bismarck, North Dakota.
- LeDoux, J. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. New York: Simon & Shuster.

- Leonard, Alison E. (2012). Moving the School and Dancing Education: Case Study Research of K-5 Students' Experiences in a Dance Residency. Retrieved from ProQuest LLC.
- Liben, L. S., Kastens, K. A., & Christensen, A. E. (2011). Spatial foundations of science education: The illustrative case of instruction on introductory geological concepts. *Cognition and Instruction*, 29(1), 45-87.
- Lopuhaa, H. P., Rousseeuw, P. J., 1991. Breakdown points of affine equivariant estimators of multivariate location and covariance matrices. *The Annals of Statistics* 19 (1), 229-248.
- Lyubomirsky, S., King, L. & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin*, 131(6), 803-855.
- Ma, J. K., Le Mare, L., & Gurd, B. J. (2014). Four minutes of in-class high-intensity interval activity improves selective attention in 9-to 11-year olds. *Applied physiology, nutrition, and metabolism*, 40(3), 238-244.
- Mehta, R. K., Shortz, A. E., & Benden, M. E. (2015). Standing up for learning: A pilot investigation on the neurocognitive benefits of stand-biased school desks. *International journal of environmental research and public health*, 13(1), 59.
- Merrell, F. (2003). *Sensing corporeally: Toward a posthuman understanding*. Toronto: University of Toronto Press.
- Meyer, D.K., and J.C. Turner. (2002). Discovering emotion in classroom motivation research. *Educational Psychologists*, 37, 107-111.
- Milasevic, P., Ducharme, G. R., 1987. Uniqueness of the spatial median. *The Annals of Statistics* 15 (3), 1332-1333.
- Moilanen, H. & Salakka, H. (2016). *Aivot liikkeelle!* (In Finnish) P-S-kustannus. Jyväskylä.
- Moore, C. and Linder, S. (2012). Using dance to deepen student understanding of geometry. *Journal of Dance Education*, 12(3), 104-108.
- Mullender-Wijnsma, M. J., Hartman, E., de Greeff, J. w., Doolaard, S., Bosker, R. J. & Visscher, C. (2016). Physically active math and language lessons improve academic achievement: a cluster randomized controlled trial. *Pediatrics*, 137(3), 1-9.
- OECD. 2017. PISA 2015 results (Volume III): students' well-being. Paris: OECD Publishing.
- Oppezzo, M., & Schwartz, D. L. (2014). Give your ideas some legs: The positive effect of walking on creative thinking. *Journal of experimental psychology: learning, memory, and cognition*, 40(4), 1142.
- Paulson, P. (2012). The brain and learning. *Journal of Dance Education*, 12(1), 81-83.
- Pekrun, R., Goetz, T., Titz, W. & Perry, R. (2002). Academic emotions in students' self-regulated learning and achievement: A program of quantitative and qualitative research. *Educational Psychologist*, 37, 91-106.
- Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, 18(4), 315-341.
- Pena, J. M., Lozano, J. A., Larranaga, P., 1999. An empirical comparison of four initialization methods for the k-means algorithm. *Pattern recognition letters* 20 (10), 1027-1040.
- [PISA 15 Ensituloksia. Huipulla pudotuksesta huolimatta](#). Results from OECD PISA 2015-survey (In Finnish). Opetus- ja kulttuuriministeriön julkaisuja 2016:41. Retrieved from <http://julkaisut.valtioneuvosto.fi/handle/10024/79052> (28.12.2017)
- Posner, M. & Patoine B. (2009). *How arts training improves attention and cognition*. *Cerebrum* (2009): 2-4.
- Prime Minister's Office. 2015. *Finland, a land of solutions: strategic programme of Prime Minister Juha Sipilä's government 29 May 2015*. Helsinki: Government Publications

12/2015.

Schmahmann, J. (1997). *The cerebellum and cognition*. San Diego, CA: Academic Press

Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. *Trends in Cognitive Sciences*, 12(11), 411–417.

Sheets-Johnstone, M. (2009). *The corporeal turn: An interdisciplinary reader*. Exeter: Imprint Academic.

Smeds, P., Jeronen, E. and Kurppa, S. (2015). Farm Education and the Value of Learning in an Authentic Learning Environment. *International Journal of Environmental & Science Education*, 10(3), 381–404.

Tammelin, T., Laine, K., & Turpeinen, S. (Eds.) 2013. Oppilaiden fyysinen aktiivisuus [Physical Activity of School-aged children] (In Finnish, abstract in English). *Research Reports on Sport and Health 272*. Jyväskylä: LIKES – Foundation for Sport and Health Sciences.

Tammelin, T., Kallio, J., Rajala, K., Hakonen H., ja Laine, K. (2016). Muutoksia Liikkuviissa kouluissa 2013–2015. Oppilaat liikkujina ja koulun aktiviteetten suunnittelijoina (In Finnish). LIKES-tutkimuskeskus 2016. Retrieved from [www.liikkuvakoulu.fi/muutoksia2015](http://www.liikkuvakoulu.fi/muutoksia2015) <http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79052/okm41.pdf> (27.12.2017)

Trigwell, K., Ellis, R. & Feifei, H. (2012). Relations between students' approaches to learning, experienced emotions and outcomes of learning. *Studies in Higher Education*, 37(7), 811–824.

THL. Finnish National Institute for Health and Welfare. Kouluterveyskyselyn tulokset. (2017) Peruskoulun 8. ja 9. luokan oppilaat, muutokset 2015-2017 (In Finnish). Retrieved from <https://www.thl.fi/fi/web/lapset-nuoret-ja-perheet/tutkimustuloksia> (27.12.2017)

Walker, W. R., Skowronski, J. J. & Thompson, C. P. (2003). Life is pleasant – and memory helps to keep it that way! *Review of General Psychology*, 7(2), 203–210.

Watson, A., Timperio, A., Brown, H., Best, K. & Hesketh, K. 2017. Effect of classroom-based physical activity interventions on academic and physical activity outcomes: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, 14, 114

[Westreich](#), G.B. (1999). *An analysis of kinesthetic learners' responses: Teaching mathematics through dance*. American University.

Williams, K. C., Williams, C. C., 2011. Five key ingredients for improving student motivation. *Research in Higher Education Journal* 12, 1.

Äyrämö, S. (2006). *Knowledge mining using robust clustering*. University of Jyväskylä.

Äyrämö, S., Kärkkäinen, T., Majava, K., 2007. Robust refinement of initial prototypes for partitioning based clustering algorithms. *Recent Advances in Stochastic Modeling and Data Analysis*: Chania, Greece, 29 May-1 June 2007, 473.