Introducing impulse to 6th-grade students kinesthetically: The impact on their reasoning

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Abstract

Pioneers of educational theory have called for a greater emphasis on kinesthetic learning, a claim also supported by interdisciplinary embodied cognition research. This article focuses on the effectiveness of a body-based intervention designed to familiarize participants with the physics concept of impulse. We investigated whether the use of one's own body as an element of activity can help 6th graders successfully adopt adequate reasoning when answering relevant questions. The assessment procedure took the form of an interview and our conclusions demonstrated that students adopt a multimodal framework (speech, gestures, body movement) to solve problems designed to include human-centered experiences, the haptic manipulation of objects, and everyday illustrated situations. The performance of a respectable number of students shifted from a lack of insight into a scientifically accepted conceptualization. Introducing purposeful planned movement when teaching physics concepts in the early years is a valuable tool for any educator wishing to add value to his students' learning.

Keywords: kinesthetic learning, embodied cognition, multimodality, impulse

Introduction

The embodied cognition paradigm has challenged the perception that knowledge is disembodied and abstract mental representations. It argues that "cognitive processes arise from...continuous kinesthetic interactions between the brain, the body and the environment" (Thompson, 2007, p. 10) manifesting that the cognitive system is organized to support the targeted action in the environment (Robbins & Aydede, 2008). Barsalou (1999) theorized that knowledge is based on perceptual symbol systems, i.e. symbols consisting of structural elements of neural activity that arise from sensory perception. In a learning setting, this thread of research reveals that humans reuse brain structures once activated during a previous action, highlighting the presence of simulations in cognitive function (see Anderson, 2010; Decety & Grèzes, 2006). The embodied cognition paradigm also stands by the notion that mental representations of abstract concepts are formed by simulations of perceptual experiences and bodily interactions with the environment (Barsalou, 1999). This argument is also supported by the work of Lakoff and Johnson (1999), who attempted to investigate why language is to a great extent, metaphorical. In their analysis, the use of a metaphor is much more than direct speech. A metaphor reveals how people represent and reflect on abstract concepts, that is, through real interactions of the body with the world.

Currently, stating that all cognition is embodied is open to debate (see Goldinger et al., 2016) and even embodied cognitivism has adopted a range of views, from the most simple (Clark, 1999) to the most radical (Kiverstein, 2012). However all approaches of embodied cognition agree that bodily experiences constitute an integral part in the construction of meaning, both for concrete and abstract concepts (Goldman, 2012). Likewise, in terms of educational contexts, its application is self-explanatory. It is therefore not surprising that recent reviews have called to further investigate the principles of body usage in an educational context, explore its potential weaknesses, and the need to create a systematic inventory of its supposed usefulness in learning (Nathan & Walkington, 2017).

Leading educational theorists and more recent examples of pedagogues consider physical activity a prerequisite for effective learning, inextricably linked to cognitive processes (see Kolb & Kolb, 2009; Montessori, 1961; Dewey, 1916). In general, the inclusion of movement in the academic lesson is an effective means to promote a student's active engagement, (Sivilotti & Pike, 2007, Griss, 2013), improve academic achievement (Beaudoin & Johnston 2011, Bartholomew & Jowers, 2011, Brusseau & Hannon, 2015), and even benefits participants' health (Norris et al., 2015), all at the same time. However, the school remains a highly sedentary environment where the learning content is mostly conveyed by the teacher (Holt, Bartee, & Heelan, 2013). An analysis of 26 studies (Duijzer et al., 2019), revealed that learning environments with lower levels of physical involvement are considered less effective. Allowing students to even observe human movement has an overall positive effect on learning, compared to more static forms of teaching (Rueckert et al., 2017; Fiorella & Mayer, 2016; Brucker et al., 2015; Castro-Alonso et al., 2015). High-level bodily engagement does not always lead to knowledge acquisition, because complex demands can lead to an unnecessary cognitive load that ultimately acts as a barrier to learning (Skulmowski et al., 2016; Ruiter et al., 2015). For this reason studies favor simple bodily activities of short duration (see Song et al., 2014; Kalet et al., 2012).

The fact that much of physics' subject matter deals with the actions and interactions of objects at the scale of the human body makes kinesthetic learning activities i.e activities that physically engage students in the learning process (Begel et al., 2004) a fruitful approach. It seems that activities that allow interactions with materials or equipment, often referred to as hands-on activities (see Sliško & Planinšič, 2010), activities where students use their bodies as a sensor for physical interactions (see Bracikowski et al., 1998) or role-playing of natural phenomena much larger or smaller than the human body (see Singh, 2010; Morrow, 2000) all fall under this umbrella term, i.e. kinesthetic learning. Existing PER (Physics Education Research) work has, to a moderate extent, designed and implemented interventions over the years (see Richards, 2020, 2019; Mylott et al., 2014; Whitworth et al., 2014; Besson et al., 2007), but how these interventions affect understanding hasn't been extensively investigated (see Coletta et al., 2019; Herakeioti & Pantidos, 2015; Hadzigeorgiou et al., 2008; Levin et al., 1990).

This paper evaluated the implementation of a full-body intervention directed to 6th grade primary school students, to introduce the physics concept of impulse and gain clarity into the following research question:

Does participation in bodily-based activities help students acquire greater scientifically accepted reasoning?

Methodology

Participants and procedures

The subjects of this study were twenty-nine 6th grade students of a Greek elementary school, who had not previously been taught the concept of impulse. They participated in pre-designed bodily-based activities, and were administered a pre- and post-intervention test. Both the intervention and exploration of students' understanding lasted 20-25 minutes and the teaching process was carried out by the first author, who was granted the necessary license from the competent primary education administration office and as such permission to access the school's ground for research purposes. The school's principal, and the teachers' assembly also agreed to the research study. The parents of the students had previously filled out a consent form agreeing to their children's participation in the interventions and to recording the entire process.

Assessment procedure

Structured one-to-one interviews were chosen as the evaluation method to provide a clear picture on each subject's understanding, the difficulties they encountered, and their held misconceptions.

The interview questions were formulated based on the following: (a) review of previous studies on the difficulties learners encounter in understanding the physics concept of impulse (b) create links to everyday situations and experiences and (c) provide a varied set of problems for which participants make predictions and assumptions, develop their reasoning and explain their answers. Students were asked three relevant questions; the first concerned a human-centered activity ("If you fall from a height, would you prefer to land on a thin or a thick mat and why?"), the second question involved objects present during the procedure ("Why is it more likely that the object will break when it falls on a table instead of a sponge?"), and the third interview question included an everyday condition illustrated on an image ("Why would the damage be greater if a go-cart accidentally lost control and hit a concrete wall, instead of running into a stack of tires?").

The three-fold interview was selected to understand the potential influence different contexts may have on students' performance, but also to minimize the difficulty on their part to imagine a situation being narrated to them, which would require an additional cognitive load.

Teaching intervention

Activity 1

We asked students to stop a lightweight ball being thrown at them, however all the while keeping their hands outstretched. We replaced the ball with a heavier one and gradually increased the throwing speed. The students were able to discover that when stopping the heavier ball they unconsciously bent their hands to feel less pain. The aim was to conclude that the intensity of pain felt is proportional to the force exerted on the ball which also depends on how abruptly students stop the motion.

Activity 2

We asked students to climb to a height of about 70cm and jump, but initially they were requested to land without bending their knees. After this first attempt, students were asked to jump again but this time to land naturally, i.e. by bending their knees. We asked them to describe how they felt and students concluded that an abrupt or prolonged stop of a real time movement affects the force exerted on their body.

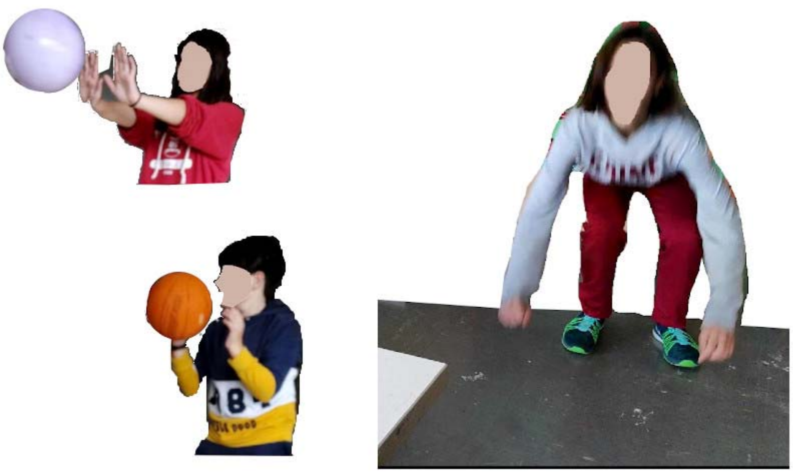

Figure 1. Visual instances from activities

Data Analysis

In this paper, we incorporated conversation analysis techniques, which involve a close examination of the video-recorded conversations to determine how students construct meaning from sets of mutually elaborating semiotic resources (Euler et al., 2019). Based on previous classifications (Givry & Pantidos, 2014), we focused on spoken language, gestures (ergotic: manipulating, deictic: pointing, symbolic: representing), and body posture. Therefore, based on the multimodal transcript created, we categorized students' responses as inadequate, fair, or adequate. Students' performance was evaluated individually by the two researchers in line with the scoring framework (Table 1), and compared and reassessed until the degree of agreement between the two independent physics teachers-researchers was over 95%.

Table 1. The scoring framework

Adequate	Fair	Inadequate
As a moving object comes to a stop, the student understands that the magnitude of the exerted force is affected by the time interval over which the force acts	Student refers to correct elements but not to the time interval	Student makes no, or wrong reference to the time interval or to any other correct elements

Results

For each assessment test, Table 2 provides the number of adequate and fair responses to the human-centered (HC), object-centered (OC), image-centered (IMC) questions of the assessment procedure.

Table 2. Distribution of students' answers

Scoring	Context	f (%) pre-test	f (%) post-test
Adequate	*HC*	2 (6.9)	13 (44.8)
	OC	0	12 (41.4)
	IMC	0	16 (55.2)
	Total	*2 (2.3)*	*41 (47.1)*
Fair	*HC*	27 (93.1)	16 (55.2)
	OC	29 (100)	17 (58.6)
	IMC	29 (100)	13 (44.8)
	Total	*85 (97.7)*	*46 (52.9)*

The activities were pre-designed for the students to experience that a similar change in momentum can be achieved with a large force over a brief period of time but also with a small force applied over a longer period of time. Apart from two students, it was observed that all other participants did not mention the exerting time of the deceleration force before the intervention. In addition, no student response was assessed as inadequate. A fair score was granted when students made references to correct elements, such as the distance from a solid surface, the softness of the material on which the object landed, or the volume of the material on which the object comes to a stop. An example of a fair response is presented below, together with a screenshot from the videotaped assessment procedure:

> "The thicker mat has a greater volume +s.g [demonstrates with hands spread apart] in terms of material so the fall is less painful."

Figure 2. A response based on the volume of the material

After participating in the activities, there is a substantial shift towards students' adequate justification (47.1% of the answers), indicating significant progress. Around half of participants, depending on the question, continued to justify their answers based on more obvious features: For question one, 16 out of the 29 students based their explanation on the distance from the hard surface-ground (3 in number) and the volume of material in a thicker layer (13 in number). For question two, 17 students based their explanation on the difference in softness among the two surfaces on which the object lands. For question three, students relied on the flexibility property of rubber tires (13 in number) and again on the difference in softness among the two materials (13 in number). All answers pertaining to the contact time interval but not explicitly expressed were assessed as fair responses.

The not-so-mismatched number of adequate responses before and after the intervention cannot allow us to comment on any potential impact on students' understanding from the content of the questions. However, it is worth noting that in the pre-test, the human-based question was the only one for which students made reference to the time interval, but not to the extent that we could argue on the radical significance of the lived experience.

Due to the activities' distinct presentation of a time interval during which a force is applied, a sound number of participants managed to scientifically clarify and communicate, using a multimodal framework, the cause behind any damaging (or not) attempt of immobilization. The following sample of the multimodal transcript accompanied by screenshots of the videotaped procedure demonstrates the progress in a student's conceptualization journey (Figure 2):

> "When I land on the thinner mat, I stop immediately + symbolic gesture [a closed fist representing the body coming to an abrupt stop], so it hurts more."

Figure 3. Posttest reasoning

Discussion

Kinesthetic activities are recommended as knowledge organizers and conceptual scaffolds, especially within the physics field, where theoretical perspectives can be difficult to grasp, as they are often separated from the tangible ways of the world (Bamberger & diSessa, 2003). Our research confirms that the increase in bodily engagement leads to an increase in knowledge acquisition (see Tran et al., 2017).

Apart from the positive learning impact where students were given the opportunity to add elements of scientifically accepted knowledge into their reasoning, a large number of students transferred their newly gained experiential knowledge to other contexts, e.g., students were able to answer an object-centered question drawing from the conclusions they made from their participation in the embodied activity. Knowledge transferability is the desired outcome because it contains elements of conceptual change since the subjects succeeded in restructuring, transferring, and applying their acquired knowledge to other settings (Herakleioti & Pantidos, 2016; Eraut 2009).

Irrespective of the subject matter or type of knowledge or skill, after one year, about 33% of the gained knowledge is lost, while after two years, this loss increases to about 50% (Custers, 2010). The long-term effectiveness of kinesthetic interventions has been previously confirmed (see Hadzigeorgiou et al., 2008) but requires further exploration to understand if and how the core components of such activities i.e. kinetic logic, kinesthetic memory and kinesthetic perception (Seitz, 2000) affect long-term retention of knowledge.

Further experimentation to measure the effectiveness of such interventions compared to others will surely build on initial findings (Levin et al., 1990). As we stated in the introduction, bodily engagement can vary from object manipulation, full-body movement, and even simply observing others' actions, thus further comparisons of these different types can shed light on weaknesses and benefits.

Conclusion

Driven by our reflection on the gap that exists between experiential learning and conceptual understanding, we investigated whether solely participating in activities that discern a single critical aspect help students form conclusions and apply them when justifying their answers. The results showed that many of the participants moved from a superficial description of the concept of impact to its scientific justification, stating as a determining factor the time interval during which the force is exerted.

One proposal arising from our results is to introduce objects of learning with first-person experiences because it is easier to link desired knowledge to previous body-centered experiences and then restructure and apply it to other contexts.

While the number of participants in this study is considered sufficient to draw safe conclusions, a wider range of student ages could provide more information regarding the mechanisms of understanding of the concept of impulse and possible alternative ideas.

As participants took part individually in the activities, in the future it would be worthwhile to implement these within a classroom environment and redesign them to include group work. Finally, seeking the psycho-emotional effects of interventions is a legitimate argument, and can be achieved by investigating participants' attitude changes towards Physics and the students' perceived usefulness of the activities.

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