European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available on-line at: www.oapub.org/edu

DOI: 10.46827/ejes.v9i10.4493

Volume 9 | Issue 10 | 2022

OBSERVING OR PERFORMING ACTIONS? UNDERSTANDING CIRCULAR MOTION VIA TWO TYPES OF LEARNING ACTIVITIES

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Abstract:
Decades of research support the benefits of movement for cognitive development however this link remains unexploited in educational practice. For this reason, embodied cognition serves as the theoretical underpinnings of this study proposing that thoughts and actions are influenced by sensory experience. Fifty-eight 6th-grade students were divided into two groups: The first group participated in activities designed for full-body movement and the second observed the haptic manipulation of materials by an educator. The study thus utilized a two-group design and was conducted in phases: pretest, intervention, immediate posttest and delayed posttest. The entire process was recorded to assess students' understanding and the multimodal text thereby created included both spoken word and bodily expressions such as posture and gestures, enabling us to closely follow the progress of every participant. The range of responses was then narrowed down to adequate and inadequate, followed by statistical processing of the data. The results showed that both execution and observation effectively contributed to the improved performance of students immediately after the interventions. Nevertheless, students who participated in bodily-based activities showed an additional advantage four months later. While this study focused solely on circular motion, the idea to investigate physical engagement and its impact on students' understanding could be extended to other content, and the long-term effectiveness of bodily-based learning ought to encourage a redesign of the official curriculum.

Keywords: kinesthetic learning, physics, embodied cognition, multimodality

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1. Introduction

The question of whether cognitive function is essentially grounded in our senses and actions within the environment is at the core of past and present discussions. According to the work of classical cognitive theorists, the sensory system is treated as an information transfer circuit to and from a central processor, in which abstract and high-level thinking takes place (Amin *et al*., 2005). What emerged later was the embodied cognition theory claiming that cognitive function is deeply rooted in the body's interactions with the surrounding physical and social world, meaning that people use body-based resources to construct meaning and relate new ideas to past experiences. Ironically, educational systems limit access to these resources, impeding the ability to learn, and significantly underestimate what people know and the extent they can deeply engage with ideas that interest them (Nathan, 2021). Several scholars have expressed strong concerns that formal education is structured in such ways as to create a conceptual distance between learners and their physical world. Educational theory, policy, and practice in western societies continue to maintain forms of cognitivism that interpret the body as a "pilot" of the mind (O'Loughlin, 2006), therefore a key obstacle to the integration of the body in learning is the widespread perception that thought and bodily activity are two distinct entities, their interdependence remaining unrecognized. One feasible way to move from the descriptive-based knowledge that prevails in education to the provision of first-class experiences (Laurillard, 2012) is through the inclusion of pre-designed kinesthetic activities that directly support learning goals and physically engage students in the learning process (Begel *et al*., 2004).

A common feature in recent classification systems of an embodiment for educational purposes, despite the fact that these are linked to the use of technological means (Skulmowski & Rey, 2018; Clifton *et al*., 2016; Johnson-Glenberg *et al*., 2014, 2016) is the degree of bodily engagement. Bodily engagement can be distinguished as high level, i.e., the execution of some movements or whole-body movement and as low level, i.e., exerting influence or observing the movement of other persons or objects (Duijzer *et al*., 2019). The idea behind introducing the observation of others' actions as a low level of engagement, is because the activity of a specific group of neurons (mirror neurons) depends both on the execution and the observation of an action (Kilner & Lemon, 2013; Seed & Tomasello, 2010).

Allowing students to observe human movements has generally shown a positive effect on learning, compared to static learning conditions (Rueckert *et al*., 2017; Fiorella & Mayer, 2016; Brucker *et al*., 2015; Castro-Alonso et al., 2015), but not always (see Ouwehand *et al*., 2015). Learning environments with lower levels of bodily engagement are generally considered less effective (Duijzer *et al*., 2019), but the hypothesis that higher levels of bodily engagement always lead to higher learning outcomes have not been supported either (Tran *et al*., 2017). As such more research is needed to compare the impact the degree of bodily engagement has on students' understanding, by evaluating the immediate and long-term performance of students who previously observed or performed actions with specific learning goals.

2. Literature Review

Much of the physics' content can be introduced kinesthetically, as it deals with the actions and interactions of objects at the scale of the human body, with concepts and principles of mechanics that have direct application to the human body, or with physical entities and phenomena that can be approached through movement (Richards, 2020, 2019; Mylott *et al.*, 2014; Redish, 2014; Whitworth *et al.*, 2014; Hadzigeorgiou *et al.*, 2008). Physics education research (PER) leverages bodily engagement to make sense of concepts and phenomena and is indeed flourishing in the data-backed design and implementation of such activities. Students can interact with physical apparatus or material (Sliško & Planinšič, 2010; Trout & Gaston, 2001), and students' bodies can be used as a sensor for physical interaction (Singh, 2010; Besson *et al.*, 2007; Bracikowski *et al.*, 1998) or they can role-play physical phenomena that may be much larger or smaller compared to their body (Scherr *et al.*, 2012; McSharry & Jones, 2000).

However, the assessment of the learning outcomes and the actual impact these types of activities have on students is still lacking. A prime example is the research of Levin *et al.* (1990) dealing with 6^{th}-grade students' alternative ideas regarding linear velocity during circular motion, which showed, among other things, that kinesthetic intervention that countered a specific misconception led to a significant improvement in their understanding. As part of a broader curriculum for teaching physics, called Thinking in Physics (TIP), designed to develop a strong understanding of key physics concepts by middle and high school students, kinesthetic experiences were designed and implemented for Newton's second law (Coletta *et al.*, 2019) but their effect on students' overall progress is unknown. As research has shown that preschool children are ready to learn various scientific ideas, Hadzigeorgiou *et al.* (2008) compared the performance of two groups of preschool children who had participated in two alternative interventions for mechanical balance. The performance of all participants improved, and although the second group had a theoretical advantage due to common features between their intervention and the assessment (i.e., use of objects), no differences in performance were identified. For participants of the same age, Herakleioti and Pantidos (2016) found a positive effect of a body-centered intervention designed to allow children to use their bodies to express their reasoning and construct knowledge regarding shadow formation. Reference to facilitating learning was made in relation to the "Particle Dance" workshop by Nikolopoulos and Pardalaki (2020), in which high-school students approached particle physics through the experiential and expressive means of dance. In an intervention designed for an electric field course, Johnson-Glenberg and Megowan-Romanowicz (2017) found that students learned more when embodied simulations were included, the benefits of which became clear when the assessment process included embodied ways of communicating.

While the previous works suggest that physics teaching can be approached kinesthetically, having already shown a positive impact on differentiating understanding, long-term knowledge retention still remains a fairly unexplored area. Hadzigeorgiou *et al*. (2008) showed that only children who had been exposed to whole-body engagement activities, compared to others that were haptically manipulated objects, maintained their ability to apply (up to 4 weeks after the intervention) the rules they had internalized from the intervention. On one hand, it has been declared that irrespective of the subject matter or type of knowledge or skill, after one year, about 33% of the gained knowledge is lost and after two years, this loss increases to about 50% (Custers, 2010). On the other side, research in education manifests that physical movements improve the retention of learned concepts as they provide additional sensory cues with which knowledge can be represented and retrieved (Lindgren, 2014; Carbonneau *et al*., 2013; Chu & Kita, 2011). We, therefore, recognise the need to clarify to what extent the degree of bodily engagement can affect understanding and the preservation of that understanding. The study sought to answer the following research questions:

1) Does participation in the interventions lead each group of students to improved understanding?
2) Is it as effective for students to observe objects' actions as it is to physically perform related actions themselves?
3) Which of the two interventions facilitates the preservation of knowledge over time?

3. Methodology

3.1. Participants

6th-grade students were chosen as study participants. This population group was selected assuming that they have already formed ideas around the targeted learning concept of this study, i.e. circular motion, and are at an age where they can fully express their reasoning. 58 students were divided into two groups: the first experimental group (EG1, N = 29) and the second experimental group (EG2, N = 29). The first group observed the manipulation of objects by the researcher while the second performed bodily-based activities. Their classroom teachers were asked to evaluate the overall academic performance of each student (A. Encounters difficulties, B. Encounters some difficulties C. Encounters no difficulties) to increase the probability of the two groups scoring analogously in the pretest.

Both the intervention and the exploration of the students' understanding were carried out after getting the necessary permission from the primary education office, the school principal and the assembly of school teachers. The parents of the study subjects had given written consent for their children's participation in the interventions and agreed to record the entire study process.

3.2. The Analytical Approach

All human communication, and how we share ways of perceiving, understanding and acting, is made up of two complementary aspects: the production and interpretation of modes or semiotic resources (Kress, 2010). No single mode is sufficient to construct all the meaning one desires, as each mode emphasizes different facets of a single whole and can carry a finite set of meanings, also known as "*meaning potential*" (Kress, 2010). Van Leeuwen (2005) argues that when having to interpret meaning-making, what may be considered marginal or central depends on the adopted context, thus from a multimodal perspective the orchestration of a multiplicity of resources is what materializes any meaning. The analytical approach used is inspired by the multimodal conversation analysis, which constitutes the review of videotaped conversations to determine how individuals act and interact (Streeck *et al*., 2011). Based on previous classifications (see Givry & Pantidos, 2014), we focused on spoken language, gestures (ergotic/e.g: manipulation of objects, deictic/d.g: pointing and symbolic/s.g: representation), physical movement or body posture/p.m. As an example, we have included a sample of the multimodal text that was developed, accompanied by photos from the actual footage. The underline indicates that two modes (e.g. speech and gesture) emerged at the same time.

Researcher: "*The athlete spins the ball (deictic gesture: he follows the trajectory with his finger:) for a few seconds. If he releases the string here (stops moving the finger), how will the ball continue to move?*"

Student: "*In this direction (symbolic gesture: shows the supposed movement of the ball in a straight line vertically to the trajectory). I rotate… and let it go (physical movement: shows the athlete's hand movement). It will move from here to there (deictic gestures: points to the start and end of the movement in the straight line vertically to the radius).*"

Figure 1: Snapshots from an answer

3.3. Assessment Test

The questions were designed based on the following: (a) a review of previous studies on the difficulties learners encounter in understanding circular motion (b) links to everyday situations and experiences and (c) to provide a varied set of problems for which the participants make predictions and assumptions, develop their reasoning and explain their answers. Specifically, each component of circular motion was approached with a question centered around a humane experience from a third person's point of view, a question related to the manipulation of objects present in the process, and via a condition presented with an image. The purpose here was to understand the potential influence different contexts have on students' performance, but also to minimize the difficulty on their part to imagine a situation solely being narrated to them, which would require an additional cognitive load. For example, for the first component, the students were asked "*As you run you grab a pillar with your hand and move around it until you release it. When this happens how will you keep moving?*", then they had to show the direction it will follow a present moving object after the release of the cord, and the same question regarding an athlete pictured from above to spin a hammer.

The pretest and posttest questions were the same, while the questions of the delayed posttest were different in order to investigate whether the acquired knowledge could be easily applied to new situations, eliminate the possibility of students answering correctly by memory, as well as increase the level of difficulty of questions that may not have been challenging enough previously.

When the two performance tests were created, both of which consisted of 9 questions, they were delivered to two physics teachers/researchers, in order to ensure their validity, confirm that they correspond to the content of the interventions and reflect the desired knowledge.

3.4. Interventions

We devised three learning activities for two alternative interventions independent of any other teaching effort. Solely based on drawn conclusions, the students had to apply the acquired knowledge to answer questions regarding daily life conditions.

For the "execution" group, the researcher asks the students to run towards him from a distance of a few meters. As they pass him, he extends his hand and holds the student's arm, exerting a vertical force on their previous linear movement. The researcher makes sure to rotate around his axis so that the student can perform a circular orbit and then releases their arm as they move into a straight line. The activity is repeated to put emphasis on the continuity of direction of the student's newly gained movement, which is perpendicular to the centripetal force exerted by the researcher's hand. For the "observation" group, holding one end of a cord steady, the researcher rotates a toy car, making it follow a circular trajectory while constantly exerting a force towards the center. The researcher asks students what they would expect to happen if he let go of the cord at a certain point in the trajectory. After having answered the question, they observed the toy car's course of action. We repeat the activity rotating the toy car by varying the speed of rotation and letting go of the cord at different points in its trajectory.

Figure 2: Snapshot from the first activity

For the "execution" group, we first make clear that the researcher and student alike would need to perform a circular movement like a clock pointer, by holding a curtain rod. The researcher would hold the rod on one end and the student would hold the other while rotating together. Students would then realize that while they were both performing the same number of spins (i.e same angular speed), they were clearly more tired, because they were completing a bigger circle, so they had to run faster. We also increase the length of the curtain rod during the movement to make it even more difficult for them. The students gradually come closer to the researcher to notice the difference. For the "observation" group, the researcher activates a battery-powered toy car while holding one end of the wire firmly so that it rotates. He adds a peg close to the axis of rotation with ease and then he tries to add another peg near the car, with observed difficulty. The students notice that the further the center of rotation is, the greater the distance traveled over the same time period, so it must move at a higher speed in order for the wire to move with the same angular speed.

Figure 3: Snapshot from the second activity

For the "execution" group, the researcher asks the student to develop a relatively moderate speed and then run through the smaller semicircle (painted on the ground) trying not to exceed its limits. He then asks them to repeat the activity, but this time to develop a faster speed, until they find it difficult to stay within the limits unless having to slow down. The researcher then holds the student's arm so that the students are able to keep within these limits, because of the additional force. The students are asked to run again, but to cross the larger semicircle, achieving this with ease and concluding that an increase in speed demands a larger radius or a specific amount of centripetal force. For the "observation" group, the researcher first releases a volos from a moderate height, in the inner slit of a wooden path and then gradually increases the height of release. After a few attempts, the marble rolls away from the wooden turn, since the centripetal force needed to keep the volos within its path is larger than friction. The activity is repeated following the same gradual procedure but the volos is placed at the outer carved slit of the wooden path. Students discover that this way it is easier for the volos to stay on track and eventually rolls away when released from a higher point further from the ramp, concluding that an increase in speed demands a larger radius or a specific amount of force.

Figure 4: Snapshot from the third activity

3.5. Scoring and Statistical Analysis

Every answer was first scored as adequate or inadequate by the two authors and miscellaneous parts of the multimodal transcript (about a 20%) were given to the previously mentioned physics teachers/researchers to compare and discuss scores, the aim of which was to achieve at least 95% agreement. An adequate vs inadequate response was based on whether the students (a) acknowledge that the movement of a body when a centripetal force is applied is circular and that it will continue in a straight line when the force stops to be applied, (b) express that speed is equal to the length of an arc covered per unit of time and (c) understand the variation brought about by fluctuations of speed and the radius of curvature in the magnitude of the centripetal force needed.

Having found the absolute frequencies for the distribution of students' answers in the two categories, a non-parametric Wilcoxon rank test for pairwise observations was applied to estimate statistical differences in the performance from pretest to posttest within the groups and the method of Change Regression to compare the learning outcomes between the two groups with regards to their performance on the two posttests, considering their pretest performance as a covariate.

4. Results

Both the somatic experience and the observation of the manipulation of objects helped students re-examine their previous assumptions and come up with the desired knowledge.

Students, at first, struggled to demonstrate the direction of movement of an object that had previously performed a circular path after a centripetal force was no longer applied. They believed that the object would follow a straight line along the imaginary straight line of the radius or continue diagonally from the position of release or hypothesized that the object would continue a circular path until it stopped.

They also encountered difficulties when comparing objects' (or points') tangential speed based on the arc traveled over a specific time period. They adopted the idea that the points closer to the center of rotation are more influenced by the centripetal force and thus would travel faster or that all points travel at the same speed overlooking the moving arc.

Although, they could easily predict the successful or unsuccessful continuity of movement of a body turning, based on changes to their own speed and distance from the center of their movement. Several students believed that when a body is closer to the center of rotation it is increasingly affected by the centripetal force so it is easier to stay on track or for a specific value of speed, regardless of the radius, the object cannot continue to move cyclically.

The categories of responses as appeared are presented in Table 1, using an actual example of a student's response, both for an adequate and inadequate version. For each answer, students' spoken words and any other resource of meaning-making are documented. For each time a meaning-making resource was used, we briefly note its type and exactly what action was represented.

Table 1: Categories of students' answers

Aspect	Inadequate	Adequate
1st	a) "*When the rope is cut, the ball will continue to move cyclically [s.g: shows the supposed movement with hand] until it stops.*" b) "*The ball will move in a straight line [d.g.: with the index finger points to a spot along the imaginary straight line of the rope] as will the rope.*" c) "*I believe it will look like this [d.g: shows diagonal movement with a closed fist] and then it will stop.*"	a) "*The ball will move in a straight line [s.g: shows the movement perpendicular to the radius of rotation with an open fist.*"]
2nd	a) "*I believe the point moving with greater speed is the one [d.g: points with the index finger] nearest the center of rotation, because it is closer to the source of movement.*" b) "*All points have the same speed since they start and finish at the same time.*"	a) "*Between two points moving at the same time, the one that travels a greater distance [d.g: the index finger points to the traveled arc] /bigger arc is the one with greater speed.*"

	c) *"I guess the one [d.g: points to the spot] on the outside but I don't know why."*	
3rd	a) *"I think that when the object is near the center of rotation it is easier to stay on track because [s.g: shows with fist that something is pulling it to the center] it is closer to the source of the rotation."* b) *"I believe that regardless of the turn, when the objects are moving at a specific speed or beyond, both may well lose their course."*	a) *"When a body travels along a greater distance from the center of rotation [d.g: points to a larger radius] with the same speed compared to another body [d.g: points to a spot close to the center], it can be pulled with less force" / "it is harder for a body that is near the center to travel as fast as another [e.g: points to a larger distance from the center] located further away"*

The adequacy of responses was divided per component, before and after the interventions, as well as 4 months post-intervention, for every one of the three problem sets (i.e., human-centered, object-centered, and picture-centered), thus three frequencies of responses are noted in every cell and their sum in brackets. As seen in Table 2, regarding component three, there were no inadequate answers immediately after the interventions and as for component two, hardly any answers were assessed as inadequate. Notwithstanding, several students continued to mistakenly answer questions on the direction of movement when a centripetal force was no longer applied. Regarding component one, two additional inadequate answers were given by students in the execution group and regarding component two, the same number of inadequate answers were given among both groups.

Four months after the interventions, students' performance in both groups demonstrated that they still encountered difficulties, yet the positive impact of their participation was apparent, since the number of adequate responses outnumbered those of the pretest. Between the groups, regarding component one, five additional inadequate answers were given by students in the execution group, regarding component two, nine additional inadequate answers were given by the observation group and regarding component three, the same number of answers (5) were assessed as inadequate.

Table 2: Adequacy of responses

	Inadequate		**Adequate**	
Group	**Execution**	**Observation**	**Execution**	**Observation**
Understanding that velocity is always tangent to the orbit				
Pretest	2|14|17 [**33**]	3|10|19 [**32**]	27|15|12 [**54**]	26|19|10 [**55**]
Posttest	0|9|8 [**17**]	1|2|12 [**15**]	29|20|21 [**70**]	28|27|17 [**72**]
Delayed P.	1|11|10 [**22**]	2|7|8 [**17**]	28|18|19 [**65**]	27|22|21 [**70**]
Understanding tangential speed				
Pretest	19|19|14 [**52**]	15|14|7 [**36**]	10|10|15 [**35**]	14|15|22 [**51**]
Posttest	0|2|1 [**3**]	1|1|1 [**3**]	29|27|28 [**84**]	28|28|28 [**84**]
Delayed P.	5|5|6 [**16**]	7|8|10 [**25**]	24|24|23 [**71**]	22|21|19 [**62**]
Understanding the relationship between force, speed and radius				
Pretest	1|10|4 [**15**]	0|6|9 [**15**]	28|19|25 [**84**]	29|23|20 [**84**]
Posttest	0|0|0 [**0**]	0|0|0 [**0**]	29|29|29 [**87**]	29|29|29 [**87**]
Delayed P.	0|1|4 [**5**]	1|1|3 [**5**]	29|28|25 [**82**]	28|28|26 [**82**]

As an attempt to quantify the impact of the interventions, Table 3 shows the results of the statistical analysis that followed the qualitative description of the answers given. As indicated by Table 3, both groups moved to statistically significant learning outcomes for components one and two, immediately after the interventions. Regarding component three, the performance of both groups was satisfactory enough even before the intervention leading to borderline p-values.

Table 3 confirms that only for component two in the delayed posttest, there is a statistically significant difference between the two groups. The students of the execution group encountered fewer difficulties in answering questions on the comparison of tangential speed between points moving circularly, thus their intervention is considered more effective to address this finer object of learning.

Table 3: Difference in performance

Aspect	Performance's Difference (%) (E.G-O.G)					
	Posttest-Pretest within groups	**p-value**	**Posttest between groups**	**p-value**	**Delayed posttest between groups**	**p-value**
1st	E.G: 19.6 (10.9, 28.2) O.G: 18.5 (7.4, 29.5)	<.001 0.004	-3.30 (-13.2, 6.62)	0.508	-4.28 (-17.7, 9.1)	0.527
2nd	E.G:37.9 (25.3, 50.4) O.G: 56.4 (41.2, 71.6)	<.001 <.001	0.0255 (-5.4, 5.9)	0.928	16.6 (3.0, 30.2)	0.017
3rd	E.G: 0.500 (30.0, 67.0 O.G: 33.0 (30.0, 50.0)	0.005 0.006	-	-	1.26 (-5.6, 8.1)	0.711

In the pretest procedure, the first type of questions (the student is immersed into the narrative as the character involved in the situation) helped students answer correctly on the direction their body would follow when they let go of a circular movement, however this didn't occur when they had to provide an answer for an analogous situation of an object in real time or when they were asked to show the direction of an image of an everyday object, like for a car movement. The same is also noted for component three, since the human-related questions helped them, express ideas assessed as adequate but they encountered difficulties in the other two types of questions.

Additionally, the students in the execution group failed to transfer the induction of their bodily experience to an object-centered question, i.e., continuity of movement when a centripetal force is no longer applied. While they experienced the natural continuity of their movement, they could not apply their understanding when the perspective had shifted. Of course, for students in the observation group, since they had observed the direction of the object in real-time, it was simpler to answer the questions on the movement of present objects.

5. Discussion

Based on the need to highlight the ability to deploy the body in the learning process, several efforts have been made by physics educational research (PER) to design and implement kinesthetic learning activities. Since the range of bodily engagement can vary from material-based activities to full-body movement, more research is needed, in order to elucidate the supposed usefulness of learning through the immediate comparison of their finer distinctions. Attempts to compare the hands-on practice to full-body movement have shown an advantage for the latter, especially when sustaining physics learning over time (Hadzigeorgiou *et al*., 2008; Hadzigeorgiou & Savage, 2001), and as such may be associated with specific cognitive factors: kinetic logic, kinesthetic memory and kinesthetic perception (Seitz, 2000). Taking one step further we compared the full-body movement to watching another person perform an action (a form of low embodiment), because the acquisition of information from a tangible external source, according to embodied cognitive theory is considered another form of bodily experience, because it leads to premotor neuronal activity (Sullivan, 2018). An immediate performance advantage of one intervention over the other cannot be highlighted, as was the case for Levin *et al*. (1990) but greater knowledge retention from the execution group was noticed after four months. Further research would be useful to investigate the impact of repeated interventions on students' understanding and retention of knowledge of physics concepts.

The possibility of knowledge transfer is sought to underline any conceptual change, similar to when individuals achieve a restructuring, transfer or application of knowledge to different contexts (Herakleioti & Pantidos, 2016; Eraut, 2009). The students of both groups, four months after the intervention, were better able to answer questions linked to different contexts: all students gave more adequate responses to image-based questions and each group performed better on questions related to the other group's intervention. Also, the participants answered with greater ease all questions that had common characteristics with the intervention they participated in.

From the analysis of the videotaped assessment, it became clear that students conceptualized critical information in a multimodal way to provide an adequate answer through their posture or gestures. We assume that important elements of thought could have been lost if we had followed another procedure. As pointed out by Johnson-Glenberg and Megowan-Romanowicz (2017), the method used to evaluate participants makes a significant difference in students' perceived learning from the educator/researcher's point of view. In their case, an embodied focus, for example, generated better performance for the groups with high physical involvement, compared to the traditional method of assessment. This suggests that not only should teaching be more tangible, but also the extent of sensitivity to bodily expression in an assessment gives greater insight into the outcomes.

Previous physics education research attempts on embodied learning to introduce basic concepts and phenomena have included kindergarten students (Herakleioti &

Pantidos, 2016; Hadzigeorgiou *et al.*, 2008), secondary students for challenging concepts (DeStefano *et al.*, 2020; Coletta *et al.*, 2019) or university students to re-explore some previously taught concepts (Whitworth *et* al., 2014; Scherr *et al.*, 2012), providing a positive impact when going beyond just the design proposal of the activities. Concepts in mechanics have a direct link with the human body and are an important presence in the daily life of students from a young age. The 6th graders of this study seem to have already developed thought patterns around these concepts, however, these are not always sufficient to explain the situations at hand or make the right predictions when needed, therefore offering a unique opportunity to establish a kinesthetic base to anticipate future school knowledge. Of course, as suggested by Erwin *et al*. (2014), collaboration with universities in the design, implementation, and development of best practices can be a useful way to educate teachers and provide them with the tools they need, because such learning activities offer a clear pedagogical advantage that can easily be supported through educational policy.

6. Conclusion

Driven by our reflection on the gap that exists between experiential learning and conceptual understanding, we tackled the issue by comparing the performance between students who participated in activities of low physical involvement (observation and minimum haptic engagement) and students whose bodies were used as a structural part of an intervention, to ascertain whether they would be equally capable of applying the conclusions they formed when asked to make predictions and justify their answers to questions.

Immediately after the interventions, both groups of students showed improvements, a performance that remained higher than before and over the long-term. Between the two groups, four months after their participation, we saw no differences on component one, the "observation group" performed slightly better on component two, while for the third component the "execution group" performed statistically better. Despite its existing potential, the use of the human body as a substitute for an element of activity may create misconceptions that a lifeless object would not. A person's body type or clumsiness may work in some cases as an obstacle for meaning construction. For example, for four students specifically, when they were let go during the movement in circular orbit, they continued moving in an unstable manner, thus the direction of a natural continuum was not clear to them (i.e. in a straight line). Until further research is realized, we'll settle on the idea that the most substantial among the two types of approaches, depends on the component of the concept being studied, while the argument of bodily involvement contribution to knowledge retention (Tran *et al.*, 2017) needs further research on other objects of learning and with different age groups.

Another proposal, derived from our results, is the need to introduce the object of learning with first-person experiences, because it is easier to link the desired knowledge to previous body-centered experiences and then restructure and apply it to other contexts. The multiplicity of contexts is also necessary when assessing any knowledge, because depending on the question a student may be considered a connoisseur.

Funding Statement
This research was financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme "Human Resources Development, Education and Lifelong Learning" in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY).

Disclosure Statement
The authors report there are no competing interests to declare.

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