The use of embodiment in physics teaching

Abstract. This work presents the results of a modelling experience about macroscopic (astronomic) and microscopic (matter components) physical systems using embodiment. The proposal was addressed for a general course of sciences with 86 pre-service primary school teachers. These results were compared with a control group of 68 students. The analysis of the students' answers in the survey shows that the observed differences between both groups are statistically significant.

1 Introduction

Physics is an area that involves the use of models [1]. Models are approaches to reality through representations that have analogies and differences with the real phenomena. They need to be efficient, reliable and useful. For that, the analysis of their limitations is very important. Modelling is proven to be a very successful tool for teaching science [2-4]. On one hand, if students actively participate in the process of modelling, automatically face their own ideas (or misconceptions). Secondly, students feel as part of the science process on building concepts, they do inquiry. Embodiment is a particular way of modelling where students are the agents of the model (they use their bodies, themselves, to do the representation) [5,6]. It has two main advantages over other ways of modelling: 1) It allows including dynamical properties of the phenomenon and 2) it makes students to be all time connected with the model's properties.

2 Methodology

We implemented 8 proposals of physics phenomena taught to students along a course of basic science. Students were pre-service teachers of a Primary Education Faculty of a University in Comunidad Valenciana. These proposals used embodiment as the main tool for teaching.

To investigate the success of embodiment in the achievement of knowledge, we established two groups: An experimental group of 86 students where the proposals were implemented. A control group of 68 students were the same concepts were covered without modelling. Both groups of students were from the same level and had similar records in the degree. The 8 proposals were about: 1) Moon phases and eclipses, 2) apparent retrograde motion of planets, 3) scale of the solar system, 4) scientific discussion of the geocentric and heliocentric models, 5) Kepler laws, 6) star formation and evolution, 7) matter states and 8) atomic and nuclear models. The proposals took 30-40 minutes to be carried out, each.

We analysed the implementation of the proposals qualitatively and quantitatively. In this work we present the quantitative results. For that, we used a survey consisted in 10 questions about the concepts involved: 6 about astronomic concepts (e.g., *5. If Copernicus was right (the Earth is moving), why don't we see the relative distance between two starts changing while the Earth moves?*) and 4 about components and states of matter (e.g., *7. Explain, using a microscopic model (particles), why the liquid changes form but not volume when it is changed to another recipient*). The answers were evaluated in a two-step (0, 1) or three-step scale (0, 0.5, 1), depending on the question.

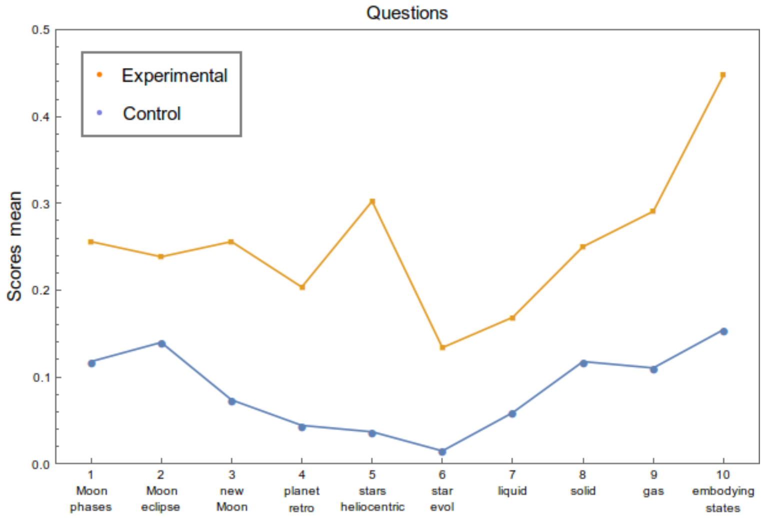

Fig. 1. Mean scores of students' answers to each question of the survey.

3 Results

Results of the embodiment are very positive. As can be seen in Figure 1, the experimental group scores significantly better than the control group in all questions of the survey (Student's T p-value < 0.001) and the size effect of using embodiment is large (Cohen's $d = 1.2$).

For example, Question 5, despite being complex, performs very well compared to others in the same group, unlike the control group. In questions related to micro phenomena (7-10) results clearly improve while moving forward. Students are asked about liquid, solid and gas properties and, finally (Question 10), have to explain a representation of altogether. We think that this progression might be due to a better understanding of the model while they are responding. This effect is not so in the control group, which could mean that embodiment plays an important role.

4 Conclusion

The evaluation of the results obtained with the students that have used embodiment to learn concepts shows that there is a better understanding of the models involved.

Acknowledgements

This research was financed jointly by the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund through the project EDU2015-69701-P.

References

[1] Valk, T., Driel, J. H., & Vos, W. (2007). Common characteristics of models in present-day scientific practice. *Research in Science Education*, 37(4), 469–488.

[2] Acher, A., Arcà, M., y Sanmartí, N. Modeling as a teaching learning process for understanding materials: A case study in primary education. *Science Education*, 91 (2007) 398-418.

[3] Etkina, E., Warren, A., & Gentile, M. (2006). The Role of Models in Physics Instruction. *Physics Teacher*, 44(1), 34–39.

[4] Van Driel, J. H., & Verloop, V. (2002). Experienced teachers' knowledge of teaching and learning of models and modelling in science education. *International Journal of Science Education*, 24(12), 1255–1272.

[5] Johnson-Glenberg, M. C., Lindgren, R., Koziupa, T., Bolling, A., Nagendran, A., Birch-field, D., & Cruse, J. Serious Games in Embodied Mixed Reality Learning Environments. *Games, Learning and Society Conference*. 8 (2012) 8.

[6] Solbes, J., & Tuzón, P. (2014). Indagación y modelización del núcleo atómico y sus interacciones. *Alambique*, 78, 34–42.