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Embodied Cognition and Minds in Orbit: Student Perspectives on the Solar System – An Empirical Survey

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Design and Results

After conducting a pilot study whose purpose was to find out which exemplary mental models about the solar system exist among pupils, we expanded the study to a sample size of 100 pupils of classes 5 to 13, with 93 pre-tests and 78 post-tests. We observed what impact the use of embodied learning could have during the Erasmus+ project "Aristarchus", which focuses on teaching astronomy basics with the "Human Orrery". This was done by conducting pre- and post-tests, the main component of which was to draw the solar system before and after the sequences carried out as part of the Aristarchus Project. With the results we inductively developed a set of items to classify the drawings, analyse their evolution and refine previously suggested classes. While the shape of a mental model can easily be captured with a drawing, the functional understanding can only be partially represented and will be subject to future studies.

„Mental models are individual types of mental modal patterns (shape) that have a functional potential (functionality) and are based on external experiences.“

Ubben(2020, p. 14)

Building upon the pilot study, the dataset of which is incorporated into the current dataset, we executed an intervention in the German partner schools participating in the Erasmus+ Project "Aristarchus." The intervention comprised four embodied learning sequences featuring the Human Orrery. During these sequences, students were instructed on the movement of planets, the definition of years, the day/night cycle, and the shape of orbits in a hands-on, embodied manner. While we are currently developing a reliable tool for objectively categorizing and grading the collected drawings, the categorization of the drawings has been done manually by us after Mayring (2014). These categories are elucidated on this poster, with further details available in Loch and Ubben (2023).

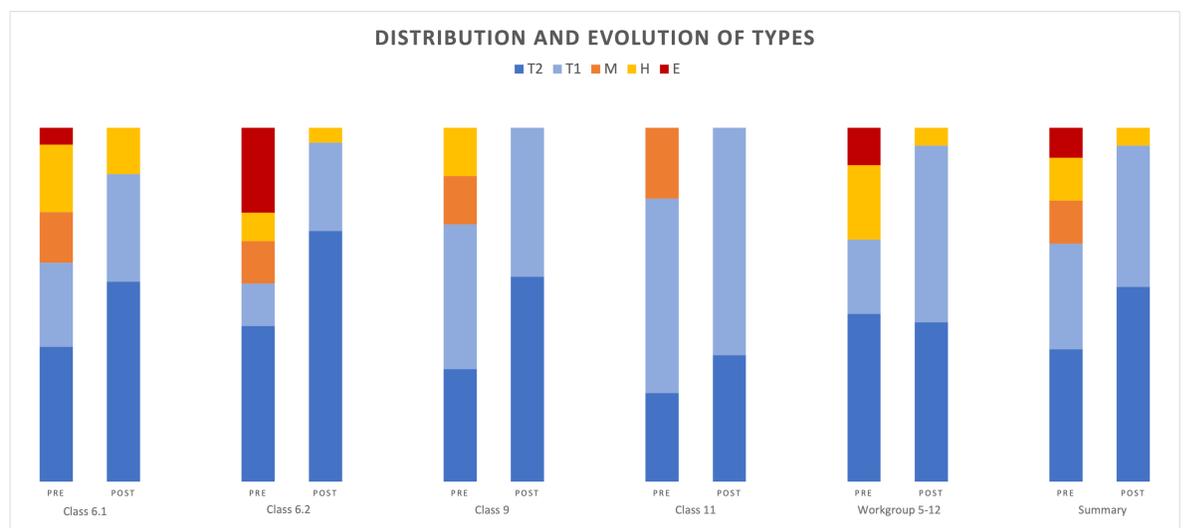
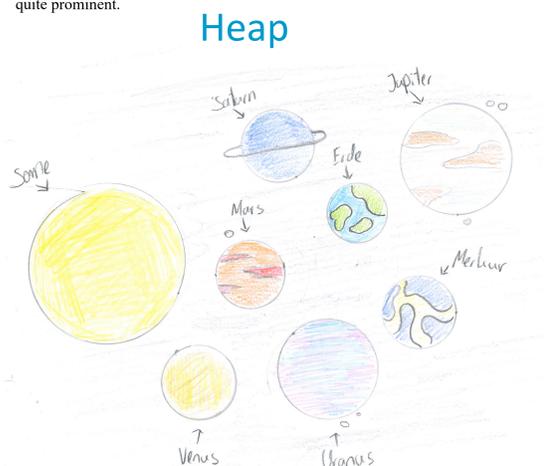


Figure 1: Shown are the 5 different classes from the Sample with the Shape-Types of the students mental models. T2 and T1 represent the Orrery types. M is the "Multiple Planet" Type, H the "Heap" and E the "Earth"-Type. The last two bars are the summary across all students. All graphs are normalised which can lead to slight distortions.

Analysing Figure 1 reveals several noteworthy observations. Following the intervention, there appears to be a trend toward disfavoring "weaker" models such as the Heap, and notably the emphasis on Earth, which seems more pronounced in younger students before the intervention. Another observation is that older students tend to commence with a higher percentage of T1 and T2 types, with some weaker types entirely absent in the sample. This implies a natural developmental progression or external influence, as these students have not undergone formal Astronomy education in school. Furthermore, T1 types appear to dominate among older students, while T2 types show a decrease, in contrast to younger students where they exhibit the most significant increase.



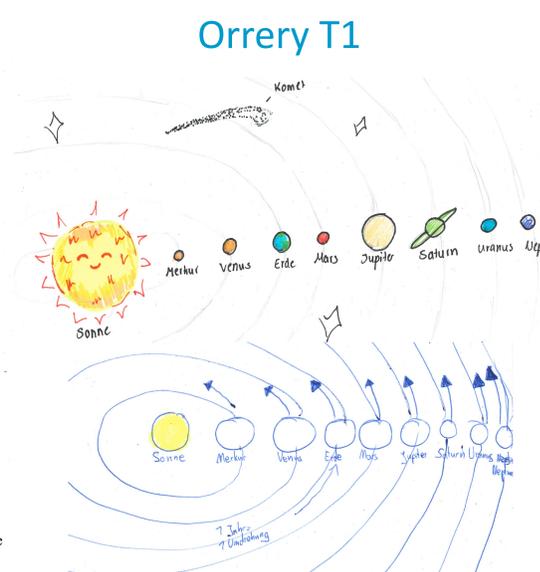
Earth: The Earth-Focus, or simply Earth, places a strong emphasis on the planet Earth, featuring an above-average size, a significant number of details/colours, or a distinctive positioning of the Earth. This Type however is not always distinctive from the others as is shown here and the "Multiple" Example, where it is also quite prominent.



Heap: Contrary to the lacking "Functional Quality" of the model, as it lacks any sort of order or movement, this type typically includes all the planets with correct names and somewhat accurate colours and sizes. Yet, this model seems to be the first to disappear.

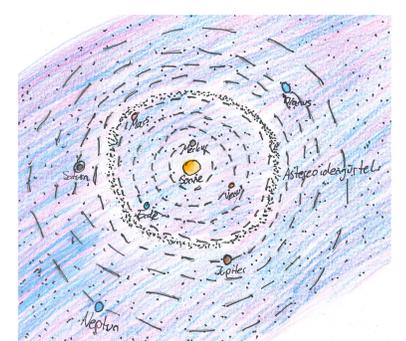


Multiple: This type typically features multiple planets on a single orbit, hence the name. Sometimes, there is an order resembling a division between inner and outer planets. In general, this model is evenly distributed across the age of the students. It could be seen as a transitional step between the Heap and Orrery models. It shows a higher understanding than the Heap, while still having some major flaws.



Outlook

Our focus will be the development of a reliable tool for grading the student drawings according to their shape, so the categorization will be a less subjective process and the categories more distinct from each other. Furthermore, we want to address the current inability to capture the functional understanding in the mental models by designing further tasks on our questionnaire with which we hope to capture the functional understanding. The main interest lies on the movement of the celestial objects in the solar system, followed by the understanding of the distances between and the sizes of the celestial objects. There is also the question as to why exactly this change in the mental models occurs. On average the students also show new knowledge that is not content of the intervention. To answer this, we will have a more detailed look with intermediate questionnaires, to understand the influence of the individual Sequences.



Orrery: The Orrery types can be viewed as two different versions of the same model, as they can appear quite similar, with the key distinction being that T2 usually, though not always, exhibits high details and a distribution of planets around the Sun. T1, on the other hand, tends to emphasize a strict order with a common lack of details. While an underlying functional reason is suggested, it has not been reliably measured yet.

Limitations

There are certain limitations to this method. One of the primary challenges is the difficulty in elucidating the functional understanding behind students' mental models through drawings. While capturing the "shape" of these models is feasible, gaining insight into the functional aspects proves more challenging. Unless we are lucky and clear indicators, like arrows for the movements, are included in the drawings, we cannot assume a student's functional understanding of the solar system. Furthermore, the sample size, encompassing 5 classes across 2 schools, is relatively small. This becomes evident in phenomena like the pronounced Earth Focus in Class 6.2. To enhance readability, the bars in the graph have been normalized, introducing a slight distortion due to single-digit fluctuations in the sizes of the pre- and post-test samples.

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