Methods for addressing strengths and weaknesses of the rubber sheet analogy

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Abstract. Designing instruction to make students aware of the rubber sheet analogy's strengths and weaknesses is crucial for fostering discussions about general relativity, gravity, and our solar system, as well as using models to visualise conceptually abstract ideas. This workshop aims to address essential approaches that aid in understanding the rubber sheet analogy's strengths and weaknesses, as identified (1,2). We will introduce hands-on activities utilising the rubber sheet analogy, involving participants in practical learning methods and showcasing assessment strategies.

The RSA (Rubber sheet analogy) model is commonly used to teach General Relativity in school. It facilitates visualisation of the curvature of spacetime, geodesics, and trajectories of bodies and shows that spacetime configuration determines body movement. Addressing the rubber sheet analogy's strengths and weaknesses is complex and involves developing activities that include discussions in the classroom. These learning approaches are crucial; however, how can we design instruction that allows learners to develop appropriate conceptions independently or in group work?

By examining Keplerian dynamics on the rubber sheet, we will explore new strengths and limitations of this model, bridging the gap in developing appropriate student conceptions. We demonstrate how students make observations and draw conclusions when using this model. We address how Kepler's laws can be simplified and add Einstein's corrections to the use of this model. Table 1 shows how Kepler's laws are simplified on the RSA and how they relate to Einstein's theories. We will expand on these ideas with hands-on activities and group work.

Table 1 In the first column, we describe Kepler's three laws. In the second column, we simplify these laws. In the third column, we contrast Kepler's laws with Einstein's corrections: Planets in our solar system precess and elliptical orbits cannot be stationary in curved space. The fourth column describes the characteristics of orbits on the rubber sheet in relation to Kepler's simplified laws and Einsteinian gravity.

Kepler's Laws	**Kepler's Laws simplified**	**Einstein's correction**	**Orbits on the spacetime simulator**
Planets move in elliptical orbits with the Sun as the focus.	Planets orbit in ellipses.	Planets do not orbit in perfect ellipse, but in a daisy pattern, because of the added relativistic shift due to spatial curvature.	We observe that marbles do not orbit in perfect ellipses but decay in daisy-like patterns.
Planets sweep out equal areas in equal time.	Planets travel faster when they get closer to the Sun.	The area-to-circumference ratio of a circle of radius R is no longer equal to R/2 because elliptical orbital patterns cannot be stationary in curved space.	When in orbit, we observe that the marbles travel faster when they get closer to the central mass of the spacetime simulator.
The square of their orbital periods equals a fixed constant times the cube of their semi-major axis.	The orbit of planets closer to the Sun travels faster than planets that are further from the Sun.		We observe that the marble's orbit closer to the central mass travels slower than marbles further from the central mass

Additionally, we will incorporate essential ideas into the discussion, drawing from our research findings and the existing literature on teaching general relativity and gravity in schools. Furthermore, the workshop will emphasise explicit identification of source and target domains in metaphors to enhance student's understanding of how metaphors are utilised. We will delve into how specific laws and concepts manifest on the lycra sheet, covering topics such as black holes, tidal locking, Newtonian forces, time dilation, curved geometry, and the bending of light. Participants can expect resources, instructional approaches, and links to relevant videos to support their learning experience.

To wrap up, we'll lead a discussion on interpreting these concepts and evaluating student comprehension. Participants will engage in small group activities to explore the potential integration of these Rubber Sheet Analogy (RSA) learning methods into their teaching or research endeavours. Lastly, everyone will have the opportunity to share their concluding reflections with the entire group.

References

[1] M. Kersting, R. Steier, Understanding curved spacetime: The role of the rubber sheet analogy in learning general relativity, *Science & Education*, **27**(7-8) (2018) 593-623.

[2] A. Postiglione, I. de Angelis, Students' understanding of gravity using the rubber sheet analogy: An Italian experience, *Physics Education* **56**(2) (2021).