

“...learners understand each single piece, but they lose completely sight of the big picture. ”

**Relativity as didactical challenge,
Sexl (1980)**

Curved space and warped time: Students' understanding of gravity

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1st of December 2016



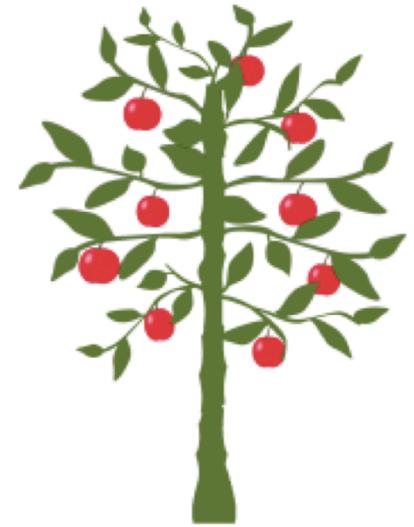
UiO : Department of Physics

The Faculty of Mathematics and Natural Sciences

In spring 2016, we introduced a program on general relativity to six upper secondary physics classes in Norway.



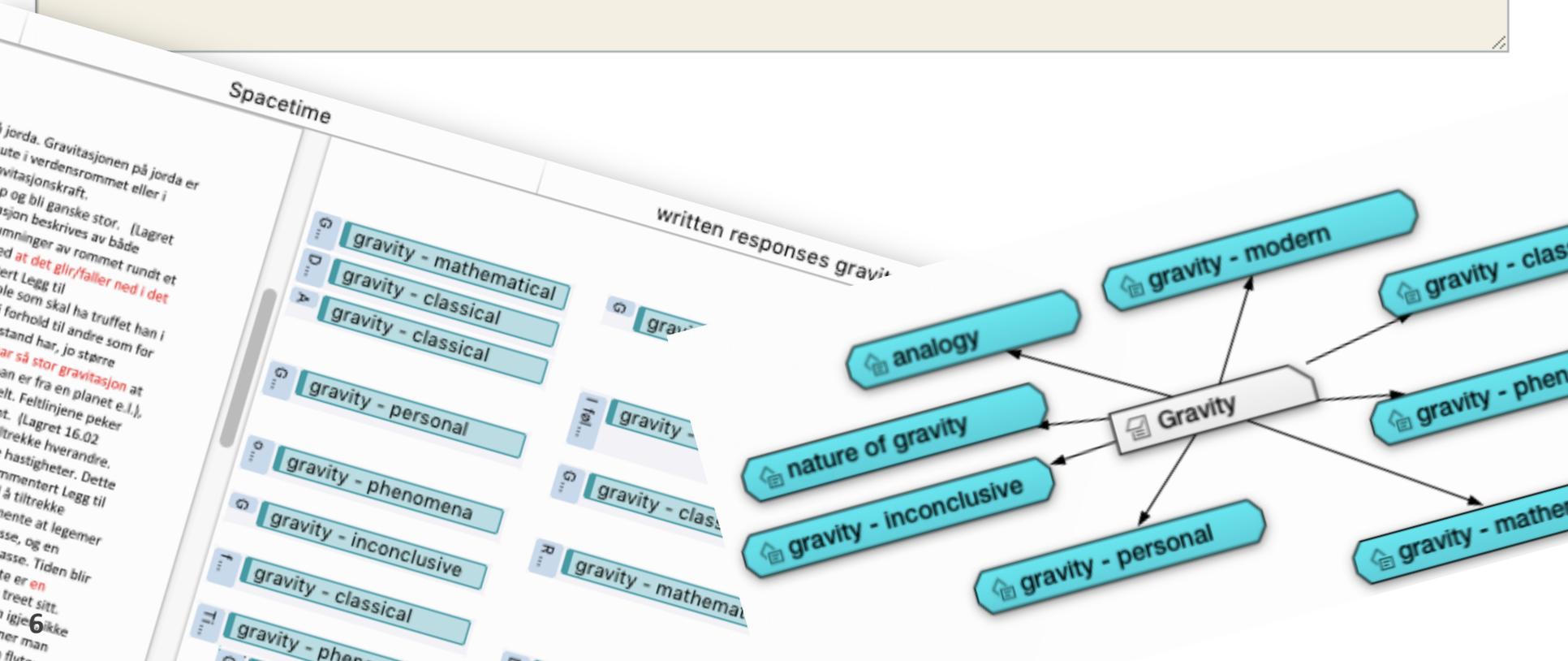
We employed thematic analysis to identify patterns in students' understanding.



Written exercise

What do you know about gravity?

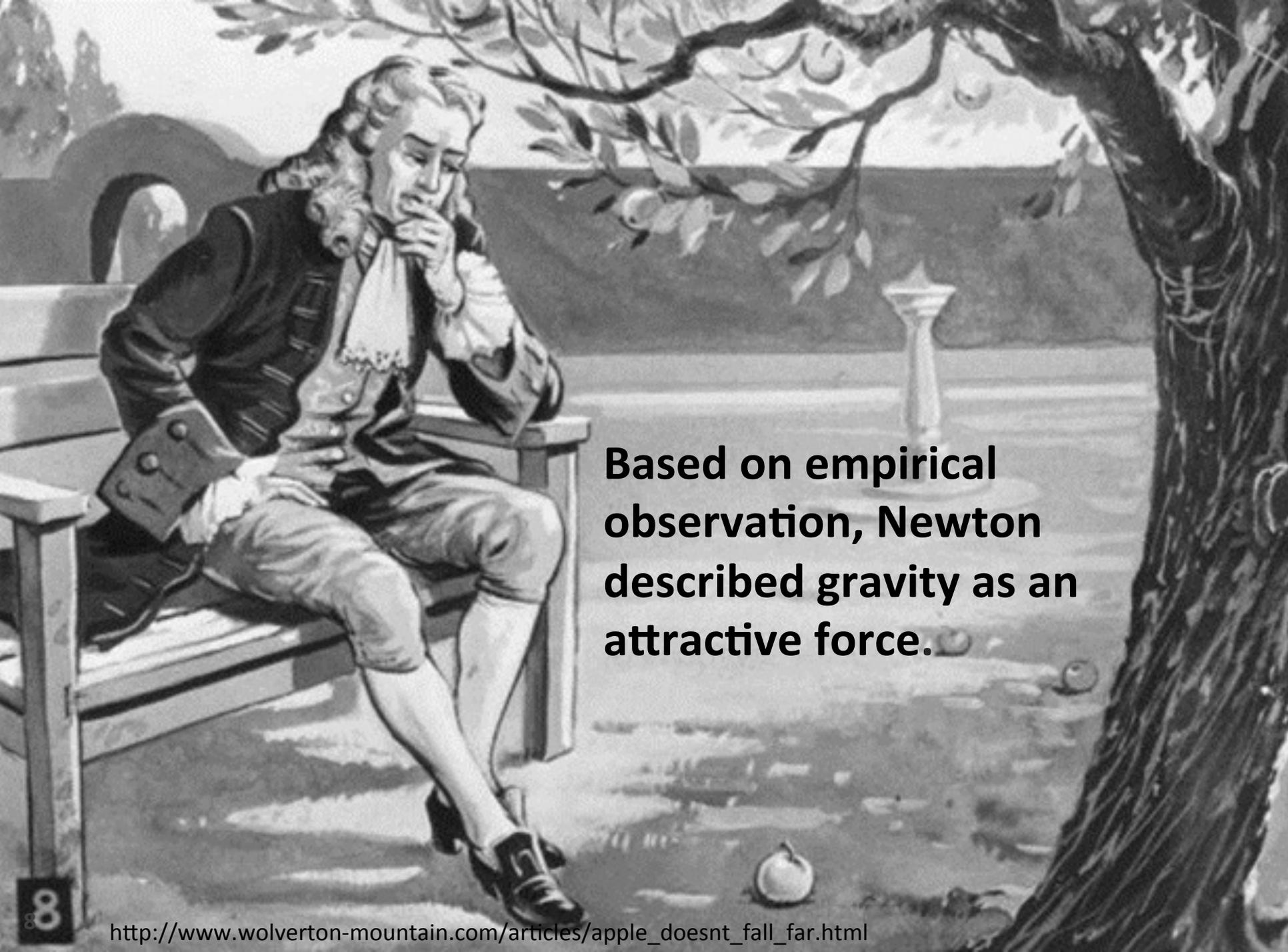
Du må være innlogget som elev for å skrive inn/lagre svar.



Initially, students drew on a big range of ideas when explaining gravity.

*"The gravitational force (G) here on earth is
Just recently it was shown that gravity creates
gravitational waves. This can explain the fact that light
gets bent by objects with big mass".*



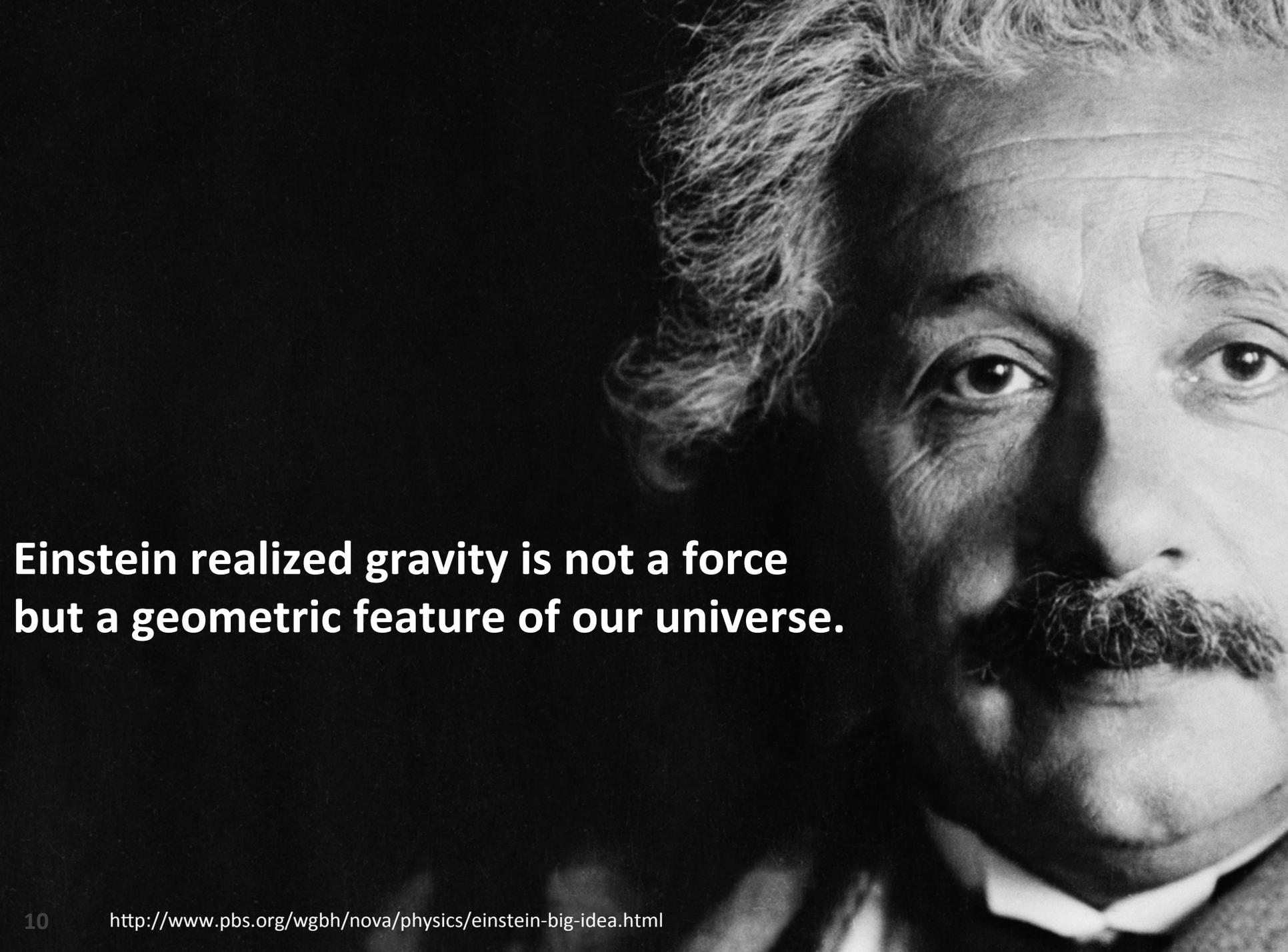


Based on empirical observation, Newton described gravity as an attractive force.

$$F = G \frac{m_1 m_2}{r^2}$$

Mathematics is a convenient language to express Newton's law of gravity.



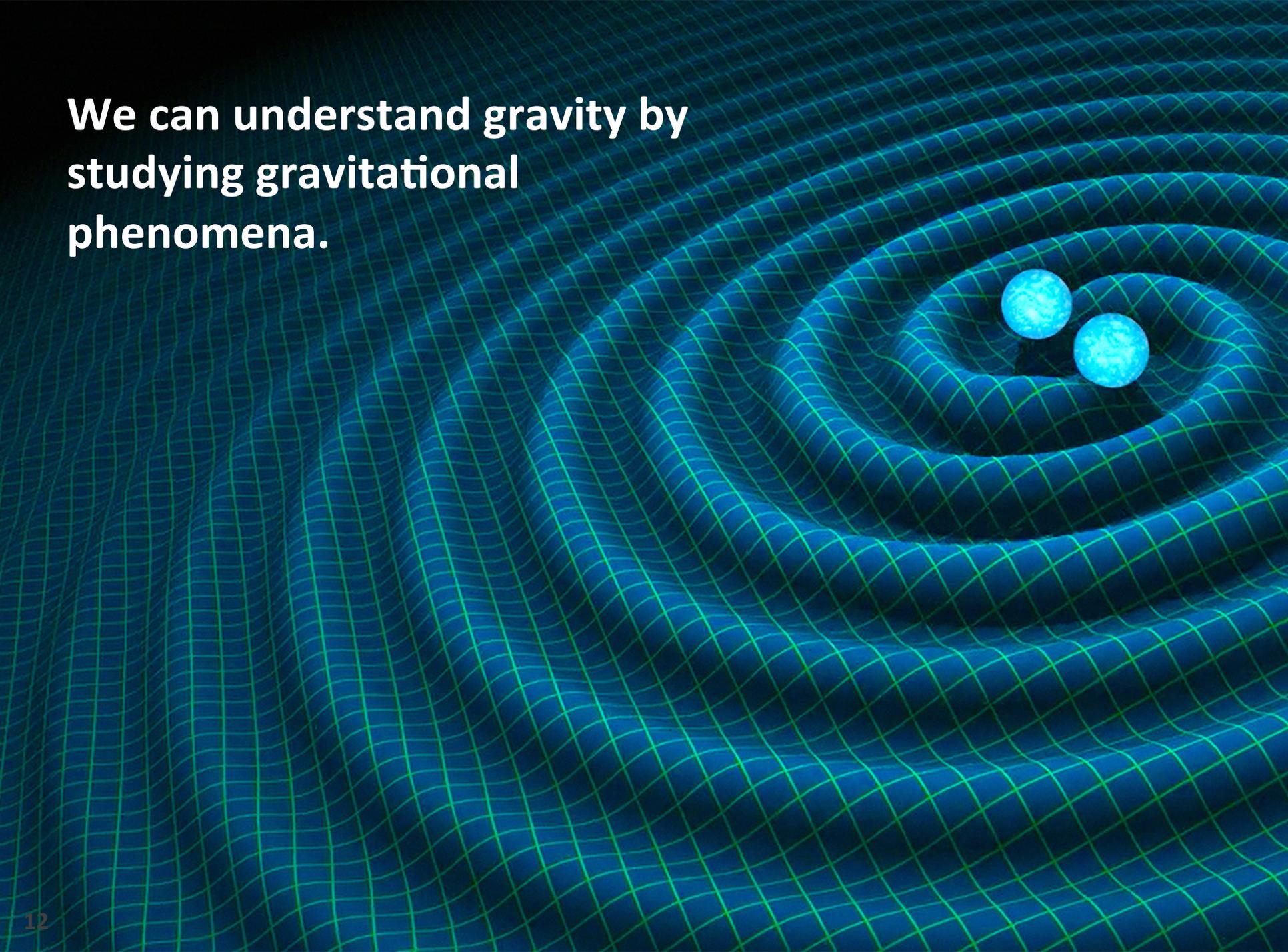


**Einstein realized gravity is not a force
but a geometric feature of our universe.**

**We experience gravity in our
everyday life.**



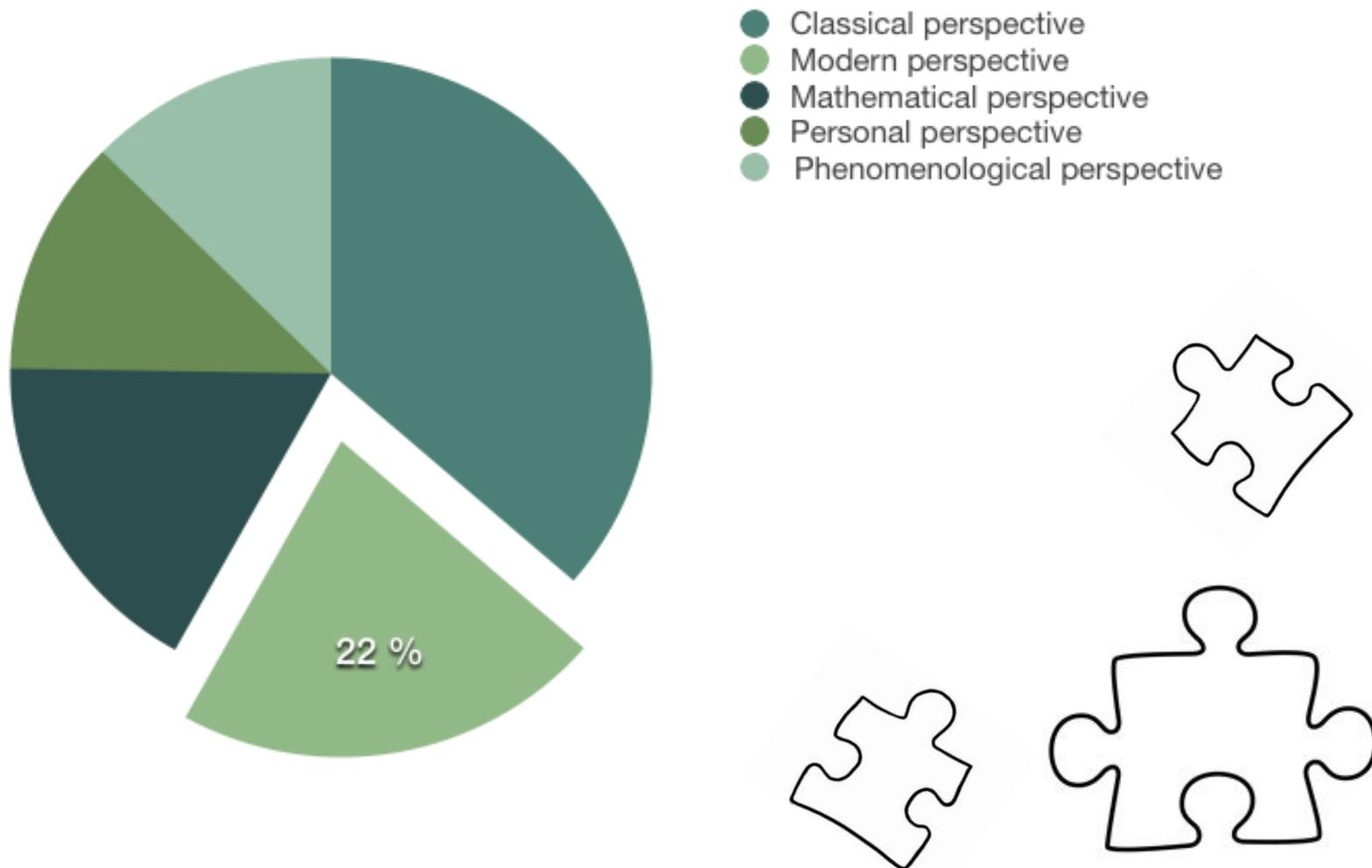
We can understand gravity by studying gravitational phenomena.



**Can we ever really know what
gravity is?**



Often, students expressed several perspectives and tried to connect different descriptions of gravity.



Video observations help us to study the actual use of our program in real class room settings.



Interaction analysis allows us to study how learning of general relativity becomes visible in social interaction.

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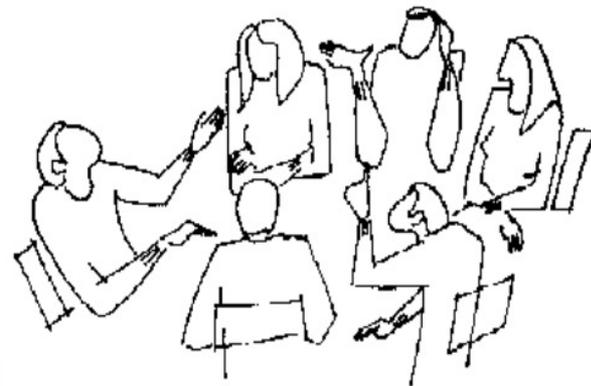
Interaction Analysis: Foundations and Practice

Brigitte Jordan and Austin Henderson
*Institute for Research on Learning and
Xerox Palo Alto Research Center*

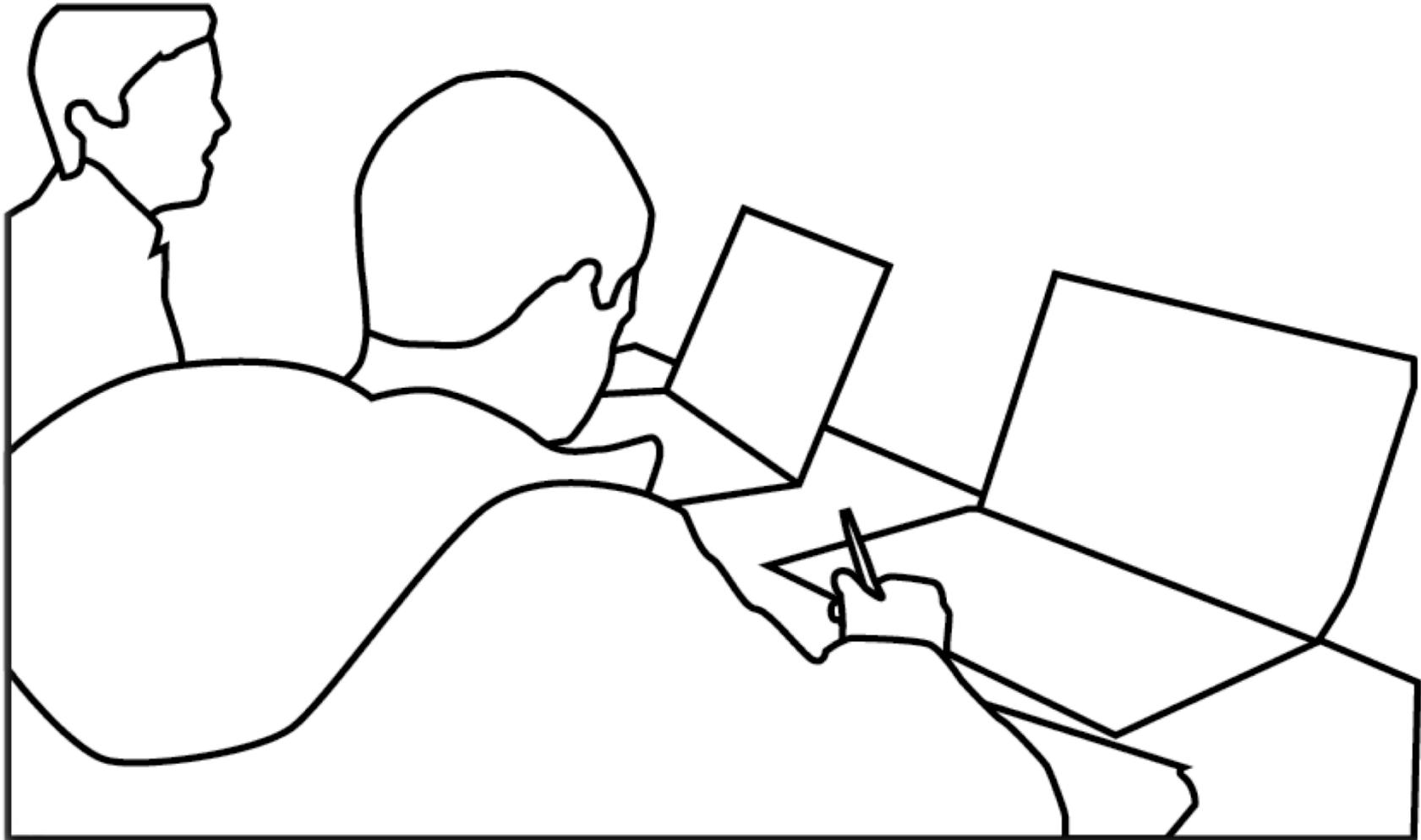
BACKGROUND AND PREMISES

Interaction Analysis¹

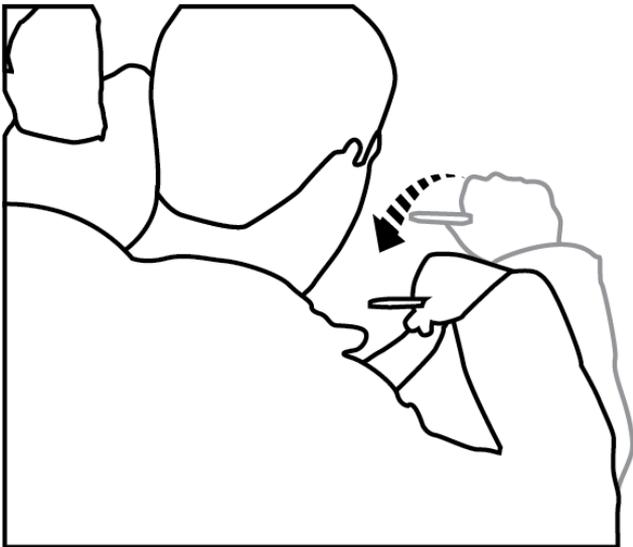
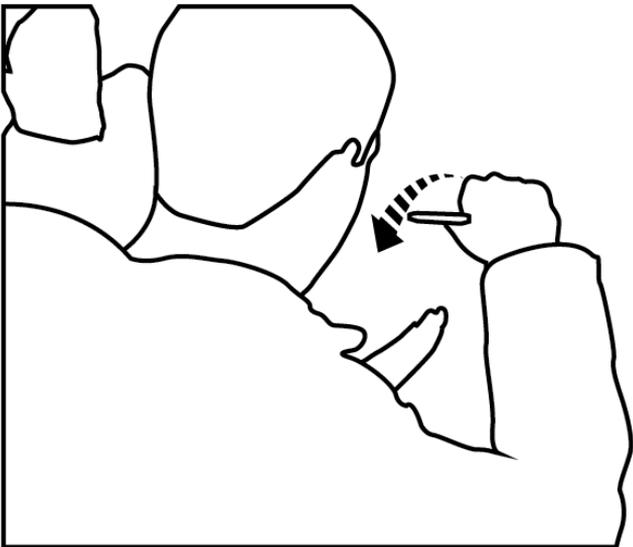
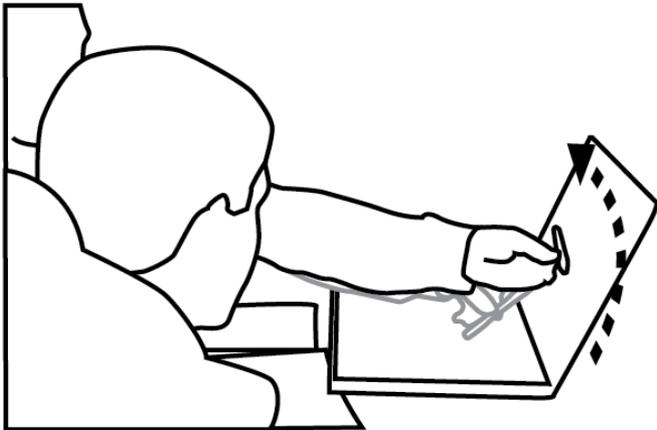
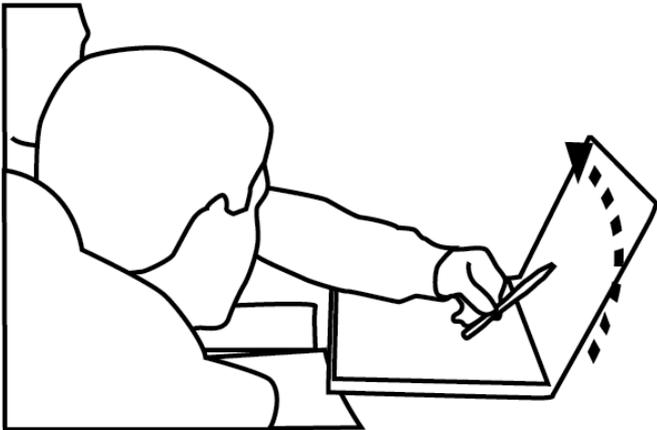
Interaction Analysis as we describe it here is an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment. It investigates human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution. Its roots lie in ethnography (especially participant observation), socio-ethnomethodology, conversation analysis, kinesics, proxemics,



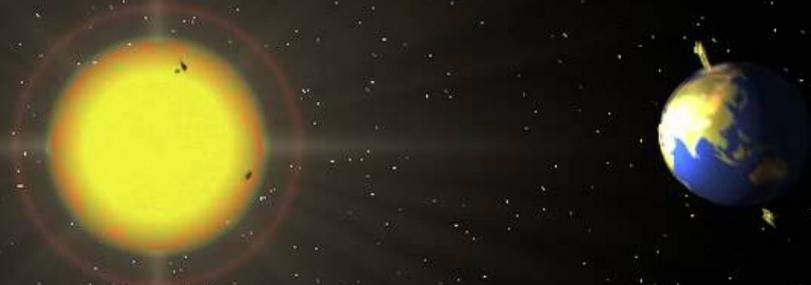
Students face conceptual challenges when trying to make meaning with conflicting notions of gravity, space and time.

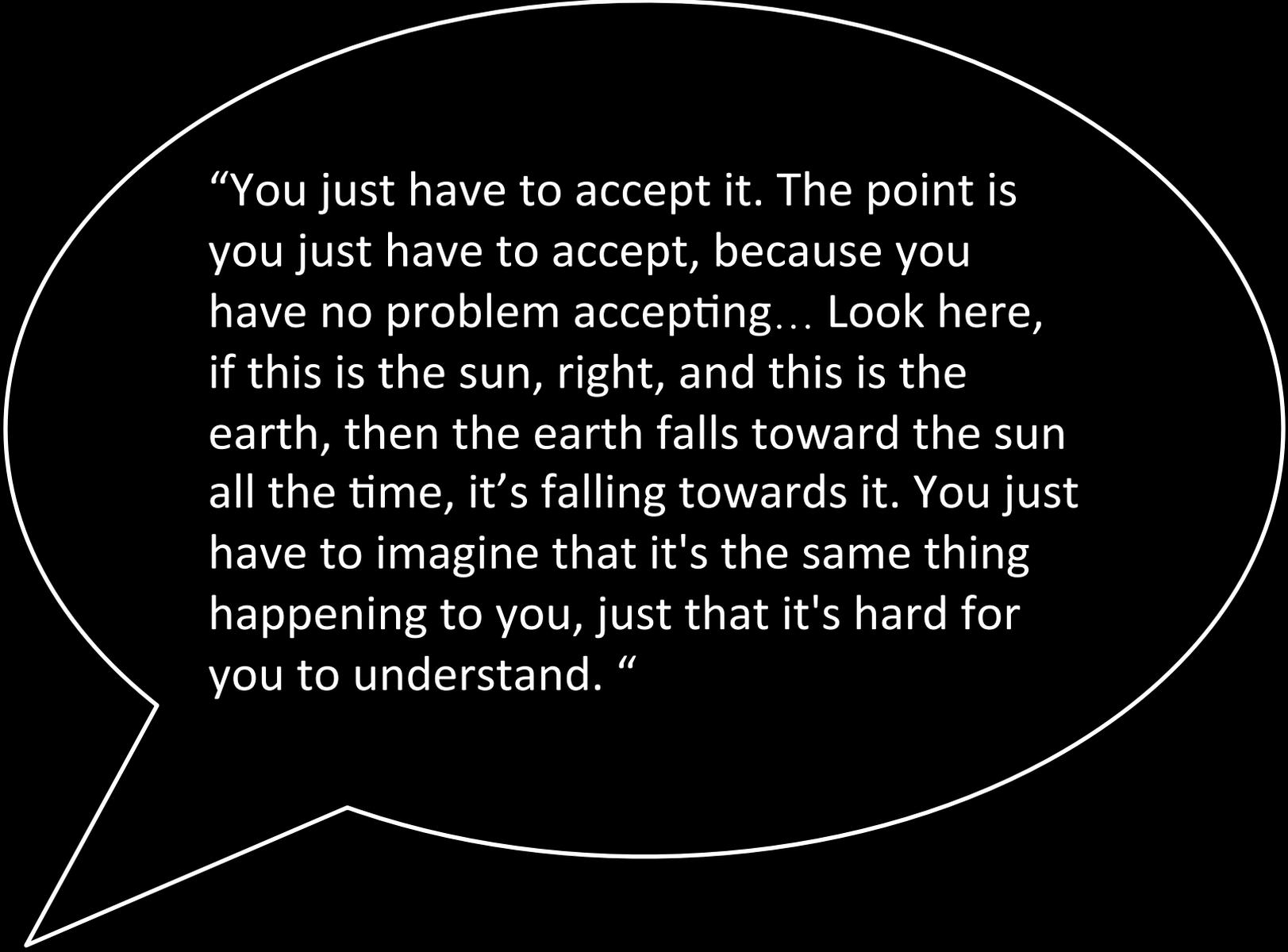


We study the relationship between imagination and embodied meaning making in the setting of gravitation.

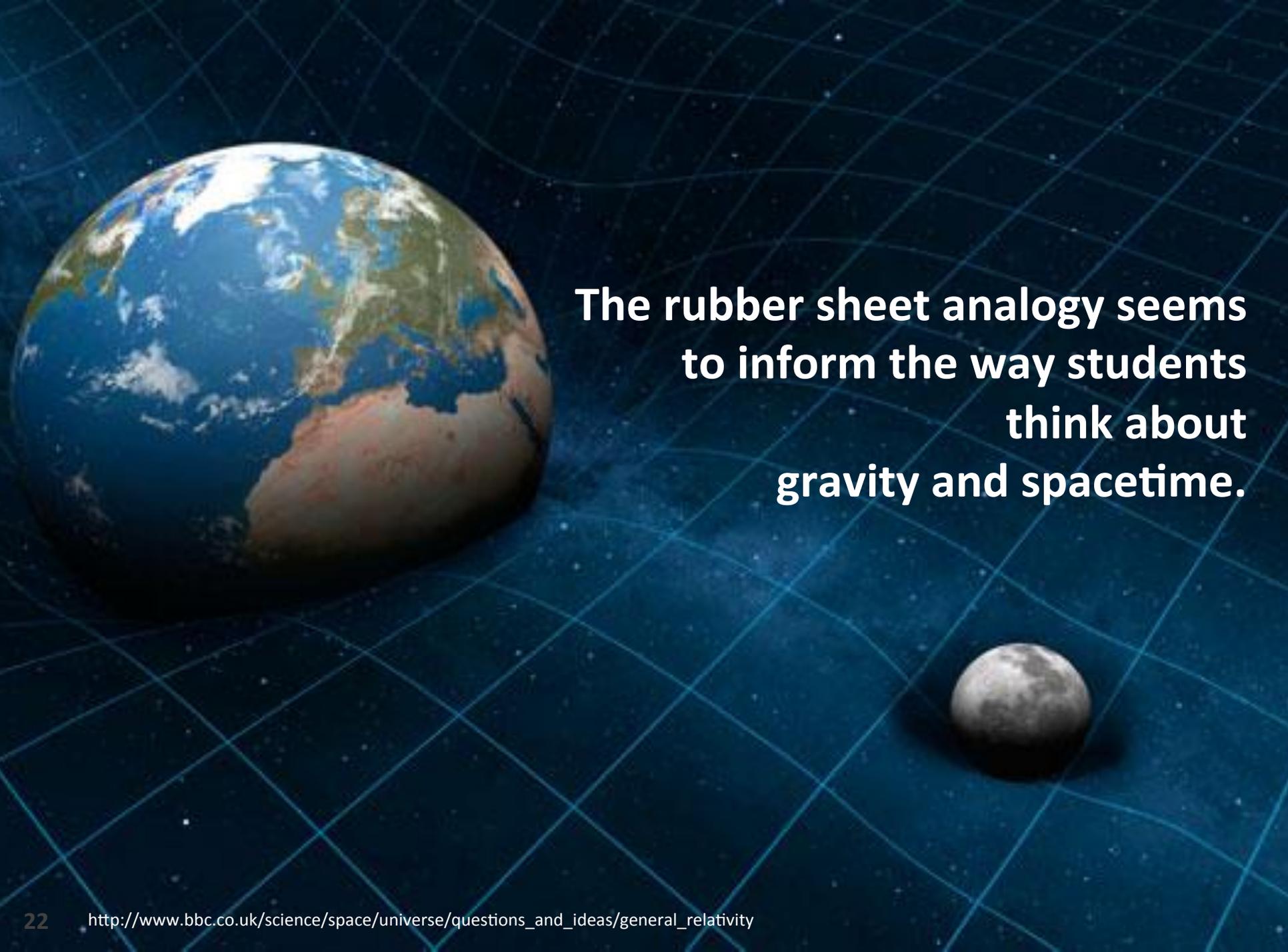


Students found it hard to relate Einstein's abstract description to their everyday experience of gravity.

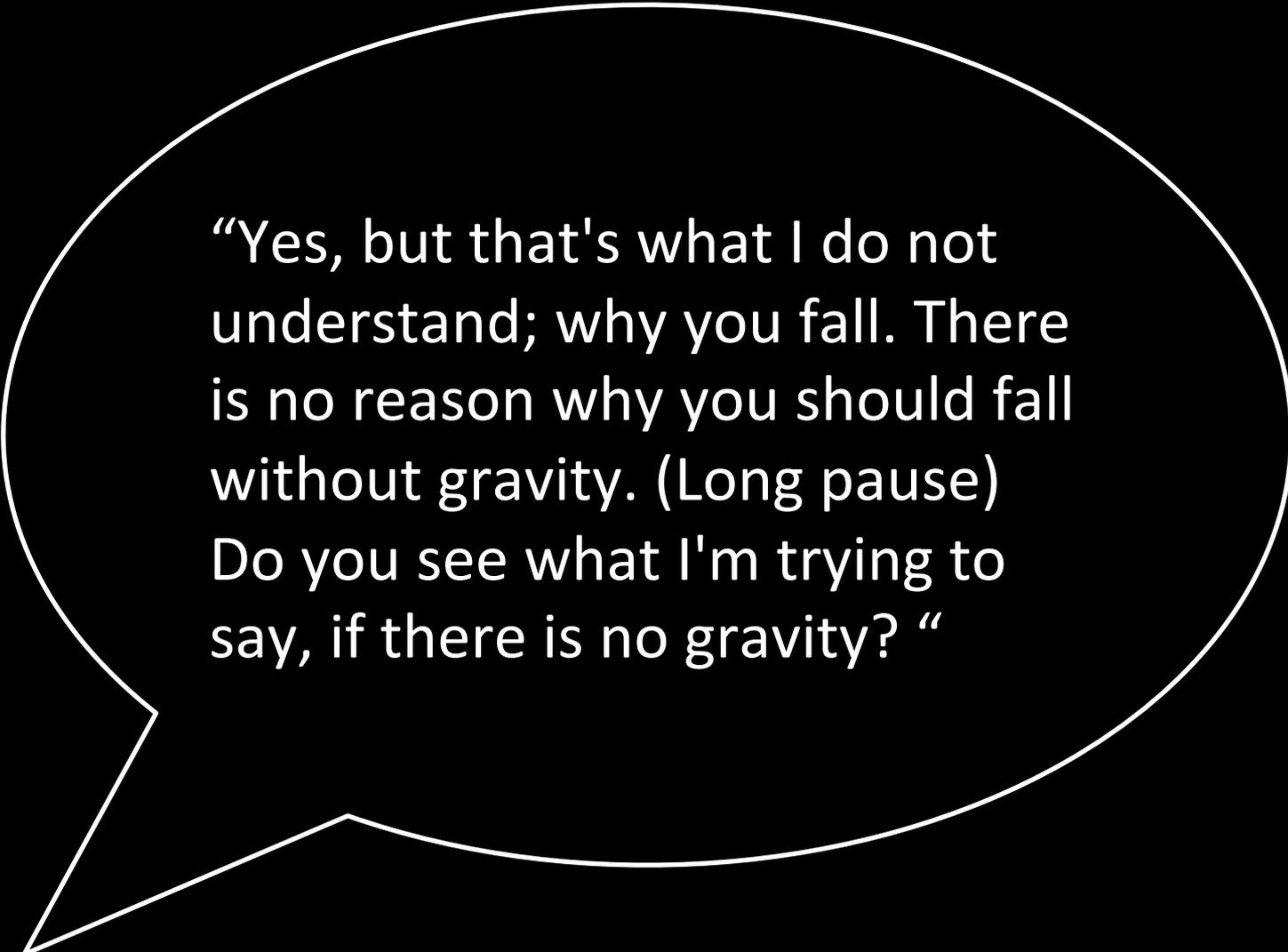




“You just have to accept it. The point is you just have to accept, because you have no problem accepting... Look here, if this is the sun, right, and this is the earth, then the earth falls toward the sun all the time, it’s falling towards it. You just have to imagine that it's the same thing happening to you, just that it's hard for you to understand. “

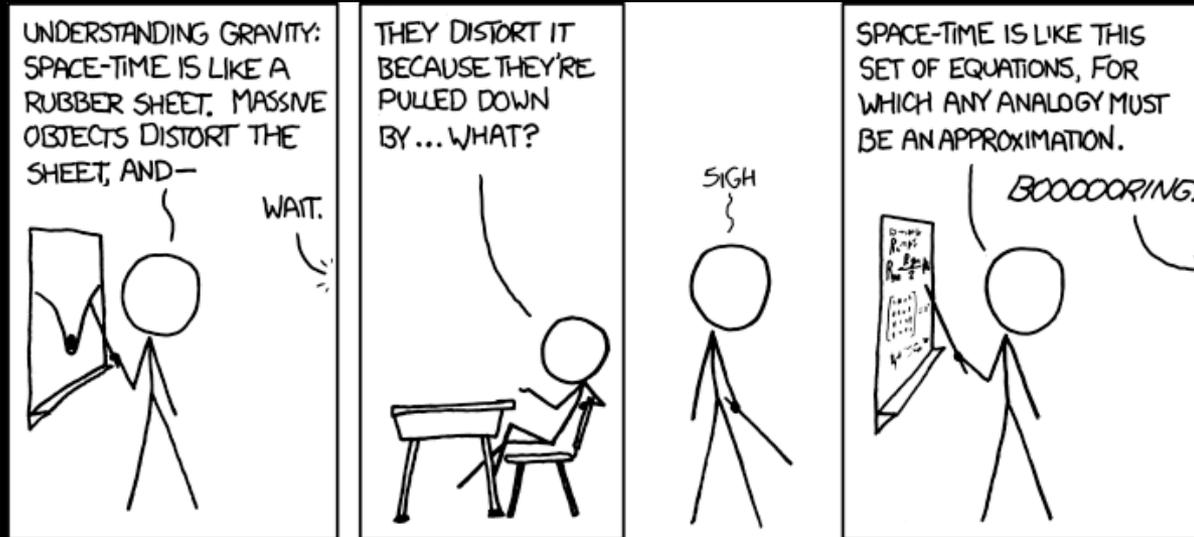


The rubber sheet analogy seems to inform the way students think about gravity and spacetime.



“Yes, but that's what I do not understand; why you fall. There is no reason why you should fall without gravity. (Long pause) Do you see what I'm trying to say, if there is no gravity? “

The rubber sheet analogy relies on gravity to explain gravity.



xkcd.com

To facilitate learning, we should be explicit about drawbacks of analogies. In particular, we should make clear that we are traveling both in time and space.

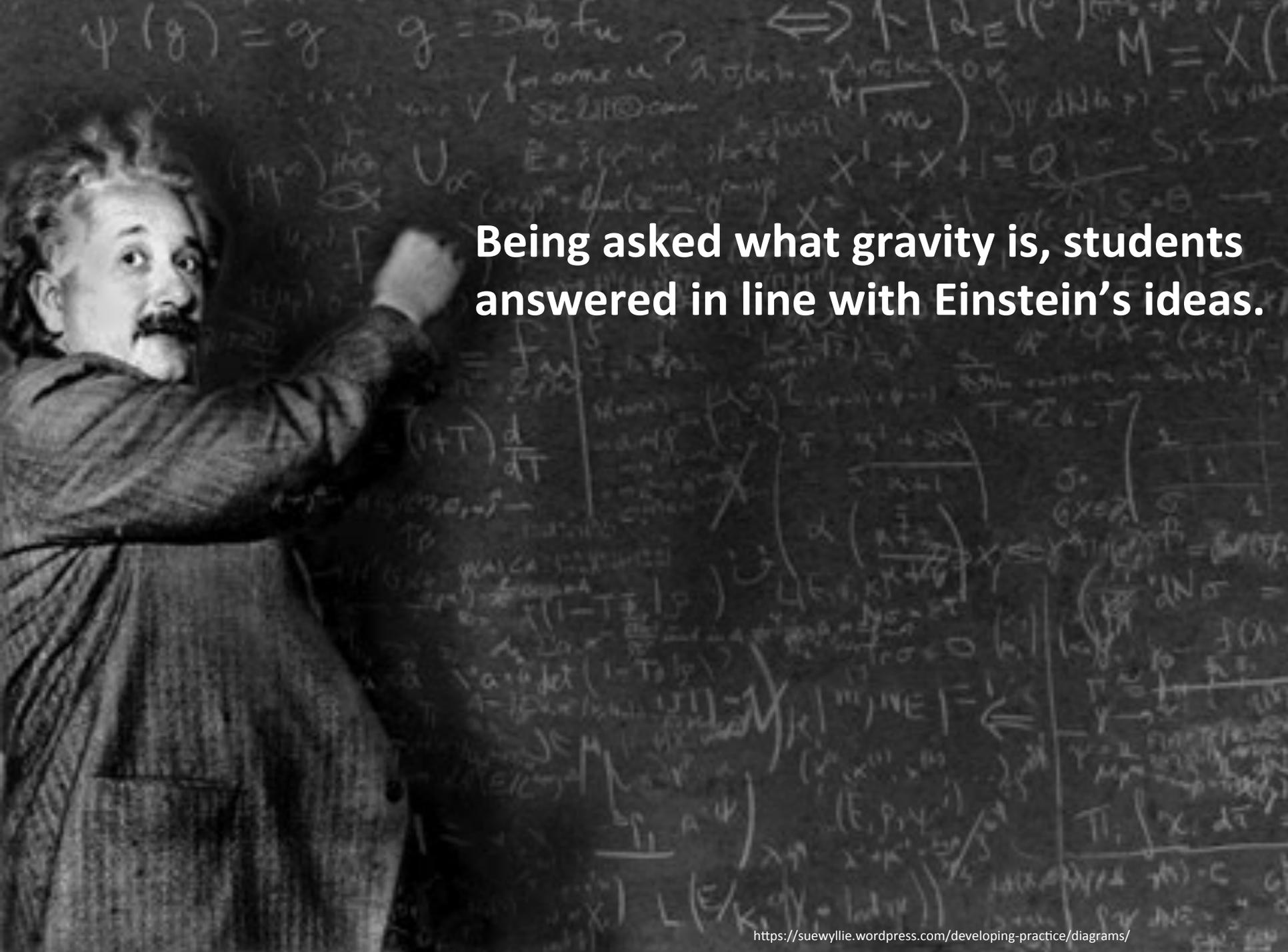


We conducted focus group interviews to contrast our observations with students' own perspectives.



Focus group interviews foster interaction between students and reveal their ideas and opinions.





Being asked what gravity is, students answered in line with Einstein's ideas.



Is Newton's theory wrong?

Einstein's explanations are perceived as far away from real life.



“It is very exciting, because you can look at spacetime which curves if there is mass around. But it is... you can imagine this in your head, but then you think that you are in there, you are on earth, you are like in a little well. Then it gets complicated again to imagine it. Because if you take a look around, you see the universe. You don't think about being in a well, which is very complicated. “

Students relied on the rubber sheet analogy to talk about the idea of curved spacetime.



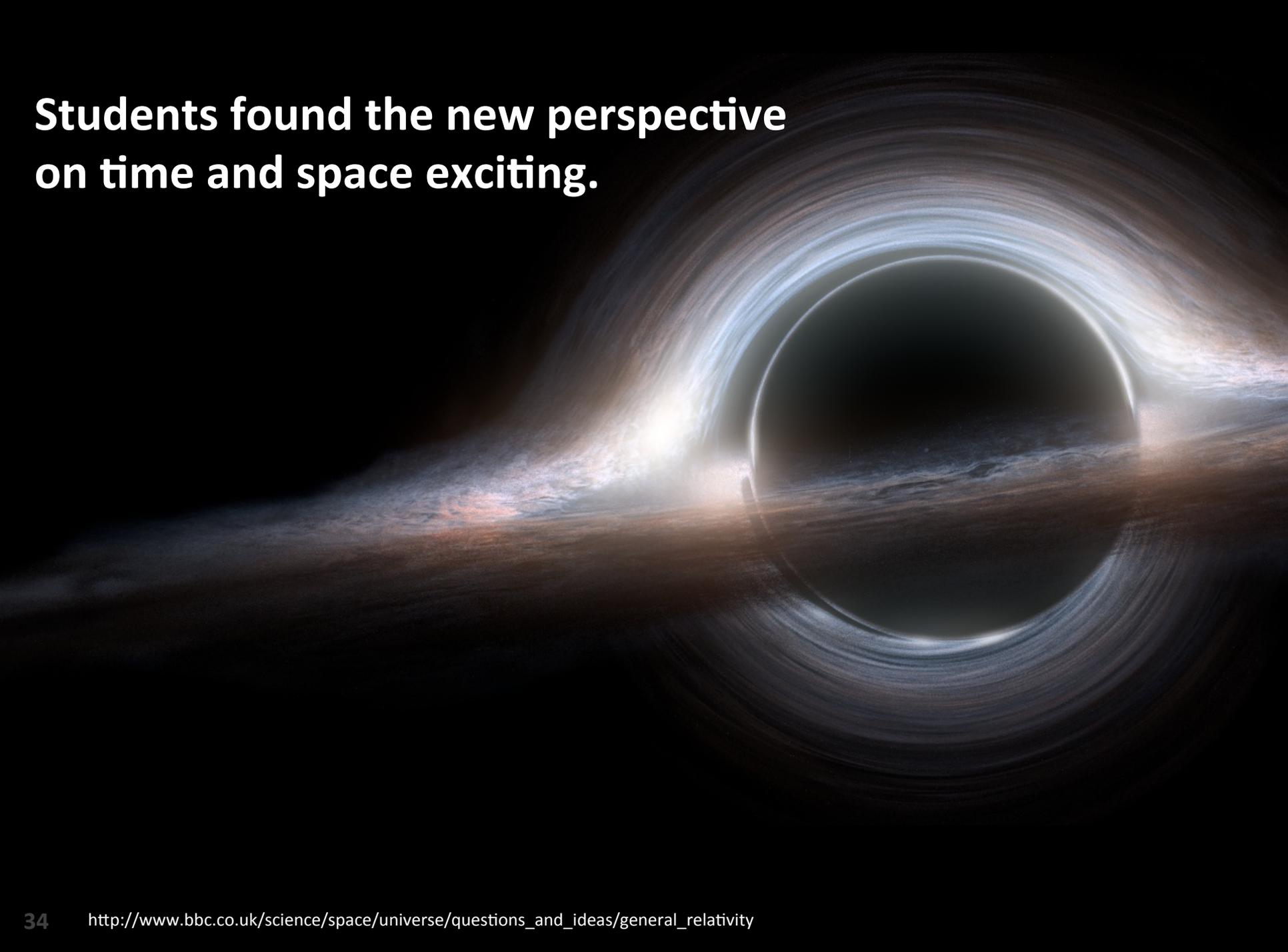
“What is gravity?”

“Yes, if you think of spacetime, then it gets much easier to understand it. “

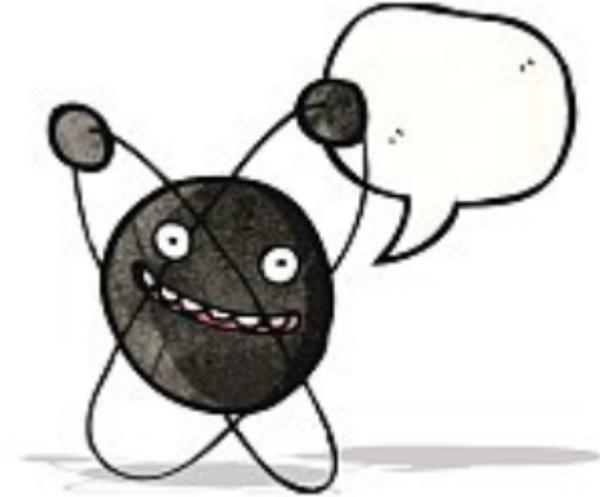
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“Hmm, the only problem I have with the trampoline is that it requires a gravity (laughs) to make the model work as well. This is what makes it difficult for me, because there is no curvature in space without a gravity that makes a well.”

**Students found the new perspective
on time and space exciting.**



“I feel that Einstein brings mass somehow to life. Mass acts like this and I think this is interesting. I think it is cool, because Newton was like *‘mass is like this’*, but Einstein tried to explain what mass really *thinks*.”



We need to build bridges between scientific and everyday thinking.





In our program, we present two complementary perspectives on the nature of gravity.



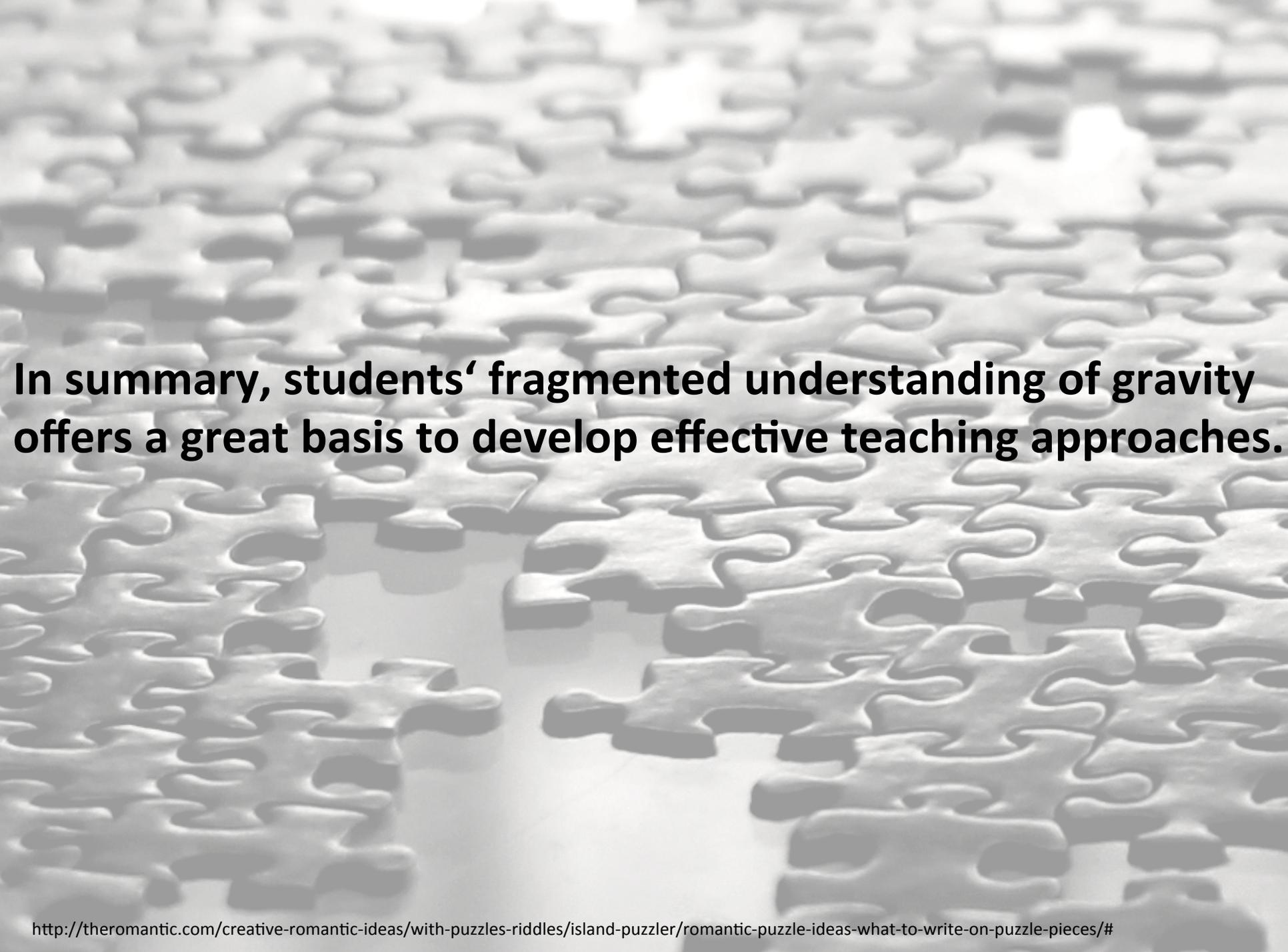
**Locally, acceleration and gravity
are two equivalent phenomena.**





**«Spacetime tells matter how to
move; matter tells spacetime
how to curve.» -J.A.Wheeler -**





In summary, students' fragmented understanding of gravity offers a great basis to develop effective teaching approaches.

Questions?

WE NEED TO CHANGE SPACE
AND TIME TO MAKE THINGS WORK!

