EXTRAPOLATION OF 3D AND ITS IMPORTANCE FOR TEACHING AND LEARNING PHYSICS AND ASTRONOMY – AN EXAMPLE FROM ASTROPHYSICS

Learning astronomy at higher level can be both exciting and challenging. Entering the discipline of astronomy involves learning the way that astronomers communicate knowledge, using a multitude of disciplinary specific semiotic recourses to understand the multidimensional universe. A new-to-the-discipline student will need to learn to "read" and "write" all these resources in her endeavour to learn astronomy and become part of the discipline. In this paper, we present a study where university students and professors are presented by different 2D and pseudo-3D resources—representations of astronomical objects—and asked about how these objects may look in 3D, i.e. we ask them to extrapolate three-dimensionality from 2D inputs. These inputs are 2D pictorial representation and world-class 3D rotating volumetric models presented on flat screens. Data were collected using a web-based questionnaire from 53 participants in four different countries. From the results, we find that all participants struggle to find cues for depth perception in the 2D pictorial representations. As could be expected, the student participants were much worse in doing so than the astronomers, but with one exception: students used the offered motion parallax as their main cue when this was available. The astronomers used many cues in their struggle to perceive depth but surprisingly did not use the presented parallax motion to a large extent. We interpret this as follows: for the students, they lack the knowledge to use disciplinary cues and used the only cue that they know from experience, namely, parallax motion. For the astronomers, they used a multitude of disciplinary cues based on their extensive disciplinary knowledge, and did not find the new cue, motion parallax, as useful as the ones that they were used to use. In this paper, we present and discuss these results and its implication for teaching astronomy.

Keywords: *Astronomy education, visualization and representation*, *Higher Education*

INTRODUCTION AND BACKGROUND

When entering the discipline of physics, and in particular astronomy, students are faced with a multitude of challenges. Not only do they need to learn to "read" and "write" the "language of the discipline", crated by all the semiotic systems and resources (representations, tools, and activities) used by the discipline and having distinct disciplinary affordances, but also to learn to think spatially, or extrapolate three-dimensionality from 1D and 2D input, e.g. mathematics, diagrams, images, etc. (Eriksson, Linder, Airey, & Redfors, 2014). Although identified as very important (see, for example, Cole, Cohen, Wilhelm, & Lindell, 2018; Hegarty, 2014; Lindgren & Schwartz, 2009; National Research Council, 2006; Plummer, 2014; Uttal & Cohen, 2012), extrapolating three-dimensionality is a severely overlooked competency in both physics and astronomy education and poses a real challenge to novice students in their meaning-making; they are often left by themselves to try to imagine what an astronomical object may look like in 3D. In their attempt in doing so, several different cues can be used but many are useless when it comes to astronomical images, and many also build on prior experiences and disciplinary knowledge in astrophysics, which students generally lack when being new-to-the-discipline. Furthermore, from the physics and astronomy education research literature, only few other efforts have been carried out to address the challenges associated with extrapolating three-dimensionality in astronomy education (eg. Heyer, Slater, & Slater, 2013). Hence, extrapolating three-dimensionality becomes an important educational aspect to consider when teaching physics and astronomy. In this paper, we investigate astronomy students' and professors' perception of depth and what cues they use and rely on in the process of extrapolating three-dimensionality.

AIM AND METHOD

In this paper we report on an international study where discernment of the third dimension, depth, in astronomical 2D imagery and psudo-3D simulations, created by Wolfgang Steffen and collaborators

(Steffen, Koning, Wenger, Morisset, & Magnor, 2007). We have chosen to focus on astronomical nebulae, as these are very common in astronomy textbooks/educational materials and teaching contexts in astronomy and astrophysics. In this qualitative study, 53 astronomy students and professors from four different countries have been asked about their discernment of depth from both astronomical 2D images and pseudo-3D simulations with the aim of mapping their competency in mentally extrapolating three-dimensionality. In analysing their responses, we used a standard qualitative research method taking as our point-of-departure Eriksson et al. (2014) hierarchical categories for multidimensionality discernment.

RESULTS

Our results suggest that the competency to discern depth in astronomical image/simulation is very limited by new-to-the-discipline students but also that psudo-3D simulations, where motion parallax is offered, could help students in their meaning-making and extrapolation of three-dimensionality in their minds. For the professional astronomers we found that, regardless of parallax motion being offered, they very often fall back on the methods they have used earlier on when analysing and trying to make sense of 2D images of nebulae—shadows overlapping objects, subtended visual angle of objects of known size, haze, contrast, etc.—instead of using and exploring the possibilities the simulations offered. We interpret this evidence as follows: for the astronomers, the new information on the 3D structure from the simulations does not offer as much new information as might be expected; for the students, parallax motion is the key to discernment of depth.

DISCUSSION AND CONCLUSION

Our results clearly show that discernment of depth from nebulae imagery is extremely difficult for students but also for many astronomers. However, using modern software and astronomical data, volumetric models can be created offering possibilities for discernment of depth by using parallax motion. This could potentially be used when teaching astrophysics for both university students and upper secondary school students, lacking relevant disciplinary knowledge, since the students are, by default, used to using parallax motion as a cue for estimating depth of an (unknown) object.

Further findings and implications in regards to these will be discussed at the conference.

REFERENCES

Cole, M., Cohen, C., Wilhelm, J., & Lindell, R. (2018). Spatial thinking in astronomy education research. *Physical Review Physics Education Research, 14*(1), 010139. doi:10.1103/PhysRevPhysEducRes.14.010139

Eriksson, U., Linder, C., Airey, J., & Redfors, A. (2014). Who needs 3D when the Universe is flat? *Science Education, 98*(3), 31.

Hegarty, M. (2014). Spatial Thinking in Undergraduate Science Education. *Spatial Cognition and Computation*.

Heyer, I., Slater, S., & Slater, T. (2013). Establishing the empirical relationship between non-science majoring undergraduate learners' spatial thinking skills and their conceptual astronomy knowledge. *Revista Latino-Americana de Educação em Astronomia - RELEA*(16), 45-61.

Lindgren, R., & Schwartz, D. L. (2009). Spatial Learning and Computer Simulations in Science. *International Journal of Science Education, 31*(3), 419-438. doi:10.1080/09500690802595813

National Research Council. (2006). *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*: The National Academies Press.

Plummer, J. D. (2014). Spatial thinking as the dimension of progress in an astronomy learning progression. *Studies in Science Education*, 1-45. doi:10.1080/03057267.2013.869039

Steffen, W., Koning, N., Wenger, S., Morisset, C., & Magnor, M. (2007). Shape: A 3D modeling tool for astrophysics. *IEEE Transactions on Visualization and Computer Graphics, 17*(4), 454-465.

Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why and how. *Psychology of learning and motivation, 57*, 147--181.