Contributed Talk
Splinter AED

Learning from Contradictions

S. Brackertz[1], A. Schulz[1]

[1] *Universität zu Köln, Institut für Physik und ihre Didaktik*

In the School Laboratory of the University of Cologne student teachers supervise small groups of pupils of the grades 5 to 10. They mainly work on extra-curricular topics like the search for exoplanets many of which are thought to be too difficult for this age.

In this setting certain challenges of teaching play a particularly important role: A culture of accurate qualitative argumentation and constructivistic theory development in the unity of word and (thought) experiments has shown to be a key to teach topics which are commonly thought to be too difficult. But pupils as well as students are usually not familiar with this culture. Additionally the pupils prior knowledge of extra-curricular topics is particularly heterogeneous, often only partly correct and also unknown by the students.

As the students are very differently familiar with this kind of approaches in the beginning of their collaboration in the School Lab the question arises which ideas and impulses are valuable to systematically support the students development in this context. Propagating a systematical work with contradictions has proven to be very useful as carving-out contradictions instead of smoothening them out which is very common among student teachers, this fulfills three different functions: First, contradictions are challenges to enter into dialogue with the world, especially with phenomena of nature and with the interests of the rest of the group. They invite to link different approaches to the same topic. Second, misconceptions often manifest as contradicting estimations (for example the prediction of the result of an experiment) of the different group members and the contradicting estimations can be used as a useful starting point to jointly construct a consistent theory. Third, explicitly mentioned contradictions enable the supervising students to quickly asses previous knowledge as well as the interests of the pupils.

This talk presents the systematic work with contradictions by means of the astrophysics project of the Cologne School Lab.

Contributed Talk
Splinter AED

A demonstration of the usefulness of the similarity theory in model the example of a cloud model

L. Bzduskova[1]

[1] *University of Siegen, Department of Physics, Observatory*

The concept of similarity is known from the field of geometry.Wherever certain lengths ratio of geometric bodies are linked those geometric bodies are similar; and transfer rules between those bodies can be found. However, the physical similarity role requires as even then, that power relations in the model and the original match. This is expressed by so-called dimensionless numbers. The similarity theory can be useful for construction of physical models for students. It allows us to assess whether a physical model can be realized. The application of this theory will be demonstrated with an example of a cloud model.

Contributed Talk

Students Photographed Objects Ranging from a Dancing School to the End of the Visible World

Hans-Otto Carmesin[1,2,3]

[1] *Gymnasium Athenaeum Stade, Harsefelder Str. 40, 21680 Stade*
[2] *Studienseminar Stade, Bahnhofstr. 5, 21682 Stade*
[3] *University Bremen, 28334 Bremen*

The *goal* of this project was that students of an astronomy club obtain an overview of the visible universe on the basis of their own photos. These students ranging from class 5 to 12 used the school observatory. The equipment includes the 11 inch telescope Celestron type C11, the camera SBIG type ST-402 and the camera Canon type EOS 1000D.

The *visibility* is limited by the maximum light-travel distance. That is the length of the path that light can have travelled since the Big Bang 14 billion years ago[1]. The most distant object photographed by the students is the galaxy APM 08279+5255 discovered in 1998 and situated at 88 % of the maximum light-travel distance of 14 billion light years.

The photos show various objects the locations of which fall into *four categories*: Earth and orbits around it, orbits around the sun, orbits around the center of the Milky Way and extragalactic locations. Each category stretches out over roughly 6 orders of magnitude.

Thus an *ideal of education* as formulated by Humboldt in 1792 was achieved: Education is the stimulation of all potencies of humans, so that these can develop by the exploration of the world in a harmonic manner and resulting in a self-determined individuality[2].

Moreover this project might be considered as an example for *inclusion* due to the heterogeneity of the astronomy club and the fact that any student is able to take a photo.

---

[1] Carmesin, Hans-Otto (2012): Schüler beobachten den Urknall mit einem C11-Teleskop. In: PhysDid B (2012), ISSN 2191-379X, D21.03.

[2] Brockhaus GmbH (1996): Brockhaus Die Enzyklopaedie. 20^{nd} ed. vol. 3, p. 330.

Contributed Talk

Students Modelled the Discovery of Gravitational Waves with Computer Experiments Developed by Themselves

Hans-Otto Carmesin[1,2,3]

[1] *Gymnasium Athenaeum Stade, Harsefelder Str. 40, 21680 Stade*
[2] *Studienseminar Stade, Bahnhofstr. 5, 21682 Stade*
[3] *University Bremen, 28334 Bremen*

The *goal* of this project was that students of an astronomy club reproduce the emission and propagation of the gravitational waves discovered this year[1,2]. These students ranging from class 5 to 12 reproduced the above observations with computer experiments.

The *modelling* was established progressively and comprehensively at four levels. At the basic level, the students constructed trajectories on squared paper. This construction is in accordance with a discretized version of Newton's axioms. With this method, a formula 1 game and a basketball trajectory game as well as planetary orbit simulations were performed. At a second level, the students determined trajectories using Excel or Java programs. With these tools, they simulated orbits according to the Schwarzschild metric and general relativity dynamics. On this basis, they modelled the perihelion precession, the relativistic deflection of light as well as the spiral trajectories typical for the coalescence of binary black holes. At a third level, the students derived the Schwarzschild metric in a simple and exact manner[3]. Moreover, they discovered equations for the propagation of light in curved space by using Huygens' principle in a new way. On this basis, they established equations for massive particle trajectories. At a fourth level, the students derived formulae for spiral trajectories as well as for the emission and propagation of gravitational waves[4].

[1] B. P. Abbott et al. (2016): Observation of Gravitational Waves from a Binary Black Hole Merger. Physical Review Letters, 116, 061102-1-16.

[2] B. P. Abbott et al. (2016): Observation of Gravitational Waves from a 22-Sun-Mass Binary Black Hole Coalescence. Physical Review Letters, 116, 241103-1-14.

[3] Carmesin, H.-O. (2012): Schüler entdecken die Einstein-Geometrie mit dem Beschleunigungssensor. PhyDid B, 2012, ISSN 2191-379-DD15p06.

Contributed Talk

Students Discovered the Curvature of Space: They Photographed a Gravitational Lens and Explained it

Hans-Otto Carmesin[1,2,3]

[1] *Gymnasium Athenaeum Stade, Harsefelder Str. 40, 21680 Stade*
[2] *Studienseminar Stade, Bahnhofstr. 5, 21682 Stade*
[3] *University Bremen, 28334 Bremen*

The *goal* of this project was that students of an astronomy club discover the curvature of space on the basis of their own photo. These students ranging from class 5 to 12 used the school observatory. The equipment includes the 11 inch telescope Celestron type C11 and the camera SBIG type ST-402. Since the telescope is relatively small, a rather bright object with obvious curvature was photographed, namely the twin quasar 0957+561.

The photo shows two seperate pictures of the same galaxy and the corresponding *explanation* was established at four levels. At the basic level, the students performed a computer simulation with a given computer program. With this tool, they discovered the curvature of the path of the light. On this basis, they explained the emergence of multiple pictures of the galaxy. At a second level, the students developed the computer program using the corresponding equations of motion. At a third level, the students derived the Schwarzschild metric in a simple and exact manner[1]. Moreover, they discovered the equations of motion for the propagation of light in curved space using Huygens' principle in a new way. At a fourth level, the students derived formulae for the deflection angle in order to analyze the multiplicity of the pictures.

In summary the students discovered the curvature of space on their own on four levels progressively. I report about the concept and experiences with teaching it.

[1] Carmesin, H.-O. (2012): Schüler entdecken die Einstein-Geometrie mit dem Beschleunigungssensor. PhyDid B, 2012, ISSN 2191-379-DD15p06.

Contributed Talk
Splinter AED

Celestial bodies dominated by gravity

S. Hohmann[1]

[1] *University of Siegen, Departement of Physics, Observatory*

Several studies, e.g. the ROSE study, show increasing interest in physics while astrophysical aspects are treated, so using physical concepts to gain astrophysical knowledge may be helpful to motivate learner. One can achieve many findings about celestial bodies by using simple methods taken out of mechanics, thermodynamics, quantum mechanics and astrophysics. The presentation shows some ways to link those different fields of physics and to estimate the masses and radii of some of the most important celestial bodies dominated by gravity, e.g. white dwarfs, gasplanets and main sequence stars.

Contributed Talk
Splinter AED

PUPILS SEARCHING FOR (HABITABLE) EXOPLANETS AT THE SCHOOL LABORATORY 'UNSER RAUMSCHIFF ERDE'

A. Küpper[1], A. Schulz[1]

[1] *Universität zu Köln, Institut für Physik und ihre Didaktik*

Since 2015, students (from 7th up to 9th grade) undertake searches for extrasolar planets in our Schoollab 'Unser Raumschiff Erde' ('Our Spacecraft Earth') at the University of Cologne with the help of model experiments.

After an e-learning preparational lesson in their school addressing continuous and discrete spectra, the students visit the Schoollab at the University and experience there the transit method searching for exoplanets and explore how the composition of their atmospheres can be determined. For example, students observe the spectral lines (Fraunhofer lines) of the sun with a spectroscope constructed by themselves and then draw conclusions about which gases can be found in the stars or planets atmospheres. Furthermore, at their visit in the Schoollab the students obtain information about the habitable zone around a star (applying Wiens law and under consideration of the greenhouse effect and the atmospheric pressure) as well as possible problems with invisible parts of the spectrum, for example the ultraviolet or stellar winds.

After establishing the chosen astronomical contexts, some of the developed experimental settings are explained in the talk. In conclusion, some of the gained experiences and resulting consequences of the Schoollab visits are discussed.

Contributed Talk
Splinter AED

Das Lichtermeer der Sterne - Erlebe und erforsche es!

I. Militschenko[1], W. Winnenburg[1]

[1] *Universität Siegen*

Am Anfang dessen, was wir heute als exakte Naturwissenschaft bezeichnen, stand und steht die visuelle Astronomie, genauer die originäre Erlebnisastronomie. Das stumme Verfolgen und auf sich einwirken lassen z. B. des Sternenhimmels weckt die menschliche Neugier, das Beobachtete zu verstehen.
Primäres Ziel an der Universitätssternwarte Siegen für Einsteiger in die Astronomie ist daher im zweiten Schritt die Fortführung und Förderung der genuinen Neugier an naturwissenschaftlichen Phänomenen und Prozessen durch aktives Lernen, Forschen und Entdecken. Fachspezifische Schwerpunkte sind geozentrische Himmelskugel, Anzahl, Helligkeit, Farbe, Bewegung sowie Parkettierung vom Beobachter wahrgenommener Sterne.

Contributed Talk
Splinter AED

Design of a didactic model for spatial analysis of the influence of the sun over the landscape

M. Zuleta[1], V. Heck[2]

[1] *Fac.Ciencias Sociales y Humanas-Universidad de Antioquia, Colombia*
[2] *University of Siegen, Department of Physics and Geography*

One of the main objectives in both primary and secondary education is to recognize the local environment and natural resources in order to strengthen in students an awareness of sustainable environmental care. One of the great challenges is to design educational models that allow students a comprehensive understanding of the dynamics of natural processes occurring in the environment, one of those dynamics and function of the incidence of solar energy over the landscape. The geographic and cartographic methods applied by manual generation of landscape relief models and simulation of the path of sunlight on it in the course of a year, offer a methodological and didactic help for both, the teacher and the student to achieve this goal. The educational model is designed to strengthen three aspects: student orientation within their local environment it does immediately provide tools for simple simulation in the classroom, offering an easy access to widen the knowledge of geography and astronomy in order to understand the importance of solar energy in the survival and development of communities and understand the dynamics of the trajectory of sunlight on the ground taking into account different latitudinal locations, finally, facilitating spatial analysis by the student, considering dynamics of solar energy over the landscape geo-factors. Therewith a space for reflection on the assessment of solar energy as a source of renewable resources within immediate environment is opened. The design made offers an easy training model to perform in the classroom with students. It achieves goals in recognition and potential of the geographical environment, taking into account methods of geography and astronomy, as well as introduces the student to the use of methods applied spatial analysis.