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# Cosmology

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### Curriculum & classroom connections

Different country have different educational needs and level of development according to science evolution. Yet, many correlating aspects can be found between different country in different continents and it's curriculum. Three continents are being considered in this paper, America, Europe and Asia, being the countries of Brazil, Dominican Republic the representants of America, Bulgaria and Ukraine of Europe and Japan of Asia.
From all these different curriculum we have the following table:

| Continent | Country | Presence of Cosmology in the curriculum | |
|---|---|---|---|
| | | Year of education | Presence of Cosmology |
| America | Brazil | University | Modern Physics course (board range, not focused on Cosmology) |
| | Dominican Republic | | |
| Europe | Bulgaria | VII to XII* | Physics and Astronomy (dedicated courses) - including Cosmology |
| | Ukraine | 3º year of High School | Astronomy (dedicated course) |
| Asia | Japan | University | Cosmology class in Physics course |

*The years VII - XII in Bulgaria correspond students from ages around 11 - 17.

Considering the different curriculums that every country has, there's a apparent compatibility between the japanese, brazilian, bulgarian and dominican republic curriculums. In all these countries, there is no

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dedicated part of the curriculum for Cosmology topics, only a very short time to work all the concepts on the end of the last High School year and in Dominican Republic, the topic is only considered in the university. Therefore, the way to approach the subject would have to be as fast and effective as possible, once the time available won't be more than some hours.

Another option for approaching it, would be spread the different topics relating to contents traditionally already present on the curriculum as the following table possibility:

| Cosmology topics | Cosmology key ideas | Relation between the traditional and the Modern Physics topics |
|---|---|---|
| Universe Evolution | Universe Origin | Thermodynamics |
| | Star and galaxy evolution - Black Holes | Kepler's Law |
| | | Gravitational Force |
| | Inflation of the Universe, Red Shift and telescopes | Optics |
| | Present and end of the universe | Star and Galaxy evolution - Black holes |
| Particles | Cosmic Rays | Nuclear Physics |
| | Atoms fusion | |
| | Photoelectric effect | |
| | Standard model | |
| | Detection Technology | Photoelectric effect |
| Relativity | Special and General Relativity | Galilean Relativity |

The following scheme shows a possibility of how to relate and apply these in the classroom acordingly to the japanese curriculum

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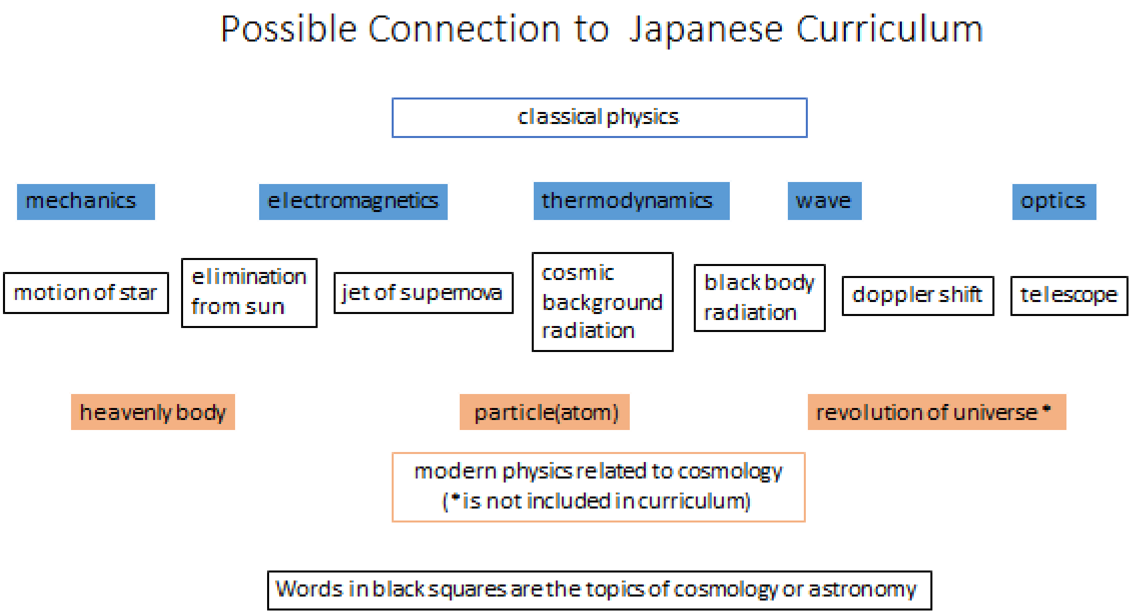


**Key ideas**

In every cosmic phenomenon and process there are manifestations of the fundamental laws of nature. On the basis of astronomical and astrophysical studies, natural and physical and mathematical knowledge is widely disseminated and generalized, principles of knowledge of matter and the universe are formed, the most important scientific generalizations, technical progress and the development of civilization are stimulated. Therefore, the course in Cosmology is an important components of the natural science in High school.
The purpose of the curriculum is the formation of general cultural competence, the scientific world outlook and the basis of the knowledge system in cosmology. Therefore, High School and teacher main goals and tasks may be said as being:
- provide general and specialized system knowledge of astronomy and astrophysics;
- to create conditions for the formation of skills and ability to conduct scientific research;
- to form skills of scientifically grounded thinking, logical and consistent expression of own thoughts;
- to develop communication abilities;
- to develop the ability to independently work with information sources, to systematize, generalize the information obtained and to use it.
The process of performing a task may not be endowed with a mathematical form. Problems with mathematical calculations should be offered only as much as their contents, once these calculations are really necessary. Also, it is not desirable the teacher to offer settlement tasks that do not include specific numeric data, once a formula in which no concrete content is put in, generates dissatisfaction to the student. Getting to the solution of the problem, is necessary to pre-understand the nature of this task, to show the necessity of using one or another formula and, which is also very important, explain the result and present it clearly. Generally, in control works, the definition of concepts should occupy a minimal place, the main thing - these are issues that, without requiring calculations, reveal an understanding of the essence of the phenomena or concept.
Among the topics and ideas to be worked about cosmology there are, for example, the determination of the parameters of the stars according to the Hertzsprung-Russel chart, beam speeds of sight; distances to galaxies for displacement of spectral lines and using the law of hubble.
The main goals when introducing the cosmology concepts to students are for them to having the following knowledge:

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- General information of galactic astronomy;
- Elements of cosmology;
- Cosmological paradoxes and principles;
- Models of the universe;
- Fundamentals of astrophotometry and spectroscopy;
- Laws of equilibrium radiation;
- Basic information about the solar system;
- On the physical nature of the stars and the main stages of their evolution;
- The main sources of star energy;
- Physical content of the Hertzsprung-Russell chart.
- To solve the exercises on the red shift and the law of Hubble.

**Potential student conceptions & challenges**

Illustrate elements of the topic that might obstruct a successful introduction in the classroom: When considering introducing Cosmology topics in the classroom, there are some issues that may be raised related to the concepts that they already know, or misconceptions that might still resist formal education.
Considering the cosmology topics presented in table 1, we could consider the following difficulties for every topic:

| Cosmology topics | Cosmology key ideas | Possibly difficulties (ideas that students have prior to learning the cosmology concepts) |
|---|---|---|
| Universe Evolution | Universe Origin | The idea of Big Bang being a literal explosion like the ones observed on Earth |
| | Star and galaxy evolution | The idea of a stable universe |
| | Black Holes | The idea of space and time as absolute and not a space-time |
| | Inflation of the Universe, Red Shift and telescopes | The idea of infinite universe |
| | Present and end of the universe | The idea of the universe having a begin but, being stable, no end |
| Particles | Cosmic Rays | The idea that fundamental particles can only be obtained in very elaborated equipment like the LHC |
| | Photoelectric effect | The idea that electrons may receive energy from light and be by freed from the atom |
| | Standard model | The idea that the proton in an elementary particle |

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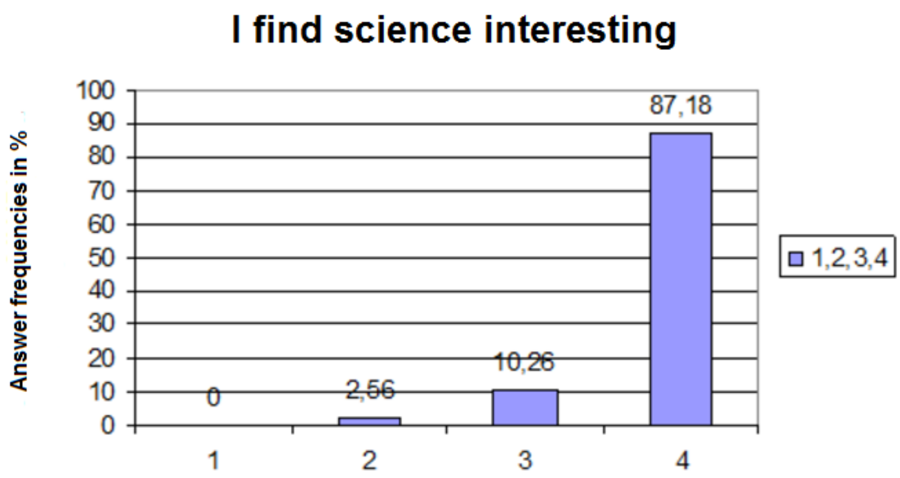
| | | |
|---|---|---|
| | Detection Technology | The idea that calorimeters are only used on thermodynamics experiments |
| Relativity | Special and General | The concept of absolute referential |

Not only the concepts above may make it difficult for the students to understand Cosmology topics, but also, there's a current lack of interest from the students related to sciences, as Linn, Bell and Davis (2004) put
"One of the major educational problems at present is the alienation from the school and the lack of willingness to study, especially in the field of science/astronomy subjects." One of the possible approaches to call their attention to sciences, if the constructivist environment and the Inquiry Based Science Learning, focusing in research activities, formulation of hypothesis, performing experiments, analysing and discussing results.
Thus, the students come to the facts by themselves and give their suggestion concerning the relationships among them. They take the role of young scientists/ researchers. Linn, Davis and Bell (2004).give the following definition: "The research work could be defined as a conscious process for problem diagnosing, doing experiments and defining of alternatives, planning of research work, giving scientific research suggestions, looking for information, designing of models, discussing with classmates, forming of clear argumentation". This approach develops skills that will be useful lifelong for the young people.
Analysing the empirical data presented below, one can conclude that students are extremely motivated for learning based activities. The results are shown in percentages. For example 87.18% of the students answered by "Strongly agree" that they find science as interesting and just 2,56% expressed disagreement. A relatively high percentage 79.49% answered "Strongly agree" that learning Science would help them find a good job.




An Inquiry Learning Cycle to specify the consecutive steps of an inquiry learning process constituted by five main phases: Orientation, Conceptualization, Investigation, Conclusion and Discussion. All phases of the inquiry learning process are closely connected with each other and provide a structure aiming at increasing the efficiency of the learning activities.
In the first two phases of the cycle (Orientation and Conceptualization) the opportunity is given to the students to gather information on a research question, take notes and build hypotheses and questions they want to investigate. Appropriate tools (like concept-map templates, search software, scratchpads, hypothesis-builder, etc) to help students to work on their own can be provided by the teachers in the Inquiry Learning Spaces.
The third is the Investigation phase (which includes Exploration, Experimentation and Data Interpretation activities) in which students collect specific data and check whether a hypothesis is correct or not by

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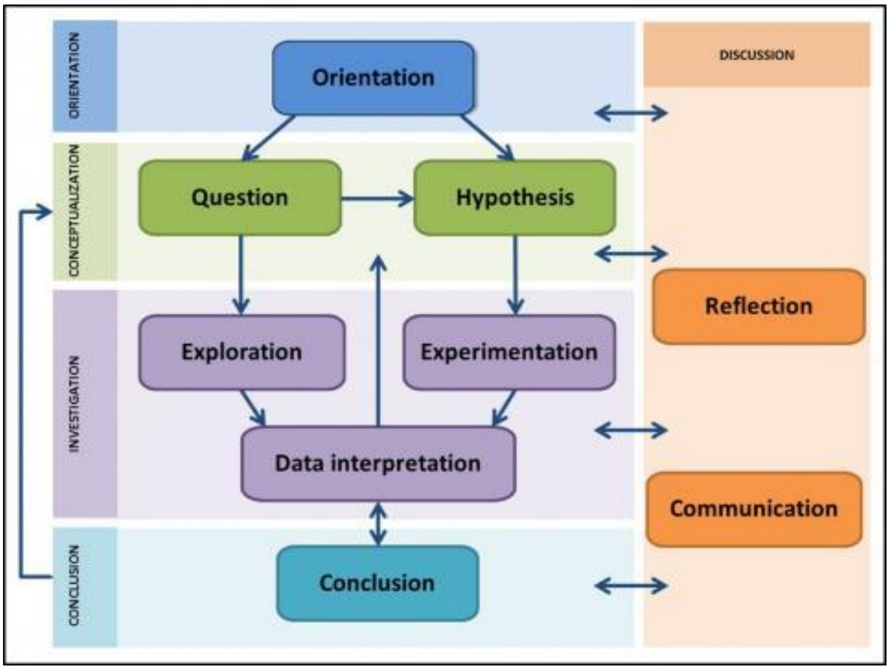
conducting personalized experiments. Also, the students can gather experiment results and conduct guided interpretation of the collected data.
During the last two phases of the inquiry learning process (Conclusion and Discussion), the students learn how to write scientific explanations linking their hypotheses with the evidence collected during the investigation phase. Further, they are reflecting on their learning processes and outcomes, comparing and discussing them with other students. Teachers can evaluate learning results of their students and define further steps for the next classes.




**Helpful material and resources**

1.General information
- http://www.ted.com/talks/richard_dawkins_on_our_queer_universe
- https://www.youtube.com/watch?v=hUJfjRoxCbk

Experiments in cern related to cosmology or astrophysics:
- CLOUD https://home.cern/about/experiments/cloud
- CAST https://home.cern/about/experiments/cast
- Cosmic ray https://home.cern/about/physics/cosmic-rays-particles-outer-space
- Dark matter & dark energy https://home.cern/about/physics/dark-matter
- Early universe https://home.cern/about/physics/early-universe

2.Application
- https://getkahoot.com/
- https://www.socrative.com/

3.Material for classroom activities and information of students' programme:
- International Particle Physics Outreach Group www.physicsmasterclasses.org
- S'Cool LAB http://scool.web.cern.ch/
- Perimeter Institute
  https://www.perimeterinstitute.ca/outreach/teachers/class-kits
  https://www.perimeterinstitute.ca/outreach/teachers/multimedia-resources

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- https://spaceplace.nasa.gov/classroom-activities/en/
- https://starchild.gsfc.nasa.gov/docs/StarChild/.../cosmology.html
- http://www.space-awareness.org/en/activities/1502/lets-break-the-particles/
- http://www.space-awareness.org/bg/games/disk-detective/
- encyclopedia.kids.net.au/page/co/Cosmology
- Quarknet data portfolio http://quarknet.i2u2.org/data-portfolio
- the community for cosmic rays in the classroom http://portal.opendiscoveryspace.eu/community/cosmic-rays-classroom-848307

4.Online lab
- Quarknet http://quarknet.i2u2.org/
- https://www.zooniverse.org/projects?discipline=astronomy&page=1&status=live
- http://portal.opendiscoveryspace.eu/content/hypatia-673571
- http://portal.opendiscoveryspace.eu/content/las-cumbres-observatory-global-telescope-673563
- http://portal.opendiscoveryspace.eu/content/chromoscope-676928
- http://portal.opendiscoveryspace.eu/content/multiwavelength-universe-677145
- http://www.schoolsobservatory.org.uk
- muon time dilation scenario: https://tinyurl.com/ybf3dvh5

5.Participation of students in experiment
- AMS http://home.cern/about/experments/ams

**Best practice example**

The use of experiments is very effective to perceive phenomena and understand models. Therefore, an example of best practice could consist in two parts:
1. Perceiving phenomena: Cosmic ray is appropriate for the topic of introduction of cosmology because tracks of cosmic ray are visible, experiment can be done in classroom and it can connect to many other topics. Shape of tracks explained by electromagnetics, and branches of tracks show nuclear interaction. Furthermore origin of cosmic ray is cosmological phenomena.
2. Understanding models: The Learning by doing method provides a very good opportunity to illustrate the topic. In this study, we present a very simple model made from handy materials "How to make a model of supernova". Students can paint the explosion of Cassiopeia A. on paper. The atoms are made of toilet paper and stained in different colors. The wool wave is demonstrated by a plastic cup and a bubble membrane.
Students are asked to make predictions on how galaxies form and evolve in the Universe. They will use the 'Galaxy Crash' tool to simulate the evolution of 2 disc galaxies over time, and see if the results match their predictions.
Finally, the students will search the data archive of the robotic Faulkes Telescopes and find observations of interacting galaxies. They will then try and use the 'Galaxy Crash' software to reproduce the images which they have found and draw conclusions on the initial conditions from which the interacting galaxies came from, and what they might expect to happen to the galaxies in the future.

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http://www.golabz.eu/big-ideas
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