The Main Ideas of Cosmology at School

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Abstract

The aim of this research study was to investigate students’ ideas and main difficulties with understanding modern cosmology science and to design based on results obtained a new cosmology course. We tried to identify factors, which might limit students’ skills and knowledge about universe. The participants were students – mostly pre-service teachers at the Science Education program in an Faculty of Education. A combination of qualitative and quantitative research approaches were used in the study. The data were primarily sourced from a standard questionnaire instrument. In addition, the interviews were conducted to determine student’s views of discussed course topics.

Keywords: Cosmology education, misconception, teaching

1. Introduction

Last couple of decades have been the golden age for cosmology. Powerful new observations have led to development of knowledge in our understanding of the origin, evolution and structure of the Universe. These gains have been vast, but their impact on common education has been limited.

A cosmology topic allows formulating well-defined interesting science problem, that could be managed by students and which helps to develop thinking ability and critical approach. Our view is that acceptance of selected cosmology aspects is fundamental for the process of deeper understanding of the world we live in, and these aspects help understand problems from other fields of physics.

The Faculty of Education at Masaryk University in Brno has been offering for some years a one-semester course of cosmology. This course offers the basic information about current cosmology: cosmological models, the

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fundamental cosmological parameters accessible to measurement, physical processes in the Universe from its early stages to the present state, including prospects for future development of cosmology as a field of application of fundamental physical theories.

We are gradually trying to design an innovative cosmology course accessible for future and contemporary science teachers, with a stress on students’ active participation in the acquisition of new knowledge. We are trying to orient teaching methods so that the students can absorb scientific cosmology concepts as well as the reasoning processes that lead to understanding of the universe, through interactive tasks.

So, the goal of our effort is not to generate teachers who captivate beams of light bending around a black hole, but cannot understand arguments or evidences of theories explaining these phenomena. Only few among science teachers will have the knowledge of differential geometry to explicitly figure out metrics and curvature of the universe, but these skills are dispensable for educational purposes. We have tried to establish if the central ideas of cosmology, and basic models of universe, can be taught without deeper mathematics base.

Cosmology misconceptions that could come from media reporting, or from reading popular science magazines are analysed and discussed in lecture-seminar format classes. We continuously conduct a research study to observe and to assess the students’ views on the nature of scientific knowledge, on their concepts and expectations for offered course.

This presented research study take into consideration frequently asked students’ questions about the Universe. Respondents were the students’ who finished the course, science students who did not take the course or science teachers, and also several laymen interested in cosmology specialized topics.

2. Aims of the study

The specific aims for our project research study can be summed up in three paragraphs:

This study seeks to assess the current awareness of a cross section of cosmology within the science students and teachers society, to ascertain how they are coping with a growing list of new cosmology findings, and to predict the prospects for the future implementation for education purposes.

This study presents the selection of the main cosmology ideas suitable and applicable for science education based on our experiences. A study seeks the correlations between successful test items for particular cosmological questions.

A related aim is to gather information to develop possible support learning material and explore how material can be implemented at school in coordination with other science subjects in curriculum.

3. Methodology

As a first step we formulated and arranged problem questions reflecting common cosmology. We encouraged all participants to talk and solve these questions and then we scrutinized the responses during a debate. Our investigation included interviews, observations and reflections upon the first year of the course. Interviews were recorded and coded. No questionnaire or interview was used to assessing learning outcomes or students’ proficiency. The purpose of selected approach was to ascertain what students know regarding modern cosmological ideas, and what sorts of teaching styles and materials can effectively overcome difficulties in learning cosmology.

As a second step of our research study we used questionnaire with eight open-ended questions. This method allows the respondent to answer in his own words. Two different reasons for using open-ended as opposed to close-ended questions can be distinguished. One is to discover the responses that participants give spontaneously; the other is to avoid the bias that may result from guessing answers.

The questions were designed to measure the integrated reasoning skills and to identify the weak and strong points of their science competencies and knowledge. Student can demonstrate his ability to solve complex problems by answering wider question.
Table 1 Scoring rubrics used to code open-ended responses

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Off topic answer, no relationship of written answer to the question.</td>
</tr>
<tr>
<td>0.1-0.2</td>
<td>Limited answer, misunderstanding of concepts, incorrect procedures.</td>
</tr>
<tr>
<td>0.3-0.4</td>
<td>Answer shows partial understanding of the concepts, errors in the application of the procedures.</td>
</tr>
<tr>
<td>0.5-0.6</td>
<td>Answer shows considerable understanding of most of the concepts, minor errors.</td>
</tr>
<tr>
<td>0.7-0.8</td>
<td>Answer shows a high knowledge and a thorough understanding of the concepts.</td>
</tr>
<tr>
<td>0.9-1</td>
<td>Answer shows an accurate knowledge application, the demonstration of a thorough understanding.</td>
</tr>
</tbody>
</table>

We categorized and coded responses for 8 complex questions from 42 participants. Almost every problem solving question could be manifested in several aspects mixed in various proportions: theory, quantity estimate, methodology, knowledge, philosophy and subjective confidence.

There are just for illustration two problems from used in our questionnaire:
- Q1: Could you suggest any method to measure the distance of an inaccessible point? Is your method applicable for the distance measurement of space objects?
- Q7: Do you think there are extra-terrestrial civilizations? What arguments do you have for your opinion?

4. Results

This study pays attention to examine the relationship between diverse skills needed for cosmology understanding. Descriptive statistic methods were used to analyse study outputs. Statistical analysis of responses was performed using Excel; the specific tests were Pearson correlation. We created a bar chart for students’ results depending on the category of prerequisites competencies.
The best score was found for answers Q2 - knowledge/quantity estimate question 70 % and the worst score for answers Q5 - theory question 43%.

The negative correlation between successful answers for Q6 - philosophy oriented question - and all other answers to the remaining questions (r = −0.21, p < 0.001) was ascertained.

There was apparent a strong positive correlation between successful answers for Q1 - quantity estimate question and Q2 - knowledge/quantity estimate (r = 0.79, p < 0.001) and between answers Q3 - methodology question and Q5 - theory question (r = 0.54, p < 0.001).

Here you can see the text of above selected questions:

Q1: Consider the distance between Sun and Earth as 1m. In this model try to guess how far from the Sun is: Jupiter, Pluto, Proxima Centauri, the centre of our galaxy, the Milky and Way.
Q2: How do we get knowledge about space objects?
Q5: Is the distance to which "we will see" in the universe, somehow fundamentally limited or may be improving techniques continue to increase it?
Q6: Do you think that space and time affect possibilities of our knowledge? How?

5. Conclusions

The data analysis shows that, in many cases, students' quantitative estimates in cosmological scale and their conceptual cosmology knowledge is quite good.

The most difficult task was to derive the implications of theoretical knowledge Q5; the easiest task was just testing clearly defined knowledge.

We would like to improve students' theoretical background including more discussion about the theoretical concepts used. We have to make clear the connections between basic physical and science ideas and modern cosmology. Powerful ideas of modern cosmology can inspire students, if teacher can these ideas interpret in language meaningful to ordinary people.

From the obtained results it can be seen that participants who show better results in the application of geometry and physics, have worse results in the area philosophically tuned questions. It seems that students inclining to exact
thinking and facts have a some distrust of philosophy. We hope that their prejudice can be overcome by careful reading and discussion of key philosophy oriented texts.

Our research study seeks to develop an understanding of barriers to the science teachers' ability to sustain current scientific view of the universe. We conducted an investigation before implementation of new cosmology course for science teachers. Our results from responses for questionnaire, and notes from interviews, show what instructional and teaching strategies we will implemented. The activity and curiosity of the students has been aroused by the search for an answer to interesting human and universe problems.

We enhanced syllabus and Cosmology course curriculum for those who are interested in learning about science and the Universe, as you can see in appendix listed below. We hope that course study will help many teachers to develop their science education in ways that are both satisfying to themselves and stimulating to their students.

6. Summary of Main ideas about the universe.

At first sight, cosmology deals with problems which are very distant from usual human interest and care. Nevertheless it extends our horizons and opens new perspectives for our future investigations. It answers fundamentals questions and in the same time introduces new attractive problems. In our opinion, this aim of study of cosmology can be traced in three closely connected regions.

1. Unique composition of the universe matter

Old thinkers (e.g. Aristotle) principally distinguished between earth and cosmic world and science. Today, especially thanks to spectroscopy, we know that chemical elements in space are the same and also its rate is elsewhere very similar (hydrogen to helium 3:1). Also other elements known from earth and forming e.g. our bodies are present in the universe and have its origin in star evolution. Also all currently observed structures from nuclei to galaxies are common to whole universe. Let us especially note that current observations suggest that number of inhabitable planets in our galaxy is very high.

On the other hand, the presence of this well-known baryonic matter is unable to explain essentials results of observations of behaviour of matter in the universe. It is therefore supposed that also some „hidden matter“ of unknown nature and even more mysterious „hidden energy“ exists in the universe in the following approximate proportions Baryonic matter: Hidden matter: Hidden energy = 5:23:72

2. Unique history of the universe.

Redshift of spectra of distant galaxies and quasars, interpreted as a Doppler shift, show that all observable universe expands in the way appears as the same for all observers at rest to the universe. Consequently cosmology is able to study history of the universe. Approximately 13.7 billion years ago all observable universe was in very small volume at huge temperatures, pressures and densities. Our contemporary observing technology makes it possible to observe a state of the universe up to the time of separation of electromagnetic radiation from matter. This relic radiation is very essentials source of information on the early universe and origin of its structures. Study of earlier history of the universe can be performed on the basis of theoretical knowledge and also by help of devices of high energy physics which are able to simulate physical conditions in early universe.

On the other hand, earliest history of the universe, the „big bang“, is still unexplained mystery and we are also not able to predict essentials features of more distant history of the universe.

3. Unique laws of the evolution of the universe

Everything around us is organized into a rich hierarchy of structures from the particles and nuclei through the atoms, chemical compounds, cells, plants, animals, Earth and other planets, the Sun and stars, up to galaxies and its groups and clusters. In so way, we observe a hierarchical universe with vast dimensional range. Its range now goes 40 orders: Proton (10–15m), atom (10–10m), cell (10–5m), the Solar System (1013m), and the galaxy (1021m), the observed universe (1026m). All structures are connected by four interactions: strong nuclear, weak nuclear, electromagnetic and gravitational. In present time, strong, weak and electromagnetic interactions are unified in the Standard model, based on relativistic quantum field theory. According to Standard Model all particles are formed by quarks and leptons and interacting by help of gluons, intermediate bosons and photons.
On the other hand, the Standard model is unable to explain hidden matter and hidden energy. Gravitational interaction is in great scale described by the General Theory of Relativity which is consistent with classical Maxwell theory, but not with Quantum Mechanics. In present time we have no completely unified physics.

Consequently extrapolating „earthly laws of physics“ on the universe requires same caution and we must be still prepared for essentials changes in our theories.

According to Stephen Weinberg (First Three Minutes) man is unable to find a sens in the cosmological happenings, but he could find an ultimate sens of his own existence in the scientific quest. In 19.century, Czech poet Jan Neruda (Cosmic Songs) compared the situation of earthbound man with the lion captured by bears of a cage and expressed a hope that man will be able exceed this limitation not only in the spiritual way:

We come closer, closer we come,
Other world we’ll live to see,
Lion spirited, we beat against these bars,
And we will break free!

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