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How Students Learn to Teach Cosmology

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Abstract

This paper reports on our research study undertaken by physics lecturers at Masaryk University. Cosmological discoveries over the past two decades have a great impact on both astronomy and Physics. We have prepared an innovation course, with topic Introduction to Cosmology, for our university students - especially future teachers. The teacher's competence in cosmology provides several advantages for thematic teaching. Teacher can help his students to acquire a cosmic vision of the world. We believe that teachers have to presents science as process that examines all of the evidence relevant to an issue and tests alternative hypotheses. We can help teachers to incorporate the process of science into curricula and show them well-established scientific theories including cosmological evolution. This topic gives an opportunity to explore knowledge of the Universe in its complexity. Our paper discusses the results of case studies undertaken by physics lecturers in Cosmology topics. Authors have tried to find achievements and misconceptions among students have completed course.

1. Introduction

We would like to present several ideas for the cosmology education for students at Masaryk University. We have completed a brief study reported student's abilities necessary to do scientific inquiry. We are developing a new design of cosmology course for future science teachers with aspiration to improve the knowledge and evidences for the origin of our Universe. Information from cosmology can influence student's worldview. Students would practice connecting scientific concepts and facts with elements of their lives, since they often take action based on how they see the world. The main objective of this mapping study was to identify the cosmology student's knowledge, and communication skills. Some common misconceptions and mistakes in cosmology are specified. The learning progress was evaluated with wide discussion.

2. Starting Points

We hope that everybody wants to get the credible information about the Universe. The Universe is the broader place where we live and act. Cosmology is the study of the Universe and its history; it is concerned with fundamental questions about its formation, evolution, and ultimate fate. For most of human history, it was mainly branch of metaphysics and religion.

Cosmology as a science originated with the Copernican system and Newtonian mechanics, which first allowed us to understand laws of motion of planets and celestial bodies. Modern cosmology began with the 20th century development of Albert Einstein's general theory of relativity, and better astronomical observations of extremely distant objects. These advances allowed the establishment of the leading cosmological model based on work of A.A. Friedmann and F. G.Lemaitre. Recent understanding Universe is closely related to high energy physics and astronomy observations, using instruments such as telescopes and cosmic ray detectors.

Cosmological discoveries over the past two decades have a great impact on physics, but the impact on science education was almost negligible. Most science students have never had any cosmology or astronomy course.

Thus, their understanding of the Universe has been formed through exposure in the news, internet sources or movies or in their limited astronomy experiences in basic school education. To support the

development of more scientifically literate teachers, we need to provide cosmology courses. There are two points of view. What would success in cosmology education look like? We feel there is difference between cosmology knowledge, which can impact the lives of the students, and knowledge, which represents the most important topics in research cosmology.
The present cosmology course is only a lecture (only 1hour for 10 weeks); we decided to introduce a new modifying syllabus and some components of active learning. This is a short syllabus, list of cosmology topics:

- The Copernican principle and observations.
- Expansion and Hubble law. Relativity and cosmology.
- Homogeneity, isotropy and the FLRW model. Redshift and cosmological distances. Critical density.
- Energy conservation equations.
- Evolution and age of the Universe. Matter content, dark matter and dark energy.
- Thermal equilibrium. Relic blackbody radiation. Matter–antimatter. Nucleosynthesis.
- The Big Bang Model. Qualitative discussion of inflation. The very early Universe.
- Evolution of structures.
- The Fate of the Universe.
- The Limits of Knowledge.

3. Method

If student understands expressions related to areas of most relevance the cosmology ideas, he achieves prerequisites for covering the cosmology problems he will meet in physics teaching.
Main aims of the study were to examine how the existing cosmology lectures affects student's approach to perform their solution of requested quiz tasks and to identify an incomplete areas that may prevent from misunderstandings in cosmology. We were interested in documenting students' preliminary ideas and in documenting students' ideas over the course of the semester. We have tried to evaluate shift in students' knowledge.
We used a mixed methods approach including both qualitative and quantitative analysis to derive a deeper overview of students' ideas. Participants were our university students, mostly future physics teachers (16 persons). They solved a set of 12 tasks in sufficient time. Interviews for each student about their approach were audio recorded. Records were transcribed. Audio transcriptions took a lot of time for data processing but we prefer this approach, as we feel the interviews evoke more personal and informative answers from students.
The method of categorization into indicators emerged during the analysis of records. The outputs are charts and brief descriptions of detected remarkable answers. Open-ended questions allow students to fully explain their views and justify their answers.
We selected two groups of participants: *A* labeled participants were students passed a semester course cosmology, *N* labeled participants didn't learn cosmology, they passed only standard physics course.
Eight observed symptoms and indicators were chosen for categorization of student's answers: *initial acceptance of the task* (without any intervention of interviewer), *critical approach to question*, *logical interpretation* based on prior knowledge, *deeper knowledge*, *spirit of initiative*, *creativity*, *understanding the problem*, *success in problem solution*.
Questions designed to encourage students to reason critically about difficult concepts in cosmology. The majority of questions were written to broadly sample the misconceptions that students bring to the Cosmology or Astrophysics course.

Here are the questions submitted to students:

1. How can cosmology prove that the Universe had a Beginning? What is the evidence for the Beginning of the Universe?
2. Are there any interactions in the Universe we don't know about?
3. Are there any chemical elements in the Universe that do not exist on Earth?
4. Bodies (Galaxies) can accelerate in relation to each other due to the expansion of space itself. Do you think that there are any forces that have influence on the "space" itself? Why do we think that the expansion of the Universe is accelerating?
5. How far in the Universe can we see? If the Universe is 14 billion years old, are the furthest objects 14 billion light years away from us? If the Universe is only 14 billion years old, how is it possible we see objects that are now 47 billion light years away?
6. What does it mean to say that the universe is homogeneous (it looks almost the same from any place) and isotropic (it is the same in every direction)?
7. What is the dark matter? Does it have corpuscular character? Is it made of any particles?
8. What does it mean when we say that the Universe is flat? Why flat?
9. When and how was the distance to closest stars measured for the first time?
10. What methods have proven to be successful for discovering and detecting planets outside our Solar System?
11. What is the redshift?
12. What dangers we are threatened from space and what you consider to be the greatest?

4. Results

The outputs of research results are charts and brief descriptions of detected remarkable answers. Several graphs were constructed for comparative analyses.

The graph shows (Fig.1) the different distribution of "performance" indicators for the first (*A red*) and the second (*N blue*) students *group*.

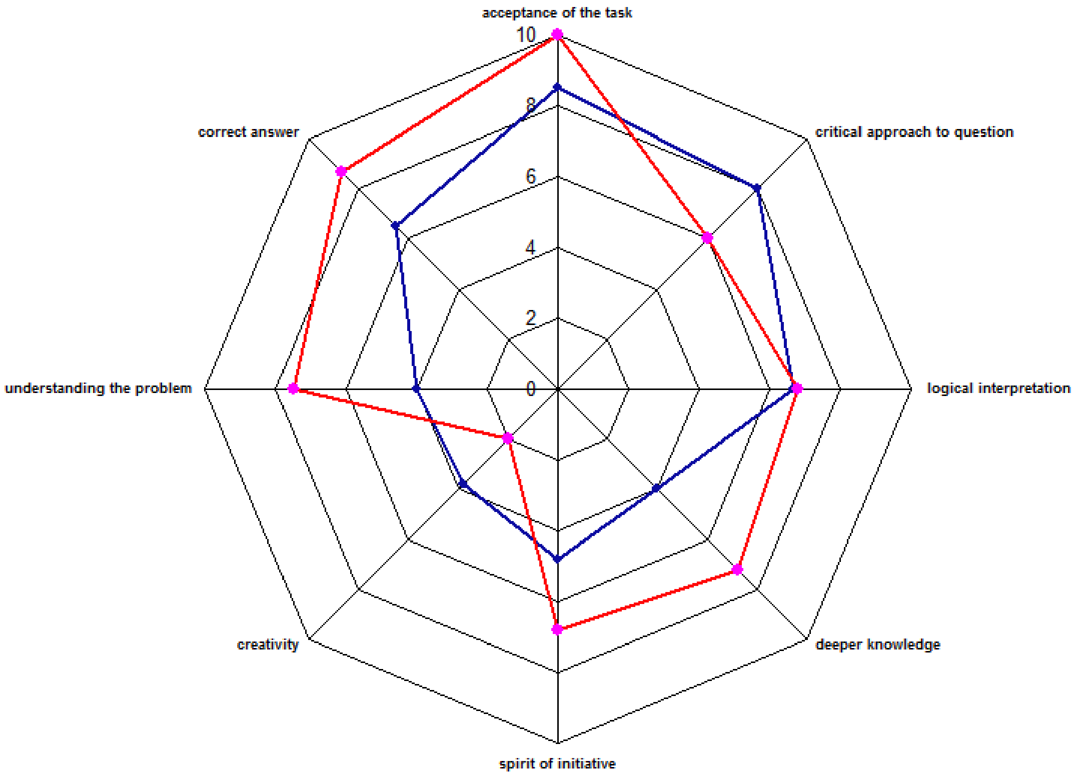

Fig.1 Summary our findings from the interviews, *red A group* students passed cosmology course, *blue N* group students didn't pass any cosmology course yet.

As expected, the most pronounced difference between both *groups* is demonstrated by indicator *deeper knowledge*. Similarly we can see relative significant differences in the indicator categories: the *understanding the problem* and the *correct answer* too. Those results are understandable and softly expected (*A group* students completed the whole cosmology course).
The indicator "*logical interpretation based on prior knowledge*" appears the same for both groups, because the physics students often train logical problem-solving tasks during studies.
The differences captured between indicators: *critical approach to question*, *spirit of initiative* and *creativity* are more interesting.
The first *group A* has a greater courage to accept tasks. *A group* students were trying to reformulate the problem and they were more sure in speculative thinking (*spirit of initiative*). It should be noted that *A group students* were more successful in solution tasks even they often think their knowledge is more accurate than it actually is.
It is evident that *N group students*, who lacked knowledge, more attempted to use their *creativity* mind. That indicator says if the students try to derive answer with openness to alternatives.
The indicator *understanding problem* observes if students are able to interpret problem correctly. Many of them did not understand the wording of questions and solved another problem.
The final evaluating discussion about cosmology educational outcome pointed out many expectations. We can conclude that students find cosmology ideas difficult because they have to work with many different conceptual thinking representations, key experiment results, formulas and graphs at the same time. But every student of both groups very appreciated that could investigate fascinating cosmology theories and explore many concepts regarding the history, origin, and evolution of our Universe. Therefore, we try to design a new syllabus and new activities for Cosmology teaching and learning. In essence, we want to realize no only conventional teaching methods such as teacher-centered lecture.

5. Misconceptions

Authors have tried to find achievements and misconceptions among student's have completed course and among the other students.
I. Students, and the wider society, are not aware of the fact, that when we talk about flat Universe we have to specify if we mean space or spacetime.
II. When we say that the observed Universe is almost absolutely flat, students think about space, not spacetime, and view it as a contradiction to the General Theory of Relativity which states that spacetime is curved.
III. Students don't understand what is exactly meant by "accelerating expansion of the Universe".
IV. It's crucial to distinguish the change of speed of an object when it's moving away from an observer and/or the change of speed in a location of a constant distance from the observer. That is the reason why students don't understand why is accelerated expanding universe is asymptotically approximated by stationary de Sitter Universe.

6. Conclusions

Our paper discusses the results of case studies undertaken by physics lecturers in cosmology topics. By comparing student performance on a set of conceptual questions posed both before and after a course on cosmology, we found that conventional cosmology course produces gains in conceptual understanding.

The comparison of both examined groups indicates that the influence of our recent cosmology course has important significance to students in majority of indicators.
The evaluation discussion with the students revealed that the course is popular, but it is difficult.
No only the increase in the number of hours is necessary, we need to adapt innovative materials and methods. Finally, we have documented students' misconceptions surrounding the cosmology theories. On the basis of completed results we will develop enhancement cosmology course ideally suited to science teachers.

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