Learning Astronomy

Project based Astrophysics with Role Playing

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Abstract
A teaching sequence in astrophysics for future science teachers that incorporates both explicit discussions of the nature of scientific models and the role of these models in explanations has been developed and tested. The goal was to promote meaningful learning in Physics. The lectures were combined with lab and project work. During the lectures the students formed groups in the classroom, thus enhancing discussions. A semi-structured role-play was used to report on the project. The students impersonated different experts, with different perspective of the phenomenon. The students expanded on the descriptions of the roles in their own way in their group work, thus adding theoretical perspectives of the phenomenon at hand – stellar birth, life and death. The teaching was well received by the students and we found that it elicited meaningful learning.

Introduction

A prerequisite for the teaching of physics is that the teacher realizes the importance of theoretical models in Physics, and their role in the interplay between Physics and the real world (Coll, France & Taylor, 2005; Crawford & Cullin, 2004; Justi, & van Driel, 2005). We believe that a teaching sequence that incorporates both explicit discussions of the nature of models and their role in explanations of phenomena can be very successful. The goal of such teaching is to provide opportunity for meaningful learning of physical phenomena (Viennot, 2003). Hence, meaningful learning is taken to mean the ability to distinguish between the world of models and the real world (Giere, 1997), the recognition of the limitations of models, and the coexistence of several theoretical models for a given phenomenon. It is crucial that students are given the opportunity to work with several different models for a given phenomenon. This will make it possible for students to discern that there is more than one model to use, which is acceptable within Physics.
The consequences of *variation theory* (Marton & Booth, 1997) for teaching are developed by Marton, Runesson and Tsui (2004). Our teaching sequence builds on both variation of the learning object and that learning in physics can be seen as the acquisition of more and more explanatory models for a given phenomenon. Thornton (1995), Taber (1998) and Redfors & Ryder (2001) all find that students use several different mental models when they talk about real world phenomena. We think that to understand something is to be able to explain it and the

mental models used in explanations are conjured up – depending on the context – as the explanation starts. Thus, use of mental models in explanations is often context dependent (Redfors & Ryder, 2001).

The teaching sequence

We have developed and implemented a research based teaching sequence in an advanced course in astrophysics. The author was the teacher and it was a student centered approach. The course was a part of the Swedish secondary science teacher program. The program takes 4½ years and comprises subject theory, teaching and learning theory and practice teaching (Redfors & Eskilsson, 2003). In the second to last semester the students take elective science courses and one of their choices was this course in astrophysics. It was a 5 week course and there were two teachers involved. The author was teaching the second part of the course, which is focused here. It was mathematically the most advanced course for the student teachers in their education. Therefore, the teaching was structured to encourage student and group activity and it was designed to promote qualitative thinking rather then mathematical problem solving. The aim was for the students to be able to use the mathematically formulated models from the first part of the course in qualitative explanations and discussions. The teaching sequence was partially based on *contrastive teaching* (Schecker & Niedderer, 1996) and it consisted of interactive lectures and lab-work, and alongside these, the students worked in groups with a project.

The lectures

The lectures were not traditional instead we worked according to the following principle. The students were divided into groups, and they were sitting with their group in the classroom. To have the students sit with their group members augments discussions in the class (Mazur, 1997). It is also quick and convenient to change between group and full class activities. The groups were used during lectures and in the project work. A typical lecture would start with the teacher giving an introduction to the material. The introduction served as an *advance organizer* (Novak, 1998) for the students who thereafter discussed and prepared the rest of the lecture in their groups. The *advance organizer* was in this case a general description of the content of the chapter, which was set in the astrophysical framework of the course. The students were given the opportunity to make connections between the new material and their previous knowledge, especially from earlier parts of the course. The *advance organizer* also helped them to see the logical structure of the content in the chapter. After this initial part of the lecture the content was divided up and given to the groups who were given time to discuss their part. The teacher was circling in the room as a resource for the groups. Taking part in discussions and challenging student ideas. The lecture continued with the student groups lecturing their part of the content for the rest of the class. Hence, the students themselves had to discuss all details, and they were helped to keep their presentations linked to the introduction of the teacher, thus giving the overall lecture a logical structure and making the introduction a true *advance organizer*. These sessions led by students were profitable for both lecturing and listening students. The lecture was concluded by a general discussion generating questions that were kept unanswered for contemplation until the next lecture.

The lab-work

The teaching sequence also contained lab-work. It was a semi-structured task. They worked with simulated observations of stellar spectra, and were asked to establish ways to categorize the different stars of an open cluster according to spectral classes. The students worked in pairs during this lab, thus they had mostly different companions compared to lectures and project. In the instruction sheet we had inserted open questions that the two students should discuss as they worked with the analysis. The questions were situated in the lab-context.

Role playing

Drama in science education can be of different sorts Ødegaard (2003) discusses this in an article on drama in upper secondary school. It can be impulsive, conjured in a moment, i.e. students are improvising. Drama can also be structured, based on a manuscript, or it can be something in between, semi-structured.
We have developed a semi-structured role playing scenario primarily focusing on the first two perspectives mentioned above. We have focused on the role of astrophysical models and in doing so the first two perspectives come to dominate. We have elaborated on an existing structure described elsewhere (Francis, 2005; Francis & Byrne, 1999) in the group based project. The students were given short descriptions of the knowledge of different experts, required to understand the process of star formation. They were asked to extend these descriptions in their preferred direction. The task given to the student was formulated like this.

> There are many giant gas clouds in space. They have diameters of about 10^{16} m, and masses of around 3×10^{30} kg. They contain chemical elements needed to form a sun and its planets. Your task is to figure out how a star with a planetary system can develop from these clouds. Below there are the opinions of nine experts described in short. Your group will elaborate on them and make comprehensive descriptions of the experts. Based on these your group will write the “star and planetary system formation” story and submit. Remember to relate your story to observational evidence of today.
>
> Your group will submit one story. However, on your oral exam you will individually act in the role playing and I will decide who plays which role. You will be expected to show that you

have acquired expertise in all nine areas.

All the experts included are needed to understand and explain the complex phenomenon of star formation, i.e. there were experts on condensation, observations, gravitation, meteorites, planets, stones and minerals, rotation, stars and stellar evolution.
Hence, it was a semi-structured drama, but the students were given the opportunity to develop the descriptions of the roles in any direction they chose, thus an ownership developed that stimulated the learning process. They submitted their extended role descriptions in the form of a complete story in writing, group by group.

Examination

The basis for the examination of the second part of the course was the student performance during lectures and lab-work. The written material was the lab-reports and the report of the project. The final examination was the oral role-playing, where the students played several different roles. The students were evaluated normatively against correct scientific arguments based on the role character perspective.

Results

The teaching sequence was evaluated through teacher observations, written questionnaires to the students and group discussions.

The lectures

The teacher (the author) made notes after each lecture. The most noteworthy observation was how the students "came alive" when they got the chance to take charge of the teaching and prepared the remaining part of the lecture. They based their work on the information given at the start of the lecture, and on information from previous parts of the course. They read the material and worked to make a comprehensive presentation, including the new material. Their preparatory work, including discussions in the group, seemed fruitful for their learning.
The students enjoyed the teaching sequence and they highlighted the importance of following the course literature closely, since it was difficult to read. They appreciated the discussions in the groups during the lectures, and deemed them to be fruitful. They concluded that discussions with peers, with supervision, were good learning opportunities.

The lab-work

The lab was found interesting and stimulating for the students. They got insights into the work of classifying that astronomers do. Some said it brought interesting questions to focus and that it was a useful part of their learning experience. Also here the role of supervisor was fruitful with frequent opportunities to challenge the student pairs and help them with additional questions.

The role-playing project

The project work was really appreciated and it was considered by the students to give a nice overview of the course content, at the same time as it was an application of the newly learnt material. Furthermore they appreciated that it was not strongly controlled. It worked to increase interest and it helped to put new knowledge into context. They thought the examination through role-playing was an interesting experience and they considered it to be a good learning opportunity. Finally they were a bit surprised that we had been able to work this way in an advanced course.

Discussion

To be able to discuss with peers in groups has in several cases been found fruitful for learning, e.g. Mazur (1997). For us, group discussions were central and the students were forced to engage with the new theory and make sense of it together. Especially, when they were asked to restructure the material and present it to the other groups during the lectures.

It seems that student learning really was improved by the project work they all did alongside the lectures and labs. An ongoing project like this where students get to engage and expand into areas chosen by them was effective (Schecker & Niedderer, 1996; Novak, 1998). The project becomes a direct application and it trains students to use new knowledge in new contexts. We conclude that there are good reasons for students to be given the opportunity to discuss in groups and challenge peer ideas in a project. The project needs to be closely interrelated with the course content and use of the new theory presented in the course should be required. Also of importance is that students get to define or expand on the project tasks themselves.

The role-playing as an examination was really interesting and it was possible to distinguish different performances. We could evaluate individually and grade students accordingly. The students appreciated this kind of examination and they considered it to be a valuable learning opportunity. Hence, we are in agreement with Ödegaard (2003) in finding role-playing interesting and we see a lot of possibilities to expand the use of it in higher education.

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