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Options for Reflective Learning on the Characteristics of Scientific Inquiry within a Students' Participation Project in Authentic Scientific Research.

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Abstract

From 2012 to 2014 high school students participated in the Sparkling Science Project: "Pollen and Respirable Dust – Mutual Allergy Triggers? " The project had the aim to investigate – together with the students – potential connections between allergy triggering substances in pollen and respirable dust. The students were involved in the research within three disciplines: Microbiology, Analytical Chemistry and Botany.

One goal of the project was to increase the understanding of the students about how science works, including the understanding of basic principles of scientific knowledge acquisition, scientific thinking and reasoning, investigation practices, standards and values of research procedures – in other words to deepen their understanding of Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI). For the development of knowledge about NOS / NOSI both an active participation in research processes and an explicit reflection on NOS / NOSI aspects are important. In the educational research accompanying, therefore, special attention was called to the development of tools for the students to reflect and to further develop their views on science and scientific research. Through a formative mind map setting, reflective workshops on NOS / NOSI as well as open questionnaires the students' views on scientific research were recorded. Experiences with those different methods were documented and discussed with regard to the further development of the Sparkling Science project.

1. Introduction

"Sparkling Science" is a research program, funded by the Austrian Government (BMWFW), in which young people and scientists together are supposed to develop ways to investigate into a specific topic. The aim of the program is to attract young people to science and to provide them with more profound and more realistic views on science and scientific research. One of the meanwhile 202 projects in the program with the title: "Pollen and Respirable Dust – Mutual Allergy Triggers?" was realized between 2012 and 2014.

In this project two high schools (BRG Kepler – Graz, HBLW Ecole – Güssing) and two universities (University of Graz, University of Vienna) participated. The main research focus of the project was to find out about the hypothetical impact of respirable dust on the pollen's capacity to cause an allergic reaction. In the field of Science therefore the three research areas Microbiology, Analytical Chemistry and Botany were involved. The students had the chance to participate in all the disciplines according to a three-step model. Thus the participation of the students could be differentiated according to their interests: The whole class participated in an introduction workshop, where principles of laboratory work and the inquiry tools of each research area were experienced. In the next step students could immerse more profoundly in one of the three research areas within a three days' advanced course. Finally those who wanted to deepen their research skills and knowledge even further, could apply for a one - month internship in the chosen discipline.

One goal of the project was to deepen the students understanding of how science works. The educational research focus within the project was therefore turned to the development and the evaluation of tools that promote a deeper understanding of the characteristics and epistemologies of science and scientific research.

Such tools were mind map settings, reflective workshops and open questionnaires on NOS issues that were employed formatively within the project. This paper has the aim to present the tools and to discuss their development potentials and limitations in a project with student's participation in authentic scientific research.

2. Theoretical Background

It is a central goal in science education to further the students understanding of Nature of Science (NOS) including the understanding of the basic principles of scientific knowledge acquisition, scientific thinking and reasoning, investigation practices, standards and values of research procedures [4]. Yet Schwartz and Crawford have shown that the engagement in an authentic research setting alone will not automatically lead to a deeper understanding of NOS [9]. One step to support the development of a more informed knowledge about NOS / NOSI is to make aspects of NOS explicitly aware [1], [2].

3. Methods and Tools used

In order to enhance the students' conceptions of NOS / NOSI, different tools and methods were developed in the course of the project An explorative setting was chosen that allowed adoptions within the two years duration of the project. The data sources were writings from the students (open questionnaires, concept maps) as well as audiofiles from the reflective workshops.
In the following passage the conception of the different tools will be described. The adjustments and variations developed during the project are discussed in chapter 4.

3.1. Formative Concept Map Setting

Aim: to evaluate the individual development of the students' knowledge of NOSI aspects.
Conception: Before the introduction workshop, the students were asked to create an individual concept map on the focus question: *"What do scientists do in their research?"* During the introduction workshop the students worked again individually on the map. They were supposed to make adjustments or to add new ideas.
At the end of the advanced course an interview was carried out with each student and as a part of it the students were asked to produce a mind map with the same focus question again in a think-aloud process [11].
Data: mind maps, audio files

3.2. Reflective workshop on NOS

A workshop lasting two hours was conducted parallel to the introduction workshops in Microbiology, Botany and Analytical Chemistry in small groups up to ten students.
The core activity of the workshop was a focused group discussion using the card sorting method [2], [5].
Aim: to find out about the socially constructed students' views about NOS [7] by fostering the argumentation on NOS aspects and challenging a discussion including different views on science and scientific research.
Conception:
As an input for the group discussion, cards with a large variety of different (contradictory) statements on NOS aspects were placed on the table. The statements were redundant to assure that all students had the free choice. Each student had to select at least four of the cards (two that she/ he agreed with and two that she / he did not agree with). One of the students started to present a statement from one card arguing why he did / did not agree with it. Other students who also had chosen the same / a similar statement were invited to join the discussion. Then the discussion on that issue was opened to the whole group.
Data: audio files

3.3. Open questionnaire on NOS aspects

An open questionnaire was constructed to further a more profound engagement with NOS aspects after the reflective workshop. Deng, Chen et al. [3] argue that with standardized closed questionnaires it is difficult to get the students' ideas on NOS. That is the reason for the wide use of open questionnaires or interviews in the literature [3], [7], [10].
Aim: to provoke a deeper immersion into aspects of NOS, based on the reflective workshop
Conception: written group work as "homework" after the introduction workshops and as a preparation for the deepening workshops. The questions were selectively taken and adopted from different authors [1], [6], [7], [10].
Variation: As a part of introduction workshops, the questionnaire was filled in individually first and followed by a group discussion.

4. Results & Discussion

4.1. Formative Concept Maps

The aim of the formative concept map setting was to make visible the development processes of the students in the course of the project in terms of their understanding of the procedure of scientific research. In the project the differentiation between mind map and concept map was not clearly made by the students. Thus, in many cases, it turned out to be something in between. Within the project it was difficult to maintain the formative character of the tool. The combination of the final mind map with the interview, offered the opportunity to ask further questions to understand better what the student was expressing in the map. However, a part of the students felt tested and therefore disliked that setting although the students were informed at the beginning that all data was treated anonymously and they were encouraged to express themselves freely.

In the future the concept map setting in its formative way should be carried out more consequently with all the students within the three time slots. It is supposed that with the development of three individual concept maps (at the beginning, in the middle and at the end of the project) the development of the individual understanding of inquiry processes can be traced more effectively. Especially the final concept map should be combined with an oral phase. Thus the student can explain his /her writing. The concept map setting should be connected more closely to the investigation process in the project: In the first concept map, that is created before the introduction workshop the focus question can be still a general one, like: *"What do you think, scientists do in their research?"* For the concept map during the introduction workshops the focus question can already be more aligned with the project, like: "*If you think about the research areas you have become already acquainted with, how do the scientists in botany, microbiology or analytical chemistry do their research?"*

The final concept map at the end of the three day's course should focus on the experiences the students have gained by immersing more profoundly in one of the research areas, like: *"What do the scientists you worked with do, to carry out their research?"*

4.2. Reflective workshops on NOS

For all the student groups the card sorting method worked well in the sense that all the students were involved in the discussions. The individually selected statements were a door opener for more quiet students to get into the discussion. They were also a support for the whole group to enter the field of NOS /NOSI, were most of them had not been explicitly involved before. For the follow-up project, a concept of how to link this tool more closely to the actual scientific inquiry the students are exploring in the project has to be developed. One idea is to additionally establish a Scientist Café during the advanced course – an informal space for students and scientists to discuss and reflect their actual inquiry process in the light of NOS.

4.3. Open Questionnaires:

We used this questionnaire in two variations within the project:

Once in the original conception, where the students grouped after the introduction workshops and sent back the writings via email autonomously. In that setting the return flow as well as the quality of the outcome were surprisingly high. Having 31 students, we got a return quote from 13 students, what reflected the number of students who were interested in participating the three days' advanced course. The answers were well thought over and showed engagement on a high level.

With the class from the second school we used the open questionnaire alternatively to the reflective workshop at the end of the introduction workshops. In a first step the whole class had 30 minutes to fill in the questionnaires individually. In a second step the questions were discussed in the plenum together with the participating scientists. This plenar discussion proved to be problematic because only few of the 24 students really participated and the scientists tended to take a teaching role. Summing up the questionnaire - especially in the first variation - turned out to be a good tool for the students' individual or group wise reflection on NOS, after they had been introduced to the field of NOS through a reflective workshop.

5. Outlook

The three presented tools do have potential to detect and enhance the students' views on NOS / NOSI. However, in the follow-up project the adjustments that were described above will have to be made and the effects will have to be evaluated.

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