New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION


The *Reflective Reviewing Café* - Qualitative analyses of Students' Views on Nature of Science

Julia Birkholz[1], Doris Elster[2]

Abstract

An appropriate understanding of the Nature of Science (NOS) and of Scientific Inquiry (NOSI) is one of the essential tools for critical thinking about and reflection on scientific knowledge. To improve this understanding, the NOS/I-aspects "(Un)certainty" and "Purposes of Scientific Knowledge" as well as "Scientific Practices/Justification " were emphasized in the "Reflective Reviewing Café" (RC) conducted in the outreach-lab "Backstage Science" (basci) at the University of Bremen.
In a long-term study the impact of the RC on the understanding of NOS/I was analysed via questionnaire (pre/post/follow-up). The quantitative results indicate that the multiple participation in modules offered in the basci-lab with following RC-dialogues leads to an improvement in the understanding of "Development" and "Scientific Practices/Justification". In addition, the recorded dialogues of the RCs (32) are transcripted, revised and encoded using the structuring content analysis.
The understanding of Scientific Practices/Justification is shifting distinguishably from first to third time attending the RC towards deeper awareness of the structures of scientific research. These findings support the findings of quantitative data, although a greater impact was expected.

1. Introduction

The increase of private funds for research and development, especially industry performed, may lead to a "Knowledge Economy" ([1], p. 8) with the implications of science marketing: strategic PR and advertising instead of scientific information. Although it is a slow trend, it will change scientific information substantially and "[p]ublic vigilance and debate are urgently required" ([1], p. 13). This critical vigilance over scientific knowledge is of great importance for future responsible citizens [2] and requires an appropriate understanding of the Nature of Science (NOS) and Scientific Inquiry (NOSI). While there is little consensus between scientists, historians and philosophers, regarding the true Nature of Science, Knowledge or even Physical World [3], these philosophical questions are of little relevance for students and citizens. If considering relevance of a NOS-aspect along with a general consensus and accessibility [4], there are some aspects of NOS/I to focus on: e.g. *the tentative nature of scientific knowledge* or the *justification of scientific knowledge* [5], [6].

2. Theoretical framework

The NOS/I aspects relevant for this study (and students) are chosen from the continuum found in Lederman et al. 2002 [5] and Schwartz et al. 2008 [6]: Main focus lies on the *Uncertainty of Scientific Knowledge*, caused by its tentative nature, whose origins are the environmental and personal influences on scientific endeavours in the broadest sense. To minimize those influences, the scientific communities have developed various procedures and processes. These *Justification/Research Practices* form the second focus aspect. As a third aspect, the *Purposes of scientific research programs* have been included to capture more mundane and societal influences.
Students' views on NOS/I aspects are characterized as the competence regarding views on characteristics of science [7], with the implications of possible evolution and improvement as well as promotion through appropriate instruction. The development of this competence, if not influenced intendedly, proceeds on an implicit level [8] with a rather naïve outcome due to the complexity of the subject and science lessons as the source of information, not focussing "doing science" but "learning about scientific knowledge". Following Lederman et al. 2002 [5] (see also [6], [9], [10]), the evaluation of students' views ranges from naïve over intermediate to informed level.

[1] University of Bremen (Germany)
[2] University of Bremen (Germany)

2.1 How to improve students' views on NOS/I

Students' views on NOS/I do not improve significantly through research activities, when merely carried out (e.g. [11]). The underlying NOS/I contents need to be addressed explicitly. A promising way to explicate these contents is to reflect about research activities guided by questions, which throw a light on the respective aspects (e.g. [9]). Reflection in this manner means to retrieve own experiences and to examine them in the light of the own views on NOS/I. Following the ICAP model of learning [12], reflective activities have a great impact on learning, especially when performed in dialogue, because of the supportive role of interactivity.
Reflective processes may take place, if the reflecting person has time and space for own thoughts with free choice on effort, extent and aspects. Writing tasks or guided dialogues can support the process [13].

2.2 Outreach-lab activities and the *Reflective Reviewing Café*

There is more than one possible way to find answers to scientific questions. Following the IBSE principles (Inquiry-Based Science Education, [14]) allows research activities as partly authentic scientific endeavors providing "reflectable" characteristics, e.g. leaving the development of hypotheses, experimental plans or analysis ways to students' discretion.
The "Backstage Science" outreach-lab (basci-lab) offers IBSE research modules for school classes. The activities are embedded in socially and economically relevant biological contexts and provide a fertile base for self-directed inquiry.
Reflection upon these activities is initiated through the *Reflective Reviewing Café (RC)*, a group-dialogue method based on the "World Café" [15]. Three guiding questions on NOS/I contents (*Scientific practices/ justification, purposes of science, influences on scientific research*) regarding basci-lab activities enable corresponding dialogues. The moderators at each table guide the dialogues and discussions, give impulses, raise further questions, summarize and point out differences and similarities according to their guidelines. Starting with thinking about the guiding question and noting thoughts on the table cloth, the group then shares their answers, ideas and comments regarding the question and related themes. After 15 minutes the group moves to the next table and discuss a further question.

3. Research question

The *Reflective Reviewing Café* was developed to improve students' views on NOS/I. The quantitative data, obtained via pre/post/follow-up questionnaire [16], shows significant improvements in the NOS/I aspects "*Development"* and *"Scientific practices/ justification"* after visiting the basci-lab three times and conducting the *RC.* To approach the mechanisms underlying this improvement effect, the question uprising is: *How are the students dialoguing about NOS/I?*
Although the dialogues are guided, there is sufficient thematic space for individual preferences, experiences and allows authentic views on NOS/I. Comparing *RC*-dialogues from different basci-modules might show development in detail of displayed NOS/I-views or application on a greater thematic range.

4. Design and method

The study was conducted in 2013/2014 with 509 middle school students aged 13 to 17. The intervention groups (N=310) visited either three basci-lab modules or only one and in both of these groups, half of the students (randomly chosen classes) performed the *RC* following the module activities. The views on NOS/I were assessed pre-post-follow-up at every visit and after 12 months after the last visit. An additional assessment (3x) took place with a control group (N=199).
The *RC* dialogues (32) were recorded, transcripted and edited by smoothing the students' statements and integrating questions, impulses and other missing fragments. An independent researcher compared every edit with its original to prevent distortions.
The transcripts were analyzed with the structuring content analysis (see Fig. 1) [17] with mandatory adaptations to meet the challenges due to the immense difficulty to interpret the expressions reliably. Every statement was assigned to one category and code.
The interrater-reliability based on the Cohen's Kappa value was .87, which indicates an excellent accordance.

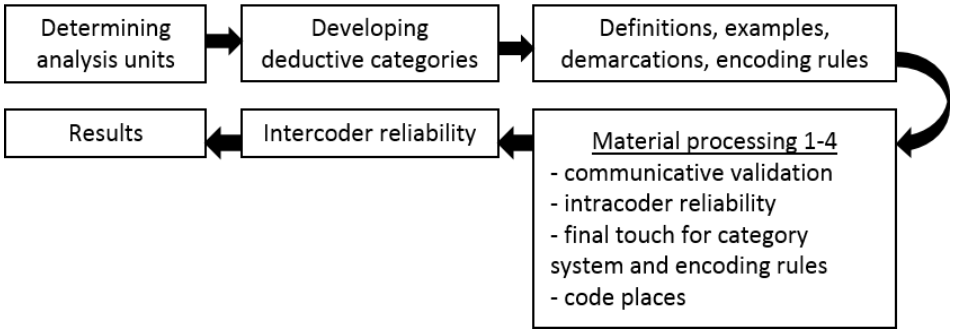

Figure 1: Process description of the structuring content analysis

4. Results – A category system of NOS/I views

The following table (see Tab. 1) shows the category system partly deductively created and partly derived from the dialogue material of the *RC*:

Table 1. Table 1: Category system with encodings and anchor sentences

Category	Code	Anchor citation (german native speakers)
Research and its Revision	methods [Rm]	*We have carried out experiments and tests with crayfish and set up hypotheses and questions. M2_8aOtt_F1_30f*
	approaches [Ra]	*When experimenting the hypotheses often are disproved and one finds out new things, from which one can set new theories. Those you have to prove again, and all this is not that difficult, if you always follow the rules. M1_8aOtt_F1_328-31*
	revision [Rr]	*It is not enough to carry out a number of experiments to get an accurate result. To get the right result, one has to conduct a lot of experiments and then you must interpret and aggregate the outcome correctly. M1_8aOtt_F1_246-49* *With repeated implementation the result would be more reliable. M1_10os_F1_332*
Purposes of Research	new insights [Pn]	*It is generally important to work scientifically to understand what happens and why it happens. M1_9bOtt_F2_162*
	decision making [Pd]	*PH and nitrate/nitrite levels were measured today because of the plants. If the soil is acidic, if the plants could grow there. If it would make any sense to grow them there. M1_9bOtt_F2_275-78*
	progress [Pp]	*Maybe science now has to make up for what she has done. M1_9aOtt_F2_169f*
	convincing argument [Pc]	*The scientific approach is useful and respectable. On the basis of knowledge and through logical thinking, experiments etc. further knowledge is obtained. Knowledge that is acquired in such a way is more credible and one has a good impression of the persons, who provide such information. M1_8aOtt_F2_18-23*
Uncertainty	science [Us]	*It's not all facts and truths. Different scientists have their own theories and they aren't accepted by every scientist. M3_9bOtt_F3_378-86*
	world [Uw]	*Nature does, whatever she likes. Because of this no one can predict a volcanic eruption. M3_9bOtt_F3_78f*
Change-ability	science [Cs]	*This has to be analyzed under various conditions and the theory has to be adapted every time new experiments and facts are available. M3_8aOtt_F2_123-25*
	world [Cw]	*Even if you repeat an experiment several times, the results are not absolutely reliable, because there can always be new things changing the outcome. M2_10os_F1_288-93*
Ethics	[E]	*[…] If the scientist got money from the client, I would also say, that we didn't need crayfish. If I got money, I would not tell the truth. M2_8aOtt_F1_128-30*

The students often begin their discussion by description of module activities and then switch to examples extracted from media or general knowledge. There are few statements that can be evaluated as undoubtedly naïve. Most dialogue parts are not conclusive enough for objective evaluation. As a result, the categories are arranged hierarchically (see fig. 2).

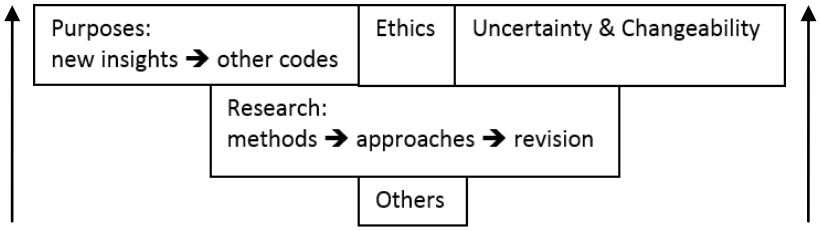

Figure 2: Categorial hierarchy

In the intervention group visiting the basci-lab three times, there is an apparent shift from naming research methods [Rm] to describing possible research approaches [Ra]. There are no essential changes in the number of research revision [Rr] statements. Statements regarding uncertainty [Us, Uw], however, are expressed in *RC* no.2 five times and in *RC* no.3 ten times more often.

5. Discussion and next steps

Dialogues about scientific activities, their reasons and consequences are able to support expressions about the "(*Un)certainty"* aspect of science. Students more frequently discuss perceptions of uncertainty and start to revive as well as refine other students' statements. This is probably caused by increasing familiarity with the *RC* method of dialoguing and reflective thinking. As the study progresses, autonomous reflective actions can be observed increasingly during the research activities and before *RC*-start. Whether the reflectivity improved mere expressivity or broadened underlying views regarding the aspect, is not conclusively to determine. The quantitative data showed highly significant improvements in "*(Un)certainty*", but also did the control group [16]. Further data, *RC*s combined with qualitative assessment, is required.

The dialogues may change the view on "how to do science", to perceive the distinction between executing an experimental method and following the underlying path directing research endeavors. This further supports results of the quantitative study [16], although an even higher quantitative improvement was observed in this aspect, leading to the expectation of increased [Rr] statements, because this code subsumes the most informed ideas about characteristics of scientific activities. Possibly, the [Rr] statements change less in number and more in quality. To determine this, the material has to be analyzed by a more subtle instrument: The documentary analysis [18] will be put on selected [Rr] dialogue loci, where interaction, partners and topics indicate fruitful analysis.

References

[1] Bauer, M. "Paradigm Change for Science Communication: Commercial Science Needs a Critical Public", in: Cheng, D., Claessens, M., Gascoigne, T., Metcalfe, J., Schiele, B. & Shi, S. "Communicating Science in Social Contexts. New models, new practices", Dordrecht, Springer, 2008, pp. 7-26

[2] Felt, U. "Gestaltungsversuche des Verhältnisses von Naturwissenschaften und Gesellschaft: Leben und implizites Lernen von Bürger/inne/n in der Wissenschaft", Report 3/2008(31), pp. 32-43

[3] Wiltsche, H. "Einführung in die Wissenschaftstheorie", Göttingen, Vandenhoek & Ruprecht, 2013

[4] Lederman, N. "Syntax of Nature of Science within Inquiry and Science Instruction", in: Flick, L. & Lederman, N. (Eds.) "Scientific Inquiry and Nature of Science", Dordrecht, Springer, 2006, pp. 301-317

[5] Lederman, N., Abd-El-Khalick, F., Bell, R. & Schwartz, R. "Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science", Journal of Research in Science Teaching 39(6), 2002, pp. 497-521

[6] Schwartz, R., Lederman, N. & Lederman, J. "An Instrument To Assess Views Of Scientific Inquiry: The VOSI Questionnaire", National Association for Research in Science Teaching Annual Meeting, Baltimore MD, 2008

[7] Mayer, J. “Erkenntnisgewinnung als wissenschaftliches Problemlösen”, in: Krüger, D. & Vogt, H. “Theorien in der biologiedidaktischen Forschung. Ein Handbuch für Lehramtsstudenten und Doktoranden”, Dordrecht, Springer, 2007, pp. 177-186
[8] Polanyi, M. “Implizites Wissen”, Frankfurt a.M., Suhrkamp, 1985
[9] Khishfe, R. & Abd-El-Khalick, F. “Influence of Explicit and Reflective versus Implicit Inquiry-Oriented Instruction on Sixth-Graders’ Views of Nature of Science”, Journal of Research in Science Teaching 39(7), 2002, pp. 551-578
[10] Khishfe, R. “The Development of Seventh Graders’ Views of Nature of Science”, Journal of Research in Science Teaching 45(4), 2008, pp. 470-496
[11] Moss, D. “Examining student conceptions of the nature of science”, International Journal of Science Education 23(8), 2001, pp. 771-790
[12] Chi, M. & Wylie, R. “The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes”, Educational Psychologist 49(4), 2014, pp. 219-243
[13] Hatton, N. & Smith, D. “Reflection in Teacher Education: Towards Definition and Implementation”, Teaching & Teacher Education 11(1), 1995, 33-49
[14] NRC, National Research Council “Inquiry and the National Science Education Standards: A Guide for Teaching and Learning”, Washington D.C., National Academy Press, 2000
[15] Brown, J. & Isaac, D. “Das World Café. Kreative Zukunftsgestaltung in Organisation und Gesellschaft”, Heidelberg, Carl Auer, 2007
[16] Birkholz, J. & Elster, D. “Wirkung von Reflexionen über Forschungstätigkeiten im Schülerlabor auf ausgewählte Aspekte des Wissenschaftsverständnisses”, in: Gebhard, U. & Hammann, M. (Eds.) „Lehr- und Lernforschung in der Biologiedidaktik“, Innsbruck, Studienverlag, 2016, pp. 75-91
[17] Mayring, P. “Qualitative Inhaltsanalyse. Grundlagen und Techniken”, 12. überarb. A., Weinheim, Beltz, 2015
[18] Bohnsack, R. “Rekonstruktive Sozialforschung. Einführung in qualitative Methoden”, Opladen, UTB, 2014