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Changing Epistemological Beliefs: How Hands-on Teaching Units in Biology Influence 5th Graders

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Abstract

Building on a study by Conley, Pintrich, Vekiri, and Harrison (2004), the survey at hand aimed at investigating two hypotheses regarding the epistemological beliefs of 5th graders in biology. One stated scientifically gifted 5th graders' beliefs would advance significantly more over a period of three months in a hands-on teaching unit than these of their non-gifted peers. The other claimed scientifically gifted students have more advanced epistemological beliefs in general when compared to non-gifted students of the same age. The teaching unit examined in this study was on the topic off light of birds and was designed in a very interactive way, meaning that the students worked in groups most of the time and the teacher acted as a facilitator of the learning process. The study was conducted in a pre-post-design with a multiple-choice questionnaire. Due to several reasons, both hypotheses could only be proven in parts, thus creating interesting questions for future studies.

Keywords: Epistemological beliefs, change, gifted, biology.

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Theoretical background

In order to have future scientists who successfully investigate a number of phenomena, already children have to be trained to question existing knowledge and to use creative ways to test and probably modify scientific concepts. Epistemological beliefs are personal beliefs regarding the nature of knowledge and the nature of gaining it, called the nature of knowing (Hofer & Pintrich, 1997). Both can be split into two general basic domains or dimensions, as depicted in Figure1.

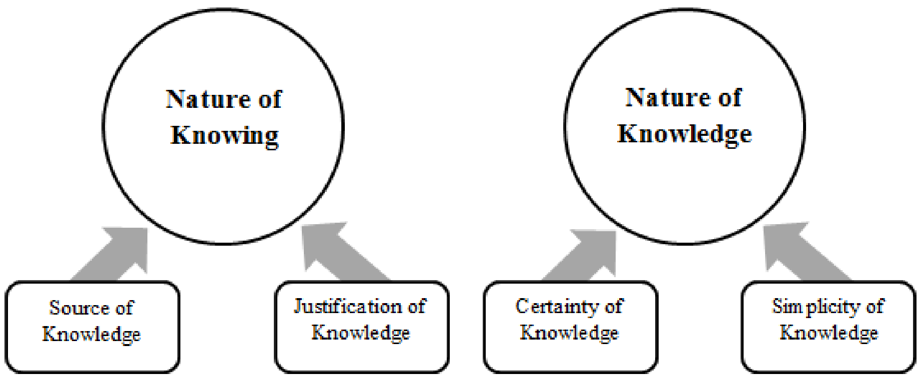

Figure 1 Nature of Knowledge and Knowing, according to Hofer and Pintrich (1997).

The nature of knowledge is divided into *certainty of knowledge* and *simplicity of knowledge*. The term *certainty of knowledge* describes the extent to which knowledge of a person is static (naïve belief) or changeable and in constant development (advanced belief) (Hofer & Pintrich, 1997). It thus describes a person's opinion about whether knowledge can change over time or not. The category *simplicity of knowledge* targets beliefs about whether knowledge is a loose collection of simple facts (naïve belief) or rather an interwoven concept (sophisticated belief) (Hofer & Pintrich, 1997). It represents opinions about the structure of knowledge.

The nature of knowing also splits into two sub-categories. The first is the *source of knowledge*, describing where a person thinks knowledge comes from and how it is gained. People of naive belief think it comes from instruction by external authorities, whereas those of more sophisticated beliefs think it comes from oneself or by working together in groups (Hofer & Pintrich, 1997). The second is the *justification of knowledge*. It describes how people justify their knowledge, for example by referring to external authorities (naive belief) or by using empirical findings (advanced belief) (Hofer & Pintrich, 1997).

Why Advancing Epistemological Beliefs Is Important

Changing students' epistemological beliefs towards a more advanced level has positive effects on the general learning outcome. Schommer (1990) proved attitudes regarding knowledge and knowing have a severe power on learning outcomes and the understanding of texts. Hofer (2001) found the same thing, stating that more sophisticated epistemological beliefs positively influence a student's level of motivation and the choice of learning strategies, ultimately resulting in a more positive performance. Apart from that, a positive development of epistemological beliefs leads to more considered ways in gaining and using knowledge, a better usage of potential in learning situations and more active participation in learning processes (Gruber & Stancouli, 2009). All of this results in students using their knowledge in a more intelligent way the more advanced their epistemological beliefs are.

Early studies regarding epistemological beliefs suggested they were only influence able in the long run by a constant supply of new impressions and experiences (Kienhues, Bromme & Stahl, 2008). However, more recent studies showed that changes can also be achieved by rather short pedagogical interventions if they are designed accordingly (Bromme & Kienhues, 2007).

[xxx] University's 'Kolumbus-Kids'

The program 'Kolumbus-Kids' was founded by the Department for Didactics of Biology in 2006 at [xxx] University. Its classes are planned and conducted by university students who intend to become teachers. The project aims at tutoring gifted children from grades four to eleven and tries to influence the students' epistemological beliefs by lessons that deal with topics from biology, chemistry, and physics and are designed according to the Scientific Way. Whereas this scheme originally consists of eight intermediate steps (defining a question, gathering information, phrasing a hypothesis, conducting an experiment, analysing the data, interpreting the data, draw conclusions, retest), it has been incorporated into three phases for these lessons: introduction phase (theoretical background), working phase (practice), and evaluation and presentation phase. This makes for lessons which are problem- and activity-oriented to an extent which exceeds regular school classes by far. The three phases are described in the following.

During the introductory phase a short theoretical introduction to the topic is presented. The students are encouraged to actively participate and utter their own thoughts, questions, and suggestions regarding the topic. The introduction is concluded by the teacher and the children phrasing hypotheses about a problem which has been presented earlier. Also, the experiments for verifying the hypotheses are developed together with a given list of materials.

Next up is the working phase during which the students conduct the experiments in small groups of four people max with the help of work sheets. Important about these work sheets is that they give enough room for the students' own interpretations and thoughts. The teacher takes a backseat and only intervenes if absolutely necessary for safety reasons or if the students have questions they cannot solve on their own.

The lessons are ended by the evaluation and presentation phase, during which the data that was collected when conducting the experiments is analyzed and presented. The students evaluate their results in their groups, thus verifying their hypotheses and answering additional questions presented on the work sheets. At the end of each session, the findings are presented and discussed in class.

For further information on the project please visit www.kolumbus-kids.de.

Hypotheses

This study aims at answering the questions about how hands-on classes change the epistemological beliefs of gifted students in grade five and whether there are differences in such beliefs between gifted and non-gifted children.

Conley, Pintrich, Vekiri, and Harrison (2004) have previously shown that practical classes can influence the epistemological beliefs of children attending grade five. Since the project's lessons are hands-on as well, we should see the same effect here. The main difference to Conley et al.'s (2004) study is, however, that this one has a control group to see whether the effects are due to another cause than the classes' nature. Hence, the first hypothesis is:

Hypothesis 1: *"The epistemological beliefs of scientifically gifted students attending grade five can be significantly changed within three months by the hands-on lessons of the project 'Kolumbus-Kids', whereas the beliefs of non-gifted children attending regular classes do not change."*

Furthermore, Thomas (2008) found that gifted students at the end of grade twelve have more advanced epistemological beliefs than their non-gifted peers. The former almost reached the developmental stage 'relativism', whereas the non-gifted students stay at the level of 'multiplicity' according to Perry's scale from 1970. The study at hand thus wants to prove the same effect can be found in younger children, which is phrased in the second hypothesis:

Hypothesis 2: *"Scientifically gifted grade five students have more advanced epistemological beliefs in comparison to non-gifted students of the same age."*

Sample Groups and Conduct

Two sample groups were investigated. Both consisted of grade five students, with one group participating in the project Kolumbus-Kids and the other being a normal class at secondary schools in [xxx], Germany.

As mentioned before, Kolumbus-Kids is a tutoring project for scientifically gifted children from [xxx] and surrounding cities. The children are chosen with a special ability test targeting their giftedness. Only the ones doing particularly good in this test are invited to take part in the project on a voluntary basis. The sample group from the project taking part in this studyconsists of 37 of such children.

The other group, used as a control group in this study, consists of 82 students from three different secondary schools in [xxx]. The choice about which secondary schools to include was made randomly.

The study followed a classic pre-test post-test design. Both sample groups were first tested in February 2012, the sample group in the first session of the Kolumbus-Kids project. The second test was then conducted after three months in early June 2012. During the time of the study, both groups had three times 45 minutes of regular biology classes a week, with the sample group attending an additional weekly 90 minutes project session.

The Questionnaire

The questionnaire used for this study was a translated version of an inquiry schedule developed by Conley et al. (2004) on the basis of Hofer and Pintrich's theory regarding epistemological beliefs. Further changes were made to its wording in order to make it suitable for biological topics. It depicts the following four dimensions of epistemological beliefs: source, certainty, development, and justification of knowledge. Each of these dimensions is represented by five to nine items in the questionnaire, all framed as statements and adding up to 26 items in total (see Table 1 and appendix).

Table 1

Translations of the Questionnaire's Items as used for this Study

Source of Knowledge
Everybody has to believe in what biologists say.
In biology, you have to believe what you read in textbooks.
Everything the teacher says in biology classes is correct.
If you read something in your biology textbook, you can be sure it is correct.
Certainty of Knowledge
There is one correct answer to every biological question.
The most important thing in biological research is finding the correct answer.
Biologists know almost everything about biology; there is not much left to discover.
Biological knowledge is always right.
Once biologists got a result out of an experiment, this is the only outcome possible.
Biologists are always united on what is correct in biology.
Development of Knowledge
Some of today's ideas in biology differ from those of the past.
Ideas presented in biological textbooks can change sometimes.
Even biologists cannot answer every biological problem.
Biological ideas change from time to time.
New findings in biology can change the way biologists view biological phenomena.
Sometimes biologists change their view regarding what is correct.
Justification of Knowledge
Ideas for experiments come from curiosity and thoughts about how things work.
There is more than just one way for biologists to investigate on their thoughts.
Conducting experiments is an important aspect of biological work.
It is important to conduct experiments several times to see if the outcome is correct.
Good ideas in biology can come from anybody, not just biologists.
Conducting experiments is a good way in biology to find out if something is correct.
Good answers in biology consider the outcome of more than just one experiment.
New ideas in biology can come from former questions and experiments.
In biology, it is important to have a hypothesis before conducting an experiment.

To each of these statements, the children have to tick a box on a scale according to their approval of the preceding item. The scale is: A = exactly, B = kind of, C = not really, D = not at all. Depending on the item, answer A either represents a very advanced epistemological belief, thus resulting in four points for the student, or a very naive and inexperienced belief, resulting in only one point.

Results

Hypothesis 1 postulated a significant development of the epistemological beliefs in scientifically gifted children because of the project's classes. At the same time, it stated there would be no such change in non-gifted students only participating in regular biology classes. There was an obvious change towards more advanced levels in the categories *source*, and *certainty of knowledge* within the sample group. A variance analysis proved these results are significant (*p*<0,001-0,008). Unfortunately, the same is true for the control group. Hence, hypothesis 1 has to be rejected regarding the dimensions *source* and *certainty of knowledge*. There are no relevant changes regarding the other two categories, *development* and *justification of knowledge*, at all. Another variance analysis revealed the changes are only significant in the dimension *development of knowledge* within the control group, while all other changes turn out to be non-significant. This means hypothesis 1 has to be rejected for the remaining categories as well. Striking about these results is the extraordinary advanced state of epistemological beliefs within both groups that was found at the pre-test already.

Hypothesis 2 stated gifted students would show more advanced epistemological beliefs in biology than non-gifted ones in all dimensions at every test. The results depicted in Figure 2 show this is true for the dimensions *source* and *certainty of knowledge*.

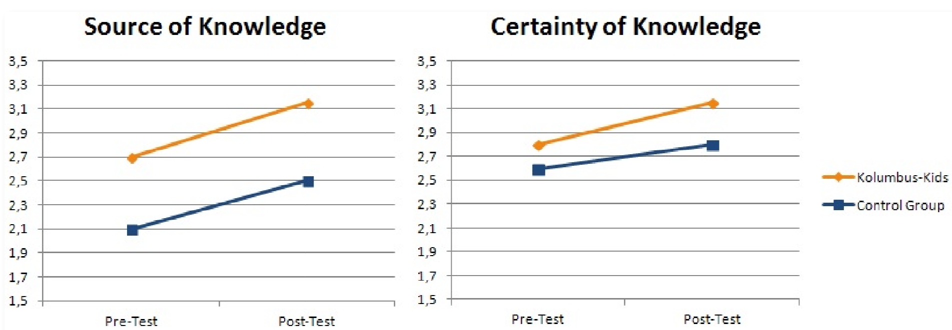

Figure 2 Results for hypothesis 2 regarding the dimensions source and certainty of knowledge.

Obviously there is a big difference between the gifted and the non-gifted children, with the former showing the more advanced epistemological beliefs in both categories. A variance analysis demonstrated these results are significant, thus approving hypothesis 2 for these dimensions.

The difference between the gifted and the non-gifted students is not that large in the dimensions *development* and *justification of knowledge*, though (see Figure 3). Still, the gifted students showed a better result which a variance analysis revealed to be significantly higher than the one delivered by the non-gifted children. Therefore, hypothesis 2 is correct for these dimensions as well.

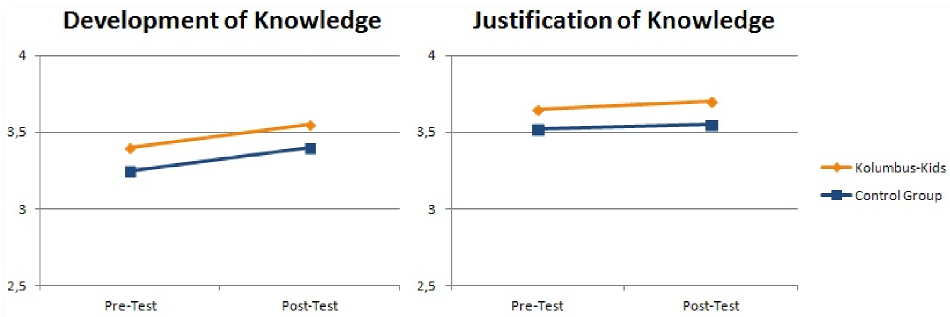

Figure 3 Results for hypothesis 2 regarding the dimensions development and justification of knowledge.

Discussion and Prospects

Conley at al. (2004) have shown there were significant changes in all dimensions of epistemological beliefs of 5th graders towards more advanced levels during a science teaching unit spanning nine weeks. It has to be kept in mind they did not have a control group, though.

The study at hand could only find significant increases in the dimensions *source* and *certainty of knowledge*. But, these changes were to be found in the sample group as well as in the control group. This means both groups did not consider authorities impeccable and knowledge unambiguous anymore at the end of the study. Significant changes could not be found for the category *justification of knowledge* in any of the groups, while the control group showed a significant improvement regarding the *development of knowledge*. This means the gifted students did not significantly change their views concerning alteration of knowledge and its justification, thus proving hypothesis 1 wrong in this regard.

As mentioned before, Conley et al. (2004) did not have a control group. Thus, it is not completely clear what affected their results. The changes in epistemological beliefs found in their study might be caused by effects of growing up or the regular teaching units their sample group was attending while taking part in the study. The study at hand shows this might well be the case as both groups' results proved to be significant changes regarding the source and certainty of knowledge.

Furthermore, the *development* and *justification of knowledge* probably were influenced by other things as they were already extraordinary advanced in both groups at the time of the pre-test. Both groups stated knowledge can be changed over time and that assumptions can be proved by experiments. Such advanced levels of epistemological beliefs are hard to improve further, thus making it difficult to get significant results here.

Therefore, the study at hand shows more research has to be done to verify the results found by Conley et al. (2004) before declaring them universally valid. Such studies might also investigate the respective teachers' intentions and plans in regular classes in order to show whether they also target the children's epistemological beliefs. This could reveal whether effects found in studies on epistemology are also due to influences from normal school lessons and of growing up.

The results found in this study also showed that gifted students have more sophisticated epistemological beliefs in all dimensions than normal students, thus proving hypothesis 2 to be correct. It additionally revealed that students can have different levels of development regarding different dimensions according to Hofer and Pintrich's (1997) theories and definitions, with the categories *development* and *justification* being more advanced. Contrary to these findings, Perry (1970) postulated a coherent model were the dimensions influence each other, hence developing simultaneously. But the results found here suggest that the different dimensions develop at their own, unique pace. In this case, the categories *source* and *certainty of knowledge* evolve faster than the other two. This would mean younger children believe in their teachers as authorities and in unambiguous knowledge more than in its constancy. They also know that assumptions can be proven with experiments. For future studies, it would be especially interesting to see whether the belief in authorities changes at different speeds in different countries because of cultural varieties.

It also became apparent that gifted students have more advanced epistemological beliefs compared to their non-gifted peers. This means they are able to handle and use their knowledge in more intelligent and more efficient ways, thus achieving higher learning outcomes. It would be interesting to see where these early advanced beliefs originate from (e.g. from how their parents treat them) and whether they influence the development of the children's learning strategies and their giftedness.

References

Bromme, R., & Kienhues, D. (2007). Epistemologische Überzeugungen. Was wir von (natur-) wissenschaftlichem Wissen erwarten können. In J. Zumbach & H. Mandl (Eds.), *Pädagogische Psychologie in Theorie und Praxis*. Göttingen: Hogrefe.

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology, 29*, 184-204.

Gruber, H., & Stamouli, E. (2009). Intelligenz und Vorwissen. In E. Wild & J. Möller (Eds.), *Pädagogische Psychologie*. Berlin, Heidelberg: Springer- Verlag.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Journal of Educational Psychology Review, 13*(4), 353-383.

Hofer, B. K., & Pintrich, P. R. (1997).The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Research in Education, 67*(1), 88-140.

Kienhues, D., Bromme, R., & Stahl, E. (2008). Changing epistemological beliefs: The unexpected impact of a short-term intervention. *British Journal of Educational Psychology, 78*, 545-565.

Schommer, M. (1990). Effects of belief about the nature of knowledge on comprehension. *Journal of Educational Psychology Review, 82*(3), 498-504.

Thomas, J. A. (2008). An analysis of epistemological change by gender and ethnicity among gifted high school students. *Gifted Children Quarterly, 52*(1), 87-91.