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Confront and Cluster—How Different Groups of Primary School Children Respond to Instruction towards Conceptual Change at an Out-of-School Learning Setting

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Abstract

We sampled the alternative conceptions of 257 third grade students (8-11 years old) using an open questionnaire. The answers were categorized into three topics and used to construct a multiple choice instrument. Following the pretest our instruction phase contained the confrontation with the students' own alternative conceptions about humans' and cats' vision at a wildlife-park. Immediately after instruction, the multiple choice instrument was presented as a post test and several weeks later as a retention test. Due to the heterogeneity within our student sample we defined and found five different groups. Our data shows that the instruction of primary school children using confrontation according to the conceptual change theory does not lead to a change of conceptions or to synthetic models, furthermore we found no detectable conceptual growth. Finally, students with the accepted scientific conception as well as students with other concepts seemed to be confused by this instruction.

Keywords

alternative conceptions, conceptual change, night vision, out-of-school learning setting, primary school

1. Introduction

What students already know is very important throughout the learning process (Ausubel, 1968). Learners' conceptions, their mental models of objects of events (Glynn & Duit, 1995), need to be addressed, especially if those conceptions differ from the scientific concept. Strike and Posner (1982) propose four steps to foster a successful accommodation leading to a conceptual change (Kubisch & Heyne, 2015; Strike & Posner, 1982): First and foremost there must be a "dissatisfaction with existing concepts". Secondly, the new conception must be intelligible. The third step should be, that the new, scientific conception has to appear initially plausible. As a fourth and last phase the conception should appear fruitful to solve further problems of the same or a similar kind (Strike & Posner, 1982).

We assembled our instructional phase based upon these four pillars using a practical approach by Petermann, Friedrich and Oetken (2008), "Das an Schülervorstellungen orientierte Unterrichtsverfahren", instruction using the conceptual change model. First we needed to get to know the alternative conceptions, then define the problem, refute and secure the new knowledge (Petermann, Friedrich, & Oetken, 2008). Considering reading and presenting skills in primary school children we used the confrontation with pictures (Kubisch & Heyne, 2015; Franke & Bogner, 2011) and a teacher centered discussion during the refutation part instead of refutation text (Tippett, 2010).

We wish to emphasize that our approach was a discontinuous one (Jung, 1986; Strike & Posner, 1982; Tippett, 2010). We ensured to use students' alternative conceptions as a starting point but instead of establishing a continuous form of learning on top of that, we intended to create a "cognitive conflict" (Franke & Bogner, 2011; Limon, 2001) by confronting them with their own alternative conceptions in a context that would assure the initial perception of said alternative conception to be neither plausible, therefore not useful to solve the current problem, nor fruitful as a solution for future problems (Tippett, 2010). Duit (1995) also states a discontinuity in the process, caused by a change in directions when students are confronted with their own concept.

Our main focus was the expected heterogeneity of alternative conceptions and the resulting groups within our participating classes. While Poehnl and Bogner (2013) determined two levels of prior knowledge, "experts" and "novices" based on the number of correct scientific conceptions, we wanted to differentiate further and therefore tried a more qualitative approach to detect changes in conceptions. We strongly assumed heterogeneity of different conceptions to be a major factor for conceptual change and designed groups of prior knowledge accordingly (Poehnl & Bogner, 2013; Tippett, 2010; Vosniadou et al., 2001).

"Conceptual change": We apply this term to students that started out with an alternative conception and changed it throughout an instruction phase to the scientific conception by means of "accommodation", the actual integration of the new, scientific information following a restructuration of prior knowledge (Tippett, 2010) and rejection of the alternative conception.

"Synthetic models": In order to define the process in which new scientific knowledge is added to the alternative conceptions we used Vosniadou et al. (2001), where mixed models of knowledge stored in the learner's mind are described. Killermann, Hiering and Starosta (2013) apply the german term "Kompartmentalisierung", compartmentalization of knowledge, painting a vivid picture of how the different models are stored in different compartments in the learner's mind. They define the process as accepting the scientific model while still embracing the alternative conception (Killermann, Hiering, & Starosta, 2013).

"Conceptual Growth": Conceptual growth in general may be applied to more than one process (Tippett, 2010). In contrast to "accommodation" described above, "assimilation" (Strike & Posner, 1982) represents a scenario where the new scientific information is stored along with the alternative conception (Tippett, 2010) or is added when there was no prior knowledge, leading to a growth rather than a change in conceptions. To define conceptual growth in a way we could detect in the questionnaires we limited the term to the growth of knowledge when there was no prior conception, meaning the students marked "I don't know" in the pretest and the scientific conception in the posttest.

These are our hypotheses:

(i) Alternative Conceptions: The "conceptual change" group should respond to the discontinuous approach according to Strike and Posner (1982) by changing their alternative conceptions towards the scientific conceptions.

(ii) There should occur a "synthetic models" group keeping the alternative conception alongside the scientific approved one.

(iii) No conception at the start: The instruction should result in a "conceptual growth" group.

(iv) Exceeding these groups we defined a knowledge'-group as well as a "non-addressed concepts"—group. We expected these groups to be confused by the discontinuous approach.

2. Method

2.1 Study Design

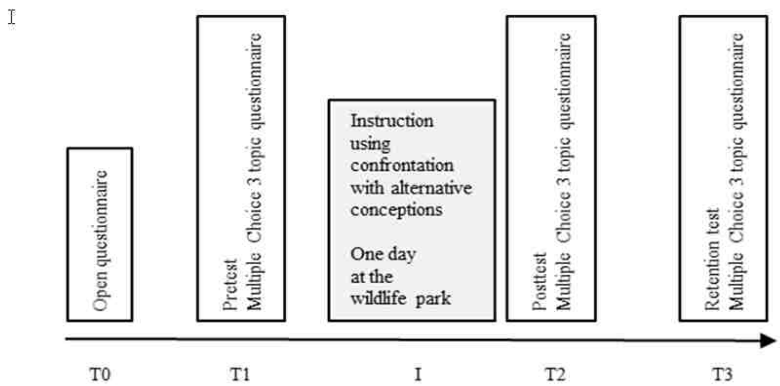

Figure 1. Overview of the Tests and Their Times as Well as the Instruction Phase

T0: 10 weeks prior to the first pretest, T1: Pretest one week before instruction, I: Instruction,
T2: Posttest immediately following the instruction, T3: Retention test 6-8 weeks after instruction.

2.2 Constructing the Open Questionnaire

To obtain students' alternative conceptions we followed Treagust (1988). Our first task was to define the content (Treagust, 1988). We investigated the main scientific concepts on human vision and the differences between humans' and cats' night vision on a third grade level following the curriculum for elementary schools. Then we collected possible answers in the literature (Çelikten, İpekçioğlu, Ertepınar, & Geban, 2012; Gropengießer, 1997; Guzetti et al., 1997; Kattmann et al., 1997).

In order to obtain information about students' misconceptions (Treagust, 1988) we created an open questionnaire. To get a high validity, we presented all students later to participate in the study with the test a few months after school had started in order to get their very own alternative conceptions not yet influenced by their science curriculum.

2.3 Instructions for Answering the Open Questionnaire

During the test students were given a short introduction by the same researcher into the human eye's parts and their names to prevent wrong answers due to confusion or lack of knowledge of nomenclature. Furthermore, students were instructed to answer regardless of specific knowledge to really get all the information and not only answers from students that were sure to know the right answer, as they are usually instructed to do in school.

2.4 Constructing the Diagnostic Test to Measure the Changing of Conceptions

For test construction of the main diagnostic instrument (T1, T2 and T3, see Figure 1) we also followed Treagust (1988) with a slight alteration. We set out to "Defining the content" (Treagust, 1988) by analyzing the open questionnaires in regard to the main content we already defined prior to constructing the open questionnaire. The phase "Obtaining information about students' misconceptions" (Treagust, 1988) took place after carefully evaluating the open questionnaires. We coded the different conceptions into categories and counted the appearances of the most frequently named conceptions. We ranked the conceptions based on the frequency of their appearance. We singled out three major topics. For the development of our diagnostic test instrument later to be used in a pre-, post- and retention design for third grade students we decided not to use the two tier method (Treagust, 1988) but merely the multiple choice items constructed for the three major topics in order to avert confusion of the primary school children.

2.5 Topics in the Multiple Choice Instrument

For Topic 1 "humans need light in order to see" we asked the question "Is it possible for humans to see something when it is completely dark?" For clarification purposes students were instructed to assume "real" darkness, not dusk or dawn or some faint light source. We provided the scientific concept "no, humans need light to see", the most common alternative conception "yes, humans can see in total darkness, they just have to get used to the darkness", "I don't know" as well as positive and negative distractors sampled from the open questionnaire.

Topics "wildcats can see better in the dusk or dawn than humans" and "function of the iris" were treated equally. For Topic 2 "Why is it that in dusk or dawn wildcats are able to see better than humans?" The scientific concept was "Wildcats' eyes reflect the light" with the most common alternative conception "Wildcats' eyes shine in the dark". Topic 3 "What do humans and wildcats need the iris for?" could be answered "The iris makes the pupil bigger or smaller" or "The iris allows to see colours" respectively.

2.6 Student Sample

Our study took place with 16 third grade classes in summer 2014 in an out-of-school learning setting at a wildlife-park (16 classes, n = 257). The diagnostic test was made up of three topics, every topic consisting of seven choices: "I don't know" (later to be used as "no concept"), the scientifically right concept, the most common alternative conception as well as four distractors. The students were allowed to mark any number of answers they found to be correct in order to get a real overview and not force them chose one concept over another when both were equally important to them.

2.7 Instructional Unit

The confrontation with the most common alternative conception was built into the instruction by showing of pictures and discussing the content, thereby addressing and correcting the conception. All students were given the same instructional unit, materials and pictures. The instruction was presented by the same researcher as a constructivist problem-oriented lesson revolving around the question "why do cats see better in dusk and dawn?" From the open questionnaire it was clear that all students knew cats have superior vision in dusk and dawn, therefore we could ask the question that way. Instructor and students took the role of scientists trying to solve the question and the confrontation with students' alternative conceptions was built into the lesson along the way. Every student had a workbook containing tasks we solved as a group and then filled in individually.

While talking about the eye's structure we found out that the pupil is in fact an opening to allow light into the eye. At that point the confrontation and discussion of the alternative conception "yes, humans can see in total darkness, they just have to get used to the darkness" took place. Right after that there arose the question, how the pupil can get bigger and smaller. At that point we targeted the conception "the iris allows to see colours". Finally, we put together all the reasons for the cat to have better night vision and added the confrontation "wildcats' eyes shine in the dark".

2.8 Group Definition by Marking Behavior

We defined three groups (see Table 1) as we saw fit according to conceptual change theory literature (Tippett, 2010; Vosniadou et al., 2001). We predicted these groups to be found due to the possible behaviour during the three points of measurement: pre-, post- and retention-test.

"Conceptual change": Students in this group started out in the pretest (T1) with the most common alternative conception. In the posttest (T2) directly following the instructional unit they changed their prior conception to the scientifically approved conception and stayed with that conception also during the retention-test (T3) administered about two months later.

"Synthetic models": These students started with the most common alternative conception to which they later "added" the scientific conception in a way that both conceptions are stored alongside. "Conceptual Growth": "I don't know" was marked in the pretest (T1), followed by the scientific concept in post- and retention-test.

Table 1. Group Definition According to the Literature by Order of Marking over Time

Group	Conceptual Change	Synthetic Models	Conceptual Growth
Pretest	Alternative conception	Alternative conception	No conception
Posttest	Scientific conception	Alternative and scientific conception	Scientific conception
Retention test	Scientific conception	Alternative and scientific conception	Scientific conception

In addition to these groups we postulated one more group "knowledge" and found another one "non-addressed concepts" (see table 2):

"Knowledge": In this group students always marked only the right conception consistently during all tests. We used this group to test whether students with the right conception would be confused by the confrontation with other students' alternative conceptions.

"Non-addressed concepts": Students in this group marked neither the scientific conception nor the alternative one, they also did not mark "I don't know" but one or more of the four remaining conceptions that were not addressed during the instruction phase. We found a variety of alternative conceptions in the open questionnaire data that we did not address in our instruction but used to build the multiple choice diagnostic test.

The "non-addressed" as well as the "knowledge"-group are tabulated "reversed". Instead of searching for all markings other than the scientific conception, we use the scientific conception and show the reverse effect.

Table 2. Group Definition New Groups by Order of Marking over Time

Group	Knowledge	Non-addressed concepts
Pretest	Scientific conception	Other conceptions
Posttest	Scientific conception	Scientific conception
Retention test	Scientific conception	Scientific conception

3. Result

Heterogeneity: Overview for topics 1 through 3 (see Table 3)

Table 3. Overview Markings in the Pretest (T1) All Topics (Percentage of Markings in the Pretest)

	Topic 1	Topic 2	Topic 3	mean
Alternative conception	23%	20%	30%	25%
Scientific conception	29%	9%	11%	16%
No conception	6%	16%	29%	17%
Other conceptions	42%	55%	30%	42%

We tabulated the pretests to get a better overview and found the predicted heterogeneity in regard to students' prior knowledge. Considering all three topics twenty-five percent of the students started out with the addressed alternative conception. This was the group we targeted with our instruction. A major part, forty-two percent, consists of students with one or more different conceptions that were not addressed later. Equally distributed were "no conception" (sixteen percent) and "scientific conception" (seventeen percent).

3.1 Groups

We worked with a nominal data set and didn't change the variables into metric ones in order to preserve the full information content. We used descriptive statistics to illustrate the amount of various ways to respond to the confrontation.

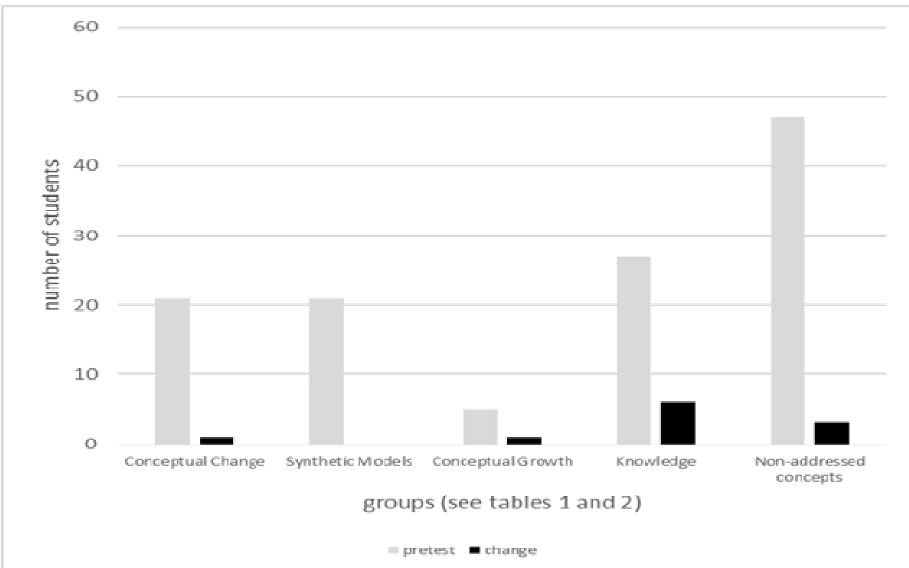

Figure 2. Marking Behavior Topic 1

Grey bars represent the number of students who marked the corresponding answer in the pretest (T1). The answer corresponding to the group can be found in Tables 1 and 2. For example, the grey bar in the "conceptual change" group stands for 21 students marking "alternative conception" in the pretest. The black bar ("change" throughout all tests) shows the change in marking behaviour throughout the three tests also according to Tables 1 and 2. For example, the black bar in the conceptual change group represents 1 student who marked "alternative conception" in the pretest (T1), the "scientific conception" in the posttest (T2) and the "scientific conception" in the retention test (T3).

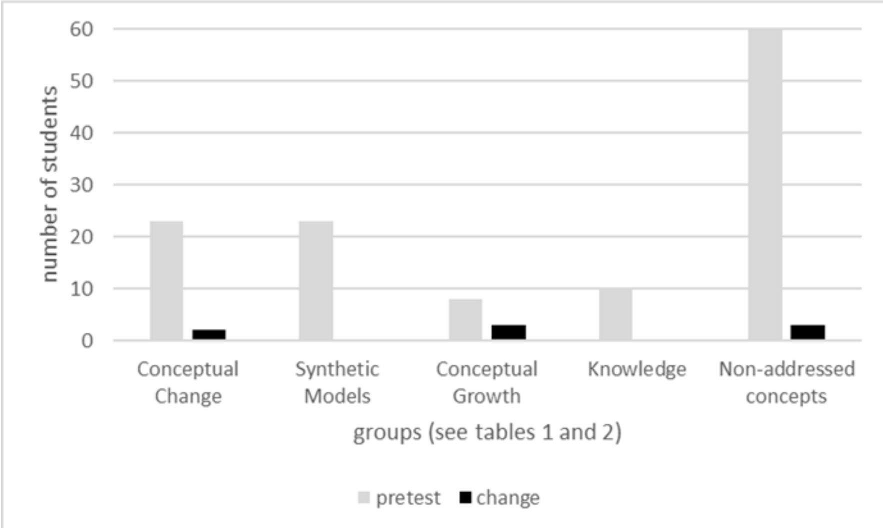

Figure 3. Marking Behavior Topic 2

Grey bars represent the number of students who marked the corresponding answer in the pretest (T1). The answer corresponding to the group can be found in Tables 1 and 2. For example, the grey bar in the "synthetic models" group stands for 23 students marking "alternative conception" in the pretest. The black bar ("change" throughout all tests) shows the change in marking behavior throughout the three tests also according to Tables 1 and 2. For example the black bar in the synthetic models group represents 0 students who marked "alternative conception" in the pretest (T1), the alternative and the scientific conception in the posttest (T2) and the alternative and the scientific conception in the retention test (T3).

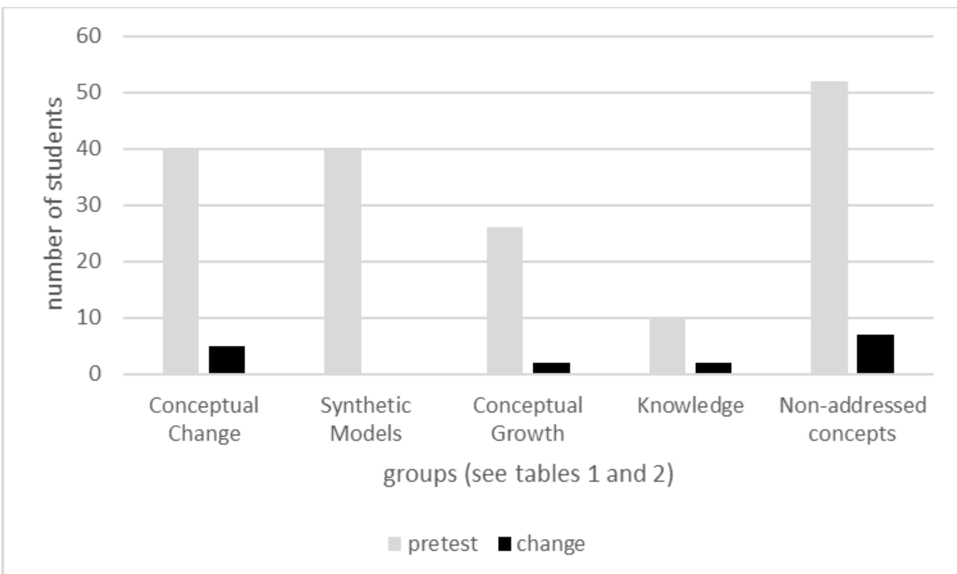

Figure 4. Marking Behaviour Topic 3

Grey bars represent the number of students who marked the corresponding answer in the pretest (T1). The answer corresponding to the group can be found in Tables 1 and 2. For example, the grey bar in the "conceptual growth" group stands for 26 students marking "no conception" in the pretest. The black bar ("change" throughout all tests) shows the change in marking behaviour throughout the three tests also according to Tables 1 and 2. For example, the black bar in the conceptual growth group represents 2 students who marked "no conception" in the pretest (T1), the "scientific conception" in the posttest (T2) and the "scientific conception" in the retention test (T3).

3.2 Alternative Conceptions: Conceptual Change and Synthetic Models

Conceptual Change: We tried to find out whether a successful conceptual change in the sense of Strike and Posner (1982)'s accommodation would be achieved. This study with third grade students promotes that this goal could not be achieved (see Figures 2, 3, 4).

Synthetic Models: We couldn't detect a lot of students that stored the information according to the "assimilation" theory that should lead to mixed models (see Figures 2, 3, 4).

3.3 No Conception: Conceptual Growth

This group was rather small to begin with due to the fact that only few students started out with no concept at all. Even those few students did not add the new scientific information frequently (see Figures 2, 3, 4).

3.4 Scientific Approved Conception: Knowledge

Only few students maintain the right conception throughout the study (see Figures 2, 3, 4).

3.5 Non Addressed Conceptions

Students with different non addressed conceptions did not change to the right conception (see Figures 2, 3, 4).

4. Discussion

Our data shows that there is in fact the heterogeneity of students' prior knowledge we predicted (Tippett, 2010). We would like to emphasize that about half the students were confronted with a conception they didn't hold in the first place while only around 25% could really be targeted with the alternative conception they actually held (see Table 3).

Contrary to our first hypothesis our methods of confronting third grade students with their alternative conceptions using pictures (Franke & Bogner, 2011; Kubisch & Heyne, 2015) could not foster changes in conceptions. This discontinuous way of learning (Duit, 1995; Strike & Posner, 1982) does not seem to be an appropriate approach for changing alternative conceptions in primary school children, neither for the targeted group nor for the other, non-targeted groups that did not start with the addressed alternative conception found in the open questionnaire.

Students who entered the instruction with the scientific approved conception or no conception at all seemed to be confused as there were only a few students who held the scientific approved conception later on. These findings for the "knowledge" group are backed up by Poehnl and Bogner (2013), who assume an "expertise reversal effect" also their results cannot be compared verbatim since they focused on a modified refutation text and cognitive load theory.

Regarding our second hypothesis the instruction also did not lead to an assimilation resulting in Synthetic Models. This model, described throughout the literature (Vosniadou et al., 2001), could not be found within our data at all.

Finally, the substantial non-addressed conceptions group reacted as well with a lack of change in conceptions. After all, they are confronted not only with the scientific conception but at the same time with a conception they never actually had. This seems to lead to confusion.

Of course we have to take into consideration that the means of confrontation might have to be changed. Kubisch and Heyne (2015) already assumed their pictures "were so explicit and memorable that the students rather remembered these instead of the scientifically correct ones". This may also be the case in this study although we had to deal with limited alternatives regarding third grade students' reading comprehension.

In addition, Jung (1986) states that the scientific conception has to be repeated many times by the teacher, otherwise students would rather forget it and return to their alternative conceptions. In our study we had a time limit therefore, they could be repeated only a few times.

Summarizing these findings we reach the conclusion that primary school children seem to be overstrained by the instruction following the conceptual change theory. From our point of view confronting this age group with more than one alternative conception during the instruction phase in each topic probably also does not lead to a change to the scientific conception, on the contrary might lead to causing even more confusion.

To test our resulting theories we need to apply a true control group with a traditional instruction without confrontation. We believe that the additional cognitive load of this discontinuous way should not be used for third grade students. To make sure we plan a comparative study where one group is confronted with their alternative conceptions and the other one is instructed without confrontation (Kubisch & Heyne, 2015). We assume the traditional instruction will lead to a better cognitive outcome for primary school children.

To evaluate the results of the planned comparative study a cognitive questionnaire should be developed to quantify cognitive outcome in addition to recording changes in conceptions. In pursuance of getting a better grasp of a change in conceptions we constructed an instrument that was not only based on factual knowledge but truly integrated the actual conceptions of our participating students. Due to the mode of construction the opportunities of statistical analysis were limited.

5. Conclusion

We found a wide variety of prior knowledge in our study, therefore we propose that in order to instruct successfully, the heterogeneity of prior knowledge must be taken into consideration. Our remaining question thereby is how to accomplish this with primary school children. Our data strongly suggests that the processes and models predicted in conceptual change literature do not apply to third grade students in an out-of-school learning setting.

Assuming that the discontinuous conceptual change process rather overstrains primary school children in general, we recommend a different kind of instruction, especially the constructivist teaching approach "guided learning at workstations" (Heyne & Bogner, 2012; Wiegand, Kubisch, & Heyne, 2013). These prior studies have shown great success in a combination of constructivist teaching approaches and teacher-centered instruction, especially in an out-of-school learning setting, as is the case at a wildlife park.

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References

Ausubel, D. P. (1968). Educational psychology. In *A cognitive view*. New York: Holt, Rinehart & Winston.

Barke, H.-D. (2006). *Chemiedidaktik. Diagnose und Korrektur von Schülervorstellungen* [Chemistry didactics. Diagnosis and correction of students' conceptions]. Berlin, Heidelberg, Germany: Springer (Springer-Lehrbuch).

Çelikten, O., İpekçioğlu, S., Ertepınar, H., & Geban, Ö. (2012). The Effect of the Conceptual Change Oriented Instruction through Cooperative Learning on 4th Grade Students' Understanding of Earth and Sky Concepts. *Science Education International*, *23*(1), 84-96.

Duit, R. (1995). Vorstellungen und Lernen von Physik und Chemie. Zu den Ursachen vieler Lernschwierigkeiten [Conceptions and learning in physics and chemistry. About the causes for several learning difficulites]. *Plus Lucis*, *2*, 11-18.

Franke, G., & Bogner, F. X. (2011). Cognitive Influences of Students' Alternative Conceptions within a Hands-On Gene Technology Module. *Journal of Educational Research*, *104*(3), 158-170. https://doi.org/10.1080/00220671003636745

Glynn, S. M., & Duit, R. (1995). Learning science in the schools. In *Research reforming practice*. Mahwah, New Jersey: L. Erlbaum Associates.

Gropengießer, H. (1997). Schülervorstellungen zum Sehen [Students' alternative conceptions about vision]. *Zeitschrift für Didaktik der Naturwissenschaften*, *3*(1), 71-87.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting Conceptual Change in

Science. A Comparative Meta-Analysis of Instructional Interventions from Reading Education and Science Education. *Reading Research Quarterly*, *28*(2), 116-159. https://doi.org/10.2307/747886

Hammann, M., & Asshoff, R. (2014). Schülervorstellungen im Biologieunterricht. In *Ursachen für Lernschwierigkeiten* [Students' alternative conceptions in biology education. Causes for learning difficulties]. Seelze, Germany: Kallmeyer in Verbindung mit Klett.

Heyne, T., & Bogner, F. X. (2012). Guided Learning at Workstations about Drug Prevention with Low Achievers in Science Education. *World Journal of Education*, *2*(6), 1-12. https://doi.org/10.5430/wje.v2n6p1

Jung, W. (1986). Alltagsvorstellungen und das Lernen von Physik und Chemie [Everyday misconceptions and learning in physics and chemistry]. Naturwissenschaften im Unterricht. *Physik, Chemie*, *34*(13), 2-6.

Kattmann, U. (2007). Die Bedeutung von Alltagsvorstellungen für den Biologie-Unterricht [The importance of everyday misconceptions in biology education]. *Unterricht Biologie*, *31*(329), 2-6.

Kattmann, U., Duit, R., Gropengießer, H., & Komorek, M. (1997). Das Modell der Didaktischen Rekonstruktion-Ein Rahmen für naturwissenschaftsdidaktische Forschung und Entwicklung [The model of didactic reconstruction—A framework for research and development in science didactics]. *Zeitschrift für Didaktik der Naturwissenschaften*, *3*(3), 3-18.

Killermann, W., Hiering, P., & Starosta, B. (2005). Biologieunterricht heute. In *Eine moderne Fachdidaktik* [Biology education today. A modern subject didactics]. Donauwörth, Germany: Auer.

Kubisch, F., & Heyne, T. (2015). Students' Alternative Conceptions about the Lotus Effect. To Confront or to Ignore? *Journal of Biological Education*, *50*(1), 86-100. https://doi.org/10.1080/00219266.2015.1007886

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, *11*(4-5), 357-380. https://doi.org/10.1016/S0959-4752(00)00037-2

Petermann, K., Friedrich, J., & Oetken, M. (2008). Das an Schülervorstellungen orientierte Unterrichtsverfahren [Education based on students' alternative conceptions]. *CHEMKON*, *15*(3), 10-18. https://doi.org/10.1002/ckon.200810074

Poehnl, S., & Bogner, F. X. (2013). A modified refutation text design: Effects on instructional efficiency for experts and novices. *Educational Research and Evaluation*, *19*(5), 402-425. https://doi.org/10.1080/13803611.2013.789229

Strike, K. A., & Posner, G. J. (1982). Conceptual change and science teaching. *European Journal of Science Education*, *4*(3), 231-240. https://doi.org/10.1080/0140528820040302

Tippett, C. D. (2010). Refutation text in science education: A review of two decades of research. *International Journal of Science and Mathematics Education*, *8*(6), 951-970.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education*, *10*(2), 159-169. https://doi.org/10.1080/0950069880100204

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction*, *11*(4-5), 381-419.

Wiegand, F., Kubisch, A., & Heyne, T. (2013). Out-of-school learning in the botanical garden. Guided or self-determined learning at workstations? *Studies in Educational Evaluation*, *39*(3), 161-168. https://doi.org/10.1016/S0959-4752(00)00038-4