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Hydrology and Earth System Sciences
Discussions

# *Interactive comment on* "Understanding groundwater – students' pre-conceptions and conceptual change by a theory-guided multimedia learning program" *by* U. Unterbruner et al.

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Response to Reviewer's Comments on our manuscript "Understanding groundwater – students' pre-conceptions and conceptual change by a theory-guided multimedia learning program"

First of all, we want to thank the reviewer for her/his valuable comments on our manuscript. The suggestions are helpful for improving the quality of our paper. Please find below our replies on the reviewer's comments.

REVIEWER'S COMMENT: General remarks: The paper describes a study concerning



the evaluation of a multimedia learning program for schools that was developed by the authors in order to change frequent and persistent preconceptions about groundwater. The most common preconception about groundwater is the idea that large subsurface openings are necessary to store it. This preconception impairs the learning of the science concepts of groundwater formation, storage and contamination. A fundamental change of this preconception concerns the comprehension of the fact that groundwater does not necessarily need large subsurface caves or tunnels to be stored underground. In the last 10 years a number of research papers have addressed this issue and are referred to in this paper. The paper is well written and structured and considers relevant publications in this field of study. Theoretical background: The MER by Kattmann et al. (1997) and the conceptual change theory served as theoretical frame of the learning program. Yet, the authors' understanding of conceptual change remains unclear. They do not explicitly explain what conceptual change means to them and this causes inconsistencies in the study. They reference a sentence by Stella Vosniadou which I take as a definition for conceptual change: "...science learning does not require the replacement of an "incorrect" by a "correct" concept, "but the ability on the part of the learner to take different points of view and understand when different conceptions are appropriate depending on the context of use (Vosniadou, 2007, p. 58)" (p. 11696, line 14-17). If this definition expresses the authors' idea of conceptual change they should have related their interpretation of the results and conclusions to it.

AUTHORS' RESPONSE: Due to the length of our manuscript, we tried to formulate our theoretical bases (Conceptual change research, MER) short and solid. We gave more space to the storyboard's dramaturgy of our multimedia learning program, because we think that it might be more interesting for people who are interested in hydrogeology education. But of course, the reviewer's wish for more details could be satisfied. Primarily, we base our work on the conceptual change approach of Gale Sinatra and Stella Vosniadou.

REVIEWER'S COMMENT: The authors claim that the design of their learning program

was theory-guided in reference to the MER but they do not disclose the methodological path they used when designing their program according to the MER. The crucial point of the MER concerns the process of how to match a science concept to the learners' pre-instructional, often "naïve" conceptions, in order to help them to learn the science concept.

AUTHORS' RESPONSE: Please see chapter 3.3.

REVIEWER'S COMMENT: The authors state that according to the MER "the science contents may not be presented in a simplified ("reduced") manner in science instruction, but a new science content structure for instruction." (p. 11693, lines 1-2). Although this statement is true, the term "new" might be a bit misleading. What do the authors mean by "new"?

AUTHORS' RESPONSE: According with Duit et al. (2012, p. 29), we assume that during the iterative approach of MER (between the content structure and the student pre-instructional conceptions) new ideas for science instruction have to be found and will be developed in a successful process of educational reconstruction.

REVIEWER'S COMMENT: Kattmann et al. (1997) meant that the science content structure has to be reconstructed for learning in schools in a way that it relates the science content to the experiences and the world knowledge of learners who do not have all the background knowledge a hydrologist has and retrieves to. Therefore, the scientific concept and the students' pre-knowledge as well as the role this pre-knowledge plays in the students' knowledge construction process need to be analyzed. To achieve the educational reconstruction of the science concept in question, the key ideas of that science concept need to be understood and the commonalities and differences between the science concepts and the students' pre-knowledge need to be identified. C5672 Unfortunately, the paper does not give any information of how the authors bridged the gap between the structure of the science content and the students pre-knowledge.



AUTHORS' RESPONSE: See chapter 3.3. (11700 – 11703) where we described in detail how we intended to bridge the gap between students' pre-knowledge and science content.

REVIEWER'S COMMENT: On p.11698, lines 12-24 und p. 11699, lines 1-7 key ideas that need to be addressed in the learning process are listed (references?).

AUTHORS' RESPONSE: The key ideas for understanding groundwater are common hydrogeological knowledge, but we can gladly refer to Hölting, B. & Coldewey, W. G. (2013): Hydrogeologie, 8. Auflage, Springer Spektrum, Stuttgart, Heidelberg; Davis, N.S., & de Wiest, R. J. M. (1966): Hydrogeology. - Elsevier, Amsterdam, Hilberg, S. (2015). Umweltgeologie. Springer Verlag, Berlin-Heidelberg.

REVIEWER'S COMMENT: On p. 11700-11701 the key idea, that played a role in the design process of the learning program, are listed. But how are these lists interconnected to each other and to the students' preconceptions? In the journal "Beiträge zur didaktischen Rekonstruktion" or in Reinfried et al. (International Research in Geographical and Environmental Education, 24(3), 237-257) you find examples of how to reconstruct a science concept according to the MER.

AUTHORS' RESPONSE: Please see chapter 3.3.! There the interconnections between the hydrogeological content and the students' preconceptions are focused on. We describe how these considerations lead to the design of our learning program. If you think that a table as used by Reinfried et al. (see above, p.241) is helpful for better understanding the program's construction referring to the MER, we will compile it in the revised version of our manuscript.

REVIEWER'S COMMENT: Design of the intervention: The efficacy of the learning program was evaluated in an experimental-control group design with two measuring times. However, the paper does not include any information concerning the learning activities of the control group. I suppose that the control group served only to fill in the questionnaire twice. If that is the case, a comparison of the experimental and the

control group does not make much sense. It is self-evident that a group of learners' who work with a learning program that is interesting and well conceived make progress and that the progress can be related to the learning program. The question is rather what kind of advantages the learning program can offer in comparison to other learning arrangements and what the conditions are to induce a fundamental conceptual change.

AUTHORS' RESPONSE: The reason for our control groups was to control repeated measurement effects (see 11704, 25) and to exclude that random events (e.g. TV-documentations, daily news regarding groundwater) could impact our results. Furthermore, we did not intend to compare different teaching methods or media with our learning program, but to investigate the learning efficacy of our multimedia learning program. We agree with the reviewer that you can expect some progress related to every learning intervention. But we also agree with many researchers in the field of teaching and learning research who consider it problematic to compare different teaching methods, learning arrangements and/or media (e.g. because of too many incomparable variables). Critics as Krapp & Weidenmann in their "Pedagogical Psychology" (2006), call these comparing studies referring to Salomon (1978) a bit pejoratively "horse race"-studies (p. 420). Aside from these methodological questions, a multimedia learning program – tested for its efficiency – is of importance, because it can be a powerful tool in the hand of teachers.

REVIEWER'S COMMENT: The expectation that the learners learn something with the learning program was confirmed by the knowledge test, but why did more than 50% of the learners still draw sketches after the intervention that include large open spaces under the surface? Why did the unclear drawings produced by both the pupils and the students increase after the intervention (see Table 2)?

AUTHORS' RESPONSE: Realistically it is to be expected that only a part of the pupils and students can be guided towards the desired learning effect – even if we can state a highly significant increase of correct answers. Vosniadou and other conceptual change researchers argue that it is already a success, when scientifically correct concepts



exist besides of the "naïve framework". The increase of unclear drawings may be interpreted as intermediate steps in the process of conceptual reconstruction. We gladly can elaborate these details in our article.

REVIEWER'S COMMENT: Results: Unfortunately the authors did not include the questionnaires. Thus, it is not possible to review the learners' knowledge gains. An interesting question concerns for example the scoring of the knowledge questions: Where they all equivalent in terms of cognitive demands?

AUTHORS' RESPONSE: In its original form, our questionnaire (pre-/posttest, see chapter 6.1.1.; p.11707, 11708) is 6 pages long. It contains various types of questions (see p.11708, lines 2-18). In our opinion, it is too long for publication, but if considered as appropriate it can be added. The items of the questionnaire were targeted on different aspects and competencies of groundwater knowledge. Why should there be any need for equivalency in terms of cognitive demands?

REVIEWER'S COMMENT: Fig. 10 displays two drawings a pupil has made before and after the intervention. The authors claim that the post-test drawing indicates a fundamental conceptual change. It is evident that the pupil has learned a lot but he still uses vertical line-shaped structures for the surface water to percolate into the ground and he depicts a sheet-shaped layer of water above the aquiclude. The key idea that clastic sediments serve as water reservoirs which means that all open spaces below the groundwater level are filled with water is not displayed in the drawing. This raises questions. The boy shows a knowledge gain, for sure, but is his sketch sufficient evidence to prove a fundamental conceptual change, especially in terms of the definition given by Vosniadou (referred to above)? From other studies in this field it can be concluded that the research design used in the present study and the research data gained through it is not suitable to answer the research question on p. 11704 "Does conceptual change occur as a result of working with the multimedia learning programÂ£'

AUTHORS' RESPONSE: Thank you for the reference that the boy's drawing might be

ambiguous. We agree that he primarily drew the process of groundwater's formation, but in the post-test he was also able to position the groundwater table correctly in a sketch. His "package" of answers in the post-test shows an amazing performance and demonstrates a far-reaching knowledge gain and conceptual change (p. 11712, line 6 – 16). But according to the reviewer's comments, we will present other drawings for demonstrating conceptual change in the revised version.

REVIEWER'S COMMENT: Discussion and conclusions: The research clearly indicats a knowledge gain but it does not say anything about the persistence of that knowledge. The students' mental representations displayed in the drawings raise the question whether the learning program can initiate a conceptual change. From a psychological point of view individual learning without phases of co-construction with others runs the risk of overlooking the key ideas provided in the learning material that challenge the deeply entrenched preconceptions. Therefore, data gained from research using a similar setup is according to my knowledge of this research area problematic to infer that a conceptual change has been effected.

AUTHORS' RESPONSE: It is amazing, indeed, that correct and partially correct drawings of groundwater increased from about 9% to 42% (pupils) and 20% to 50% (students) in the post-test, although the participants just worked on the learning program by their own for about 15 to 20 minutes - without support from teachers, without phases of co-construction. And not to forget: our post-test was not performed immediately after the intervention (as many researchers do), but 2 weeks after. In a recent study, we are investigating how the incorporation of the learning program as part of a learning environment in class might enhance its effectiveness.

REVIEWER'S COMMENT: My final remarks concern a few details: - p. 11693, lines 19-20: "Everyday conceptions usually resist change". This is not the case for all everyday conceptions but especially for those that are considered intuitively correct. Review research by Andrea diSessa. - p. 11697, lines 4-20: In which way were all these recommendations considered in the design of the learning program? - p. 11697, lines



21-24: "...the students' preconceptions of underground lakes, rivers and waterfilled caves are expected to be "strong ideas" – not least because they have existed for centuries – while the coherence and C5674 the commitment with the topic groundwater probably are at relatively low levels." I do not understand this sentence.

AUTHORS' RESPONSE: As we have argued in chapter 2.2. (p.11694, l. 22-28 to p. 11695, l.1-28), the misconceptions of groundwater are strong ideas because of many factors (e.g. old metaphors, reproduction in media and schoolbooks). On the other hand the pre-concepts' coherence is probably weak and neither can it be expected that Austrian youth have a high commitment with this topic. Groundwater is generally available, why should they especially care for it? Therefore, following Sinatra's categories, possible entry points for conceptual change process are the two "weak"' factors. Constructing the learning program, we tried to take these ideas into account. As data from our formative evaluation show (see table 3), pupils as well as students found the topic groundwater after working with the multimedia learning program very interesting. Apparently, we succeeded in increasing the factor "commitment".

REVIEWER'S COMMENT: Strike & Posner's prerequisites for a conceptual change are explained in chapter 2.3. On p. 11703, lines 19-21 the authors write: "We made sure that the scientifically accurate conception is communicated in an "intelligible and plausible" way (Strike and Posner, 1992). Note, that even if authors take Posner's and Strike's prerequisites into account, it is the learners who have to find the concept presented in the learning material intelligible and plausible. Was this aspect explored? –

AUTHORS' RESPONSE: Yes, it was explored: see table 3

REVIEWER'S COMMENT: p. 11706, lines 12-14: "In order to ascertain long-term – as opposed to short-term – knowledge acquisition, the post-test was conducted two weeks after the participants had worked through the program." An evaluation of the knowledge gains two weeks after the intervention does not say much about the persistence of that

knowledge. This time span is just too short.

AUTHORS' RESPONSE: If you compare with many other appropriate studies, the interval of 2 weeks between intervention and post-test is longer than usual. The "forgetting curve" is already relevant after this period. Of course, a follow-up-test after 2 or 3 months would be a good thing, but most of the time it is difficult to realize when you investigate in schools.

REVIEWER'S COMMENT: p. 11720: Does Table 2 only refer to the drawings? The idea that ground water is stored in large subsurface openings decreased in the pupils only from 68% to 45% and in the students from 60% to 26%. Surprisingly, the number of unclear drawings has more then doubled. The higher figure of unclear conceptions after the intervention indicates that new knowledge has been assimilated but not deeply understood.

AUTHORS' RESPONSE: We interpret the fact that unclear drawings increased, in the same way as the reviewer does. (see excellent interrater reliability – p.11707. l.3-5)

REVIEWER'S COMMENT: Because others have researched conceptual change issues concerning groundwater and groundwater related concepts extensively, I advise the authors to clearly mark their own new and original contribution to that research and to carefully distinguish it from the research of others.

AUTHORS' RESPONSE: We clearly want to reject the reproach that can be read out of these lines! Based on international scientific work about conceptual change and teaching & learning hydrogeology, we developed and evaluated our multimedia learning program about groundwater. We do not know any comparable programs.

REVIEWER'S COMMENT: Questions concern for example the list on p. 11698, lines 12-24 and p. 11699, lines 1-7. The references are missing here.

AUTHORS' RESPONSE: As already mentioned above, Sylke Hilberg is professor for hydrogeology, her book and other publications will be cited.



REVIEWER'S COMMENT: The title should be honed by addressing the fact that the paper describes the learning progress achieved with the learning program (not conceptual change).

AUTHORS' RESPONSE: Sorry, but here we must contradict: Our results demonstrate that conceptual change has occurred. Significantly more pupils as well as students drew correct sketches of groundwater after having worked with the learning program. How could you explain these results without a change of conceptions? It clearly can be seen that there are no more underground lakes, rivers or water filled caves. The drawings can be traced to a new underlying conception: that of water within porous and permeable rocks. Independent of the learning progress that is expressed by drawings and verbal descriptions of groundwater (see figure 7, 11728), the increase of knowledge is described in chapter 7.3. (11710, lines 8-25; 11711, lines 1-9).

REVIEWER'S COMMENT: Final conclusion: The learning program is very interesting and the educational aims of the authors related to it are entitled to be discussed. Unfortunately, the paper includes many inconsistencies and unexplained observations. The research design of the study is only in parts unsuitable to answer all of the research questions. Additionally, the paper does not clearly explain how the theoretical foundations on which the learning program is based have been implemented. Due to these substantial weaknesses the paper should be rewritten without a focus on conceptual change.

AUTHORS' RESPONSE: So, why does the reviewer recommend to discard conceptual change in this context, although it is clearly proved by our study? Or does it generally not match the reviewer's opinion that conceptual change can be fostered by a multimedia learning program?

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