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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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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. 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. 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"? 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. Unfor-

tunately, 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. 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?). 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.

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. 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)?

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?

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 program¿'

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.

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

the commitment with the topic groundwater probably are at relatively low levels.“ I do not understand this sentence. - 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? - 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. - 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. - 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. Questions concern for example the list on p. 11698, lines 12-24 and p. 11699, lines 1-7. The references are missing here. - The title should be honed by addressing the fact that the paper describes the learning progress achieved with the learning program (not conceptual change).

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.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 11689, 2015.