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The role of confidence in Ordered Multiple Choice items about the universe's expansion

Motivation

The Big Bang theory being the currently most accepted theory describing the evolution of the universe has, therefore, formed our modern scientific worldview. Imparting this to students through science teaching is a frequent request in science literacy discussion (e.g., American Association for the Advancement of Science, 1993; Schecker et al., 2004). Furthermore, the interest of young people in astrophysical and cosmological topics is above-average, irrespective of their country or gender (Schreiner & Sjøberg, 2004). But apparently, there is a need for better education development concerning better approaches for teaching certain topics in modern physics such as cosmology (Schecker et al., 2004). A common basis hereof is often the prior investigation of students' conceptions (Ausubel, 1968; Anderson, 2007). When teaching cosmology, the expansion of the universe is a very important aspect as one of the three pillars of the Big Bang theory. To assess students' cognitive level of understanding hereof, follow their progression in an efficient and not time consuming way and, thus, to adapt and improve teaching, there is a need for easily applicable and evaluable tests.

Theory: Construct Maps and Ordered Multiple Choice items

To assess students' level of understanding of a concept, Ordered Multiple Choice (OMC) items can be used. The underlying basis for such items is a construct map, which consists of different consecutive levels each representing a certain level of understanding such as for example the model of student understanding of matter (Hadenfeldt & Neumann, 2012) or of force and motion (Alonzo & Steedle, 2009). Assuming that the progression of understanding is following the structure of a construct map, students should be situated in one or else two adjacent levels. On the basis of such a construct map OMC items can be developed – the second principle according to Wilson (2009) of the BEAR Assessment System. In such an item each answer option corresponds to one level of understanding of the underlying construct map. Therefore, a students' answer is not just correct or wrong, but can be classified into a certain cognitive level of understanding. These items have the same time efficiency as conventional MC items, but at the same time can provide more diagnostic information. They were first suggested by Briggs et al. (2006) and could ultimately “help schools and teachers adapt their instructional and intervention strategies” (Lin et al., 2010, p.3). There has been no research yet on OMC items in cosmology or on how the consideration of confidence levels affects their outcome regarding students' assignment to levels of the construct map.

Research Questions

- Can the students be assigned to a certain level or two adjacent levels of understanding by means of OMC items on the basis of the construct map and how does the level distribution look like?
- Which influence does the consideration of students' confidence in their response behaviour have on the students' assignment to the levels of understanding?

Design and Method

On the basis of our developed construct map of the ‘expansion of the universe’ (Aretz et al., 2017) with five levels plus a level 0 for no answer or idea, we designed OMC items including confidence levels for each item to be chosen by the students. The first intention was to investigate if the developed OMC items work in terms of assigning the majority of students to one level or two adjacent levels of the underlying construct map by means of these items. The second intention was the investigation of the role of the students’ confidence in that process. The hypothesis here is that the consideration of the confidence level has an impact on assigning the students properly to certain levels of understanding.

The sample consisted of N=822 high school students (15-20 years) from 20 different German schools in six federal states. All students completed a questionnaire with 20 questions about cosmology and 10 questions about the structure and composition of matter including the four developed OMC items about the expansion of the universe. This was conducted in normal class situations under the supervision of their teacher before any instruction took place (if at all). The test was anonymous and directly sent back by the teacher after its application. In order to test our construct map, we are focussing here on the results of the OMC items about the expansion of the universe. Each OMC item had five possible answer options, in which the students were only allowed to choose one of them. After each question the students should state their confidence of the corresponding answer on a scale from 1 (low confidence) to 5 (high confidence). The data was then analysed with the statistic programme ‘R’.

Results

After recoding the answer options of the OMC items according to the levels of the underlying construct map, the data was analysed regarding how many different levels were chosen per student. In the first step the stated confidence levels of these answers were not taken into account yet (see left side of Figure 1). For the assignment along the x-axis, the mean of the achieved levels of understanding was calculated. Subsequently the students were divided into the so-called level range. Hereby ‘1’ in Figure 1 means that students in this category chose answer options in the OMC items referring to the same level of understanding of the construct map. Students, who chose answer options referring to two adjacent levels of the construct map, are in ‘2’ concerning the level range. ‘1 slip’ means that all answer options except for one are referring to the same level of understanding. All other possibilities are represented in ‘3 and more’, for instance having either chosen 3 adjacent levels or 2 levels separated by another one (e.g., levels 1 & 3).

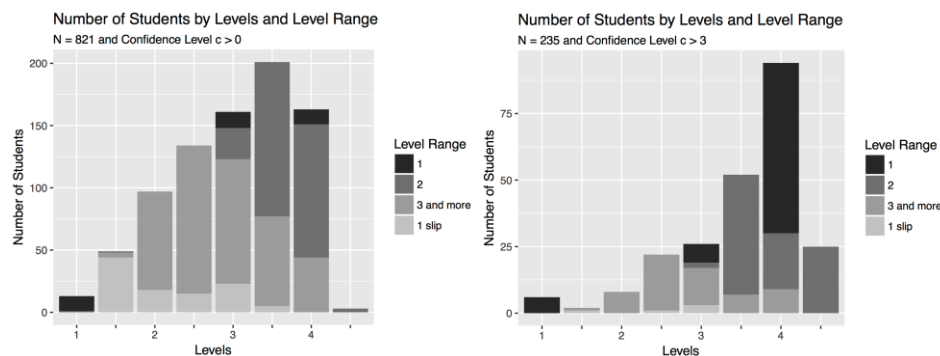


Figure 1: Students’ assignment to levels of understanding with (right) and without (left) consideration of their confidence

Looking only at answers of OMC items with stated confidences of 4 or 5 on a scale from 1 to 5, the bar chart on the right in Figure 1 is obtained. For that diagram N=235 students contributed with at least two given answers with confidences of 4 or 5. All other students either had stated lower confidences or only one of four possible answers was left with a confidence of 4 or 5. In the latter case the assignment would have been trivial and, therefore, these students were taken out.

Without consideration of students' confidences about one third can be assigned to one or two adjacent levels of the underlying construct map. These students are mainly situated in levels 3 and 4. Taking the confidence into account, many students drop out, but more than 70% of the remaining students can be assigned properly to the levels of understanding.

Discussion, Conclusion and Outlook

The developed OMC items about the expansion of the universe and our analysis approach seem to work in general quite well regarding the resulting assignment of students to the levels of the underlying construct map, but only if the students' confidence is taken into account. Looking at the left side of Figure 1, 63,7% of the students can't be assigned to one or else two adjacent levels of understanding. If only answers with the highest confidences of 4 or 5 are taken into account (right side of Figure 1), many students drop out, but more than 70% of the remaining students can be situated well into the levels of the construct map. Moreover, it is also evident that teaching has to take into account huge differences in students' conceptions regarding different levels of understanding as well as spontaneous associations, which might occur just at the moment students are confronted with a subject.

The consideration of students' confidence has also an effect on the sample size of the remaining students. Many students drop out because of their low stated confidences. These students seem to have no underlying conceptions fitting into a construct so that the developed construct map with its different consecutive levels cannot apply here. Therefore, these students might just guess every answer and, thus, can't be assigned properly. Here the results suggest that when there is no existing concept, the consideration of confidence can improve the overall outcome.

It is also important that students can be assigned relatively secure with a minimum of items. Obviously the sensitivity of OMC items increases with confidence as shown in Figure 1. The stated confidence levels after each question being taken into account, it is evident that a good assignment of the students into the levels is possible for the majority of the remaining students by means of just a few items. The next step is an item response theoretical approach and the application of a Partial Credit Model for the whole test instrument. The questionnaire has been translated into 18 different languages. Hence, data is collected in parallel and will be analysed from countries all over the world. Furthermore, another possibility is the implementation of an intervention in school and/or university and the analysis of the impact on the results shown above.

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References

- Alonzo, A. C., & Steedle, J. T. (2009). Developing and assessing a force and motion learning progression. *Science Education*, 93(3), 389–421.
- American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy – Project 2061*. Oxford University Press (1993).
- Anderson, C. W. (2007). Perspectives on science learning. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 3 – 30). Mahwah, NJ: Erlbaum.
- Aretz, S., Borowski, A. & Schmeling, S. (2017). Development and Evaluation of a Construct Map for the Understanding of the Expansion of the Universe. *Science Education Review Letters*, Volume 2017, pp. 1 - 8.
- Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart, and Winston.
- Briggs, D. C., Alonzo, A. C., Schwab, C., & Wilson, M. (2006). Diagnostic assessment with ordered multiple-choice items. *Educational Assessment*, 11(1), 32–63.
- Hadenfeldt, J. C., & Neumann, K. (2012). Die Erfassung des Verständnisses von Materie durch Ordered Multiple Choice Aufgaben. *Zeitschrift für Didaktik der Naturwissenschaften*, 18, 317–338.
- Lin, J., Chu, K., & Meng, Y. (2010). Distractor rationale taxonomy: Diagnostic assessment of reading with Ordered Multiple-Choice items. Paper presented at the annual meeting of American Educational Research Association, Denver, Colorado.
- Schecker, H., Fischer, H. E. & Wiesner, H. (2004). Kerncurriculum Physik. In A. Pitton (Eds.), *Chemie- und physikdidaktische Forschung und naturwissenschaftliche Bildung* (pp. 126–128).
- Schreiner, C., Sjøberg, S. (2004). Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE (the relevance of science education) – a comparative study of students' views of science and science education, *Acta Didact.* 2004, University of Oslo, Dept. of Teacher Education and School Development.
- Wallace, C.S. (2011). An investigation into introductory astronomy students' difficulties with cosmology and the development, validation and efficacy of a new suite of cosmology lecture-tutorials. Ph.D. Thesis. University of Colorado at Boulder.
- Wilson, M. (2009). Measuring progressions: assessment structures underlying a learning progression. *Journal of Research in Science Teaching*, 46(6), 716–730.