1

Making it stick: the effect of active learning on knowledge retention

Joeri Witteveen

Department of Science Education
University of Copenhagen

Introduction

How do we establish 'success' in learning in academic educational environments? According to a family of influential constructivist outlooks on teaching-and-learning environments, successful learning is brought about by aligning teaching and learning components such as teaching activities, forms of assessments, learning objectives, and the classroom environment (Biggs, 1996; Hounsell et al., 2005). More generally, constructivism as a theory of learning holds that effective and productive learning should not aim at the *transmission* of concepts, theory and methods through one-way *instruction*, but should instead promote the capacities for *understanding* in learners by creating a learning environment that prompts learners to *actively build* on a foundation of previous learning (Applefield et al., 2000; Piaget, 1980). These theoretical insights have been translated into a range of teaching methods and strategies that fall under the umbrella of 'active learning'. Active learning will here be understood in the broad sense of the attainment of knowledge and understanding through engagement in activities that require reflection and invite problem solving (Collins & O'Brien, 2003; J, 2020).

Although it is widely recognized that active learning tends to have a positive effect on knowledge *acquisition* (Freeman et al., 2014; Haan, 2005), it is less evident that is also promotes long-term knowledge *retention*. Standard measures of success in learning such as assessment results and course evaluations only provide insight into short-term memorization and recall, during and at the end of the course. To establish that skills and

competences acquired through active learning will 'stick' in the longer term – here defined as >6 months after the learning experience, – longitudinal research is required. Although several research efforts of this kind have been completed, their results are ambivalent.

The present study aims to further probe the question of long-term knowledge retention by examining whether active learning is associated with higher knowledge retention compared to traditional (passive, lecture-based) teaching approaches at around 6 months after the relevant learning experiences have taken place. The study draws on learning experiences from the Philosophy of Science for Geography (Geografiens Videnskabsteori) course that ran in block 2 of 2020/21. This course is compulsory for second-year students of Geography at the University of Copenhagen. The author of the study was course responsible for this course.

Knowledge retention and active learning

Knowledge retention has long been a topic of intense study in cognitive and educational psychology circles. This has yielded an expansive literature on knowledge retention that focuses predominantly on strategies for increasing recognition and recall, e.g. through rehearsal and repetition (Belmont & Butterfield, 1971; Roediger & Butler, 2011), spaced-learning (Cepeda et al., 2008), interleaving of different skills and activities (Carvalho & Goldstone, 2014) summarization (Brown & Day, 1983), and integration exercises (Gholson et al., 2009).

Although the results from most of these studies appear to be robust and well-founded, their wider significance for knowledge retention in academic teaching-and-learning environments is limited. Most of the cognitive psychological studies are based on simple vocabulary or image learning tasks. It is hard to extrapolate from these tasks to educational settings that aim at fostering a deep understanding of complex constellations of concepts, theories, methods and practices. To address this gap, several researchers have in recent years carried out longitudinal studies in genuine academic teaching-and-learning environments. Much of this research has been motivated specifically by the question whether active learning increases long-term knowledge retention compared to one-way, non-collaborative, lecture-based teaching approaches.

The results from these research efforts are somewhat equivocal. On the one hand, there are several studies that have found a clear positive cor-

relation between active learning and increased knowledge retention. For example, a study of clinical reasoning in neurology education has shown that team-based learning enhanced knowledge retention 1 year after the clerkship, even if it had no effect on examination results at the end of the clerkship itself (Alimoglu et al., 2017). Likewise, Hartmann et al., 2015 report that the use of collaborative learning techniques in a physiology course significantly improved retention of learned concepts after 24 months. Similar results have been reported for courses in pharmacotherapy (Lucas et al., 2013), chemical engineering (Bullard et al., 2008) and mathematics (Narli, 2011). On the other hand, there are several studies that have found only very weak or no support for the hypothesis that active learning promotes knowledge retention. For example, Morgan et al., 2000 found "minimal differences in long-term" between lecture-based teaching and cooperative, active learning approaches in undergraduate-level special education courses. Even more interestingly, Emke et al., 2016 showed that active learning was advantageous in the short-term, but not in the longterm. They report that in pre-clinical pediatrics curriculum, students who were educated in an active learning environment showed significantly higher performance at the end of the course relative to students who received lecture-based learning, but that after two years this difference had completely disappeared.

Some of the discrepancies between these knowledge retention studies can likely be attributed to different implementations of active learning strategies (team-based, inquiry-based, etc.) to the kind of knowledge that was the subject of the knowledge retention test (factual knowledge, conceptual knowledge, reasoning skills), and to the methodology that was used to test knowledge retention. Furthermore, some of the differences may be related to variation in the activation and use of learned knowledge in teaching modules or practicals that followed the course but preceded the knowledge retention test. However, there are no systematic reviews or meta-analyses that account for these differences. In sum, it is still an open question under which conditions, to what extent, and in which form active learning can make a positive contribution to long-term knowledge retention.

Didactic context

The present study was carried out in the context of the course Philosophy of Science for Geography (Geografiens Videnskabsteori), which is compulsory for second-year students of Geography at the University of

Copenhagen. In the academic year 2020/21 responsibility for this course was transferred from the Department of Geosciences and Natural Resource Management (IGN) to the Department of Science Education (IND). Along with this change in course ownership, the course was completely redesigned. This included the formulation of new learning objectives and an overhaul of the syllabus to bring it in line with the practice-based approach to philosophy of science research and teaching that has been spearheaded by IND (Green et al., in press). Among the new themes that were adopted for the revised syllabus was a module on philosophical aspects on 'modeling and mapping'. From this course module, two subtopics were selected to survey the effects of active learning vs. passive (lecture-based) teaching on knowledge retention.

The first subtopic was taught in a traditional, lecture-based teaching format. It concerned a discussion of the 'epistemic division of labor' in model-building, which was illustrated using a case from fluvial geomorphology. In the lecture, it was explained that modeling strategies that are useful for making predictions about the flow of specific braided rivers tend to be poor at explaining why braided rivers in general flow the way they do, and vice versa. The lecture was delivered online from a prerecorded video that was posted in the Absalon course environment. The pre-recorded format prohibited direct interaction with the lecturer.

The second subtopic was prepared with a didactive approach of active learning in mind. The topic concerned the difference between the representational and rhetorical (including ideological) roles of map projections, illustrated using the case of a controversial map projection, the so-called 'Peters projection', that presents equal areas at equal size, at the cost of severely distorting the shape of countries. Some have argued that world maps based on this map projection are 'fairer' that others since, they present countries in the Global South at their 'true size' – much larger than on most traditional world maps. Others have argued that world maps based on the Peters projection method are neither very useful nor obviously 'fair'. Moreover, many of them object to the introduction of other motives than representational adequacy into cartography.

The controversy over the Peters projection was the topic of a 45-minute seminar class section that relied on an active learning approach. After a 5-minute (mini-lecture) introduction to the history of the Peters projection controversy, the students were informed that they would be asked to 're-enact' the controversy in a mock TV-debate based on a fictional, close-to-home scenario. This scenario involved a proposal by The Danish Federa-

tion of High Schools to supply all Danish high schools with new atlases based entirely on the Peters projection, as part of an initiative to decolonize the geography curriculum. The students were told that this proposal had already been met with strong responses for and against from various stakeholders. After sorting the students into groups of three to four members each, they were given a handout that stated which stakeholder they were asked to represent. The handout provided some background on the stakeholder's position in the controversy but required the students to develop this into a clearly articulated position (15 mins) (sample handout in Appendix A). The students didn't know which other stakeholders would take part in the debate, but the description on the handout gave an idea of the kind of opposition they could expect. Each group was asked to send one student as delegate to the debate. The rest of the group could take part in the debate as audience. The debate was moderated by the class teacher (15 mins), who made sure that everyone participant had their say and who tried to involve the audience. The exercise was concluded by discussing and evaluating (in plenum) the arguments for and against that had come up during the debate (10 mins).

Methodology

To assess whether the use of an active learning approach had a positive impact on knowledge retention, all students that had completed the Philosophy of Science for Geography course in block 2 of 2020/21 were invited to take an online survey. The survey, composed in Google Sheets, tested students' knowledge on the two subtopics from the 'modeling and mapping' theme described above. The survey was launched when the students had completed this course module just over 6 months ago and when they had taken the final exam around 4.5 months ago. By quizzing them on two subtopics from the same course week, it was expected that recency and primacy effects could be avoided. A link to the survey was posted on the Absalon course page[1] and an announcement was posted on Absalon to invite students to complete the survey. A reminder was posted a week later.

The survey consisted of nine questions in total (see Appendix B). Three yes/no questions asked whether they could recall having encountered to

[1] 'Absalon' is the name of the Canvas learning management system implementation at the University of Copenhagen.

topic of 'modeling and mapping' (Q1) and if they could recall the cases (as described above) from the modeling part (Q2) and the mapping part (Q6). Four multiple choice questions quizzed them on some of the specifics from the two cases (Q3 and Q4; Q7 and Q8). The series of questions on each case was concluded with an open question that invited the student to share anything else they recalled having learned on that topic. The survey was structured such that students would receive feedback on their answer to the previous question before being introduced to the next question. For example, students who answered 'no' to Q1 were be presented with Q2N, whereas those who answered 'yes' would proceed to Q2Y. The same approach was implemented for right and wrong answer to multiple-choice questions. Answer options for the multiple-choice questions were presented in a random order. For a detailed overview of the survey structure, see Appendix B.

Upon completing the survey, the students were asked to leave their email address if they were willing to volunteer for a short follow-up to the survey. With a sufficient response, a group interview with a focus group would be set up. The aim of the focus group would be to assess students' substantive *recall* of knowledge items, over and above the capacity for *recognition* of that was primarily tested using the survey (Ebbinghaus, 1885). In addition, the focus group could serve to find out how students thought the different teaching methods contributed to improving their skills in critical reasoning – a key focus of philosophy of science training.

Results

Online survey

The survey was completed by 35 respondents (53% response rate). All respondents answered the yes/no and multiple-choice questions (Appendix C) and the two open questions received a total of 17 responses (Appendix D). Results were not subjected to any statistical analyses.

94% of the respondents reported remembering that one of the week themes was 'modeling and mapping'. Regarding the two subtopics, 82% of the respondents reported remembering the case on modeling that was taught in a lecture-based format, whereas 100% remembered the case of mapping that was taught through an active learning exercise. For the first multiplechoice questions on each subtopic, a total of 83% of respondents gave the right answer for the lecture-based case (Q3Y: 26 out of 29 (90%) +

Q3N: 3 out of 6 (50%)) compared to only 31% for the active learning case (Q7Y: 11 out of 35 (31%) + Q7N: 0 out of 0 (0%)). On the second multiple choice question, 77% of respondents provided the correct answer for the lecture-based case (Q4Y: 23 out of 29 (79%) + Q4N: 4 out of 6 (67%)) compared to 89% for the active learning case (Q8Y: 11 out of 11 (100%) + Q8N: 20 out of 24 (83%)). See Appendix C for a complete overview.

The responses to the open questions reveal that some respondents could recall other learning components from the week theme on modeling and mapping in quite some detail. Interestingly, several respondents alluded or referred to the exercise on the Peters projection in their response to first open question (underlined in Appendix D). This was before the respondents had reached the part of the questionnaire that quizzed them on this subtopic.

Focus group

Seven respondents left their email address at the end of the survey. All were invited to take part in the focus group, but none responded to the invitation. After two reminder emails, one student responded to say that they were very busy with other courses and a project. Following this response, the idea of arranging a focus group was abandoned.

Discussion and conclusion

While it is hard to draw firm conclusions from this small study, it is interesting to observe that for both subtopics, overall knowledge retention through recognition appears to be high. With the exception of Q7, 79% to 100% of the respondents reported remembering a subtopic and/or recognize the right answer to specific questions. Moreover, in hindsight there are reasons to think that the answer options for Q7 are ambiguous: apart from answer 7A, 7C could arguably also be counted as a correct answer to the question. Even so, this would only yield a correct response rate of 63% for the first multiple-choice question about the active learning exercise, compared to 90% for the same kind of general multiple-choice question about the lecture. This could be taken to suggest that the lecture-based format was better at bringing across a conceptual/ theoretical distinction than the active learning exercise.

However, this suggestion needs to be qualified in light of the response to the second multiple- choice question for each of the cases. In each case,

this question tested for knowledge about the implications of the conceptual/theoretical distinction that was the subject of the first multiple-choice question. Not only did a larger share of the respondents provide the correct answer to the second-multiple choice for the active learning exercise (89% vs. 77%), it is also striking that of the 69% who answered the first multiple-choice question incorrectly 83% managed to answer this second multiple-choice question correctly. Overall, then, we can perhaps conclude, very provisionally, that the lecture-based teaching achieved higher knowledge retention on bringing across a conceptual distinction, whereas the active learning exercise provided higher knowledge retention on understanding the implications of this distinction in scientific practice.

A more robust study of knowledge retention would test of recall over and above recognition of learned materials, though it is challenging to measure this in practice. In addition, a research design based on two groups that were taught the same topics with different didactic strategies (lecture-based vs. active learning) could overcome the limitations of the present study in formulating comparable multiple-choice questions on different topics. Since the current study was initiated after teaching in the Philosophy of Science for Geography course had completed, it was not possible to adapt the course design to the study design in this manner. Another important limitation of the study design is the brevity of the survey, which makes it hard to generate sufficient data for a meaningful comparison of study approaches. Keeping the survey short was a conscious choice, though, since it was expected that a longer survey would fail to generate a sufficient response from students.

The methodology and results of the study were discussed with a department colleague (Sara Green). It emerged from our discussion that testing for knowledge retention is especially difficult in case of philosophy of science courses, since the focus of these courses is not so much to educate students about key concepts and their applications, but rather to develop their skills in analyzing texts, to hone their critical and analytical thinking skills, and to contribute to a more general sense of self-cultivation in the form of *Bildung*. Thus, even if it had turned out that lecture-based teaching promoted long-term retention of factual and conceptual knowledge about course elements, it could still be that active learning activities were more effective for developing students' critical reasoning skills. A study of the kind that has been conducted will not be able to detect this difference. Since critical and analytical reasoning skills are to a considerable extent domain-general, a methodology based on semi-structured interviews would have been a more

fruitful approach toward gaining insight into whether the didactic approach makes a difference to the learning of these skills. Yet, for reasons of time and access to students, this was not an option in the current study.

Acknowledgements

I would like to thank Sara Green and Lars Ulriksen for helpful discussion and feedback.

References

Alimoglu, M., Yardum, S., & Uysal, H. (2017). The effectiveness of tbl with real patients in neurology education in terms of knowledge retention, in-class engagement, and learner reactions. *Advances in Physiology Education*, *41*, 38–43.

Applefield, J., Huber, R., & Moallem, M. (2000). Constructivism in theory and practice: Toward a better understanding. *The High School Journal*, *84*(2), 35–53.

Belmont, J., & Butterfield, E. (1971). Learning strategies as determinants of memory deficiencies. *Cognitive Psychology*, *2*(4), 411–420.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, *32*, 347–364.

Bligh, D. (2000). *What's the use of lectures?* Jossey-Bass.

Brown, A., & Day, J. (1983). Macrorules for summarizing texts: The development of expertise. *Journal of Verbal Learning and Verbal Behavior*, *22*(1), 1–14.

Bullard, L., Felder, R., & Raubenheimer, D. (2008). Effects of active learning on student performance and retention. *American Society for Engineering Annual Conference 2008*, 13.473.1–13.473.8.

Carvalho, P., & Goldstone, R. (2014). Effects of interleaved and blocked study on delayed test of category learning generalization. *Frontiers in Psychology*, *5*(936), 1–11.

Cepeda, N., Vul, E., Rohrer, D., Wixted, J., & Pashler, H. (2008). Spacing effects in learning: A temporal ridgeline of optimal retention. *Psychological Science*, *19*(11), 1095–1102.

Collins, J., & O'Brien, N. (Eds.). (2003). *The greenwood dictionary of education* (3rd edition). Greenwood.

Ebbinghaus, H. (1885). *On memory*. Dover.

Emke, A., C., B. A., & Larsen, D. (2016). Effects of team-based learning on shortterm and long-term retention of factual knowledge. *Medical Teacher*, *38*(3), 306–311.

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–15.

Haan, R. (2005). The impending revolution in undergraduate science education. *Journal of Science Education and Technology*, *14*(2), 253–269.

Hartmann, J., Toksvang, L., & Berg, R. (2015). Collaborative teaching strategies lead to retention of skills in acid-base physiology: A 2-yr follow-up study. *Advances in Physiology Education*, *39*(2), 120–121.

Hounsell, D., Entwistle, N., Anderson, C., Bromage, A., Day, K., Hounsell, J., & Xu, R. (2005). Enhancing teaching-learning environments in undergraduate courses. *Final report to the economic and social research council on tlrp project l, 139251099*.

J, M. J. (2020). From constructivism to active learning in college science. In M. J. & W. E (Eds.), *Active learning in college science* (pp. 3–12). Springer.

Lucas, K., Testman, J., Hoyland, M., Kimble, A., & Euler, M. (2013). Correlation between active-learning coursework and student retention of core content during advanced pharmacy practice experiences. *American Journal of Pharmaceutical Education*, *77*(8), 171.

Morgan, R., Whorton, J., & Gunsalus, C. (2000). A comparison of short term and long term retention: Lecture combines with discussion versus cooperative learning. *Journal of Instructional Psychology*, *27*(1), 53–58.

Narli, S. (2011). Is constructivist learning environment really effective on learning and longterm knowledge retention in mathematics? example of the infinity concept. *Educational Research and Reviews*, *6*(1), 36–49.

Piaget, J. (1980). The psychogenesis of knowledge and its epistemological significance. In MPiatelli-Palmarini (Ed.), *Language and learning* (pp. 23–34). Harvard University Press.

Roediger, H., III, & Butler, A. (2011). The critical role of retrieval practice in longterm retention. *Trends in Cognitive Sciences*, *15*(1), 20–27.

A

Active learning exercise handout example

Re-enacting the Peters Projection controversy

Who are you?
You are a geography teacher from a high school in Copenhagen. You have been teaching students with the current atlases (which mainly contain Mercator maps) for more than two decades and this has always worked out fine.

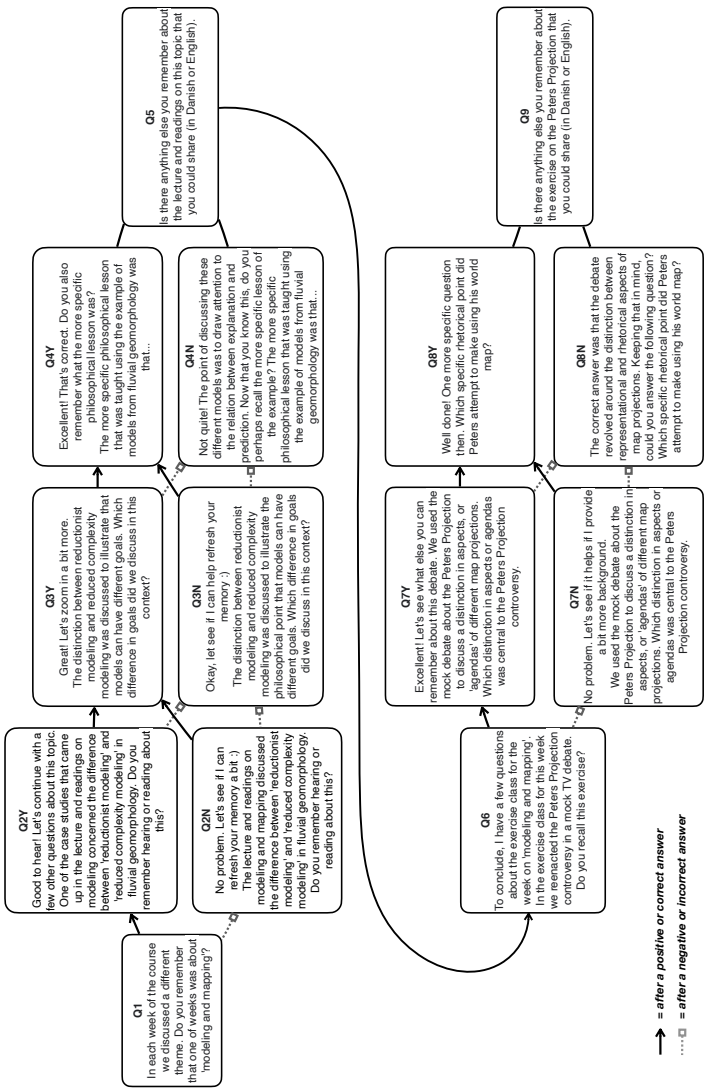
What is your position?
You are unhappy with the recent proposal by the Danish Federation of High Schools to adopt the Peters projection in the geography curriculum and to introduce new atlases based on this projection into high schools. What is needed is not new atlases, but better education for geographer teachers. You always take time to explain that all map projections introduce distortions. Of course you also point out that the Mercator projection distorts the earth in certain ways. But you know that some of your younger colleagues don't explain this as well. They might not even be aware of some of the technical aspects of map projections that you learned in university, back in the day. You still think that the Mercator projection is a great projection for teaching geography, especially because it shows Europe clearly, which is useful for your teaching (which is mainly about geographical issues in Europe).

What can you expect from the others?
You don't know which others will join the debate, but you do know there is opposition from both sides. Some are also opposed to proposal from the Danish Federation of High Schools, but for different reasons. For instance, you know that some think that the current Mercator-based atlases should be replaced with atlases that contain many different projections. You don't think this would be confusing to the students. You are also aware that others, who support the introduction of the Peter projection maps into Danish high schools, do so as part of a larger effort to "decolonize the curriculum". They want to remove what they regard as the Western, imperialist bias that is inherent to the Mercator projection.

How should you prepare?
At the opening of the debate, you will be given about a minute to present who you are and what your position is in this controversy. After all the other participants have introduced themselves, you will debate each other. Try to think of the arguments the others may have against your position, and think of a strategy for how to respond to them.

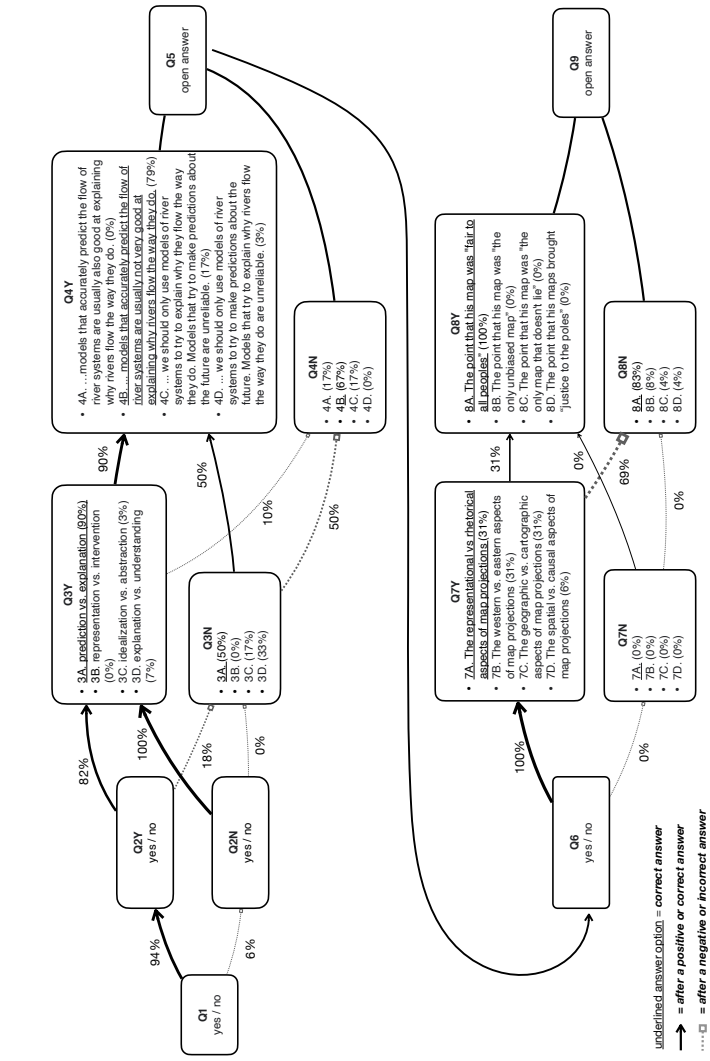
B

Knowledge retention survey – question structure



C

Knowledge retention survey – answer options and results



D

Knowledge retention survey open question answers

Answers to Q5: "Is there anything else you remember about the lecture and readings on this topic that you could share (in Danish or English)."

- A case about a London map, walking time and contructivism
- London metro maps, 'the orange', history of cartography,
- all of it :)
- den ene slags model var meget stedspecifik og kunne sige meget præcist hvordan en flod bevægede sig i det specifikke sted, men kunne ikke forklare hvad der foregik og kunne ikke appliceres på andre floder. Så høj forudsigelse inden for det specifikke sted, men mindre generaliserbarhed
- Jeg husker at både modeller og kort kan være med til at forklare og forstå virkeligheden, men det er altid forsimplet og der er taget stilling til hvilke aspekter der er vigtige at have med, og hvilke der er "ok" at udelade.
- Nice picturez
- I really liked the class exercise with the oranges and the map-projections!
- Eksamensspørgsmålet, der lagde op til det handlede om den "epistemologiske arbejdsdeling" af modeller, hvor nogle er gode til at forklare og nogle er gode til at forudse.
- I remember we discussed Peters Projection a lot! And the division of cognitive labor
- That the different terms of models 'reduced complexity' etc. were hard to distinguish from one another.
- projektioner, abstraktion, idealisering, peters projektion
- The lecture & readings

Answers to Q9: "Is there anything else you remember about the lecture and readings on this topic that you could share (in Danish or English)."

- The debate exercise in the class room. That all maps "lie". The purpose is essentiel - what are we gonna use the map for
- Vi lavede også en øvelse i grupper, hvor vi skulle udpege hvilken projektion, der hørte til et givent billede. Jeg mener også, at vi talte noget om atombombers udbredelse, og hvorfor det ikke bare ville være en rund cirkel på et kort med fx mercator-projektionen.
- kortet var areal-tro mod landes størrelse, men vinklerne/formen var forkerte.
- Vi lavede en diskussion med et panel, der alle på forhånd i grupper havde fået en karakter, hvis holdninger vi diskuterede og så skulle udtrykke i panelet.
- Peters projection er kritiseret af kartografer, men er brugt af forskellige organisationer, fordi mercator-projektionen, der oftest bruges, anses for at være kolonialistisk.
- That the peters projection for educational purposes in my opinion is a bad map, but that it succeeded in winning over the equally bad for education mercator projection. PR is always important.
- Peter var en god reklame mand, ellers var kortet aldrig blevet så kendt. Var ikke den første der havde lavet denne type projektion.
- The exercise class