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Hydrology and Earth System Sciences Discussions

Interactive comment on "Flowing with the changing needs of hydrogeology instruction" *by* T. Gleeson et al.

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Reviewer 1

GENERAL COMMENTS This manuscript presents a literature review of hydrogeology instruction with a primary focus on introductory physical hydrogeology courses. The main body of the manuscript is largely based on the analysis of survey data conducted in 2005 and the review of the papers published in the Journal of Geoscience Education. The manuscript is well organized and written. It presents a nice summary of the current status of hydrogeology education and makes useful suggestions for the future. As a hydrogeology instructor myself, I agree with many of the points made by the authors. This article will serve as a particularly useful guide for young hydrogeology instructors

who are starting to design their own courses, and also for more established instructors who are planning to redesign their courses. While the manuscript is generally in a good shape, I do feel that the manuscript can be improved by addressing a few comments below.

–>Thank you for your positive comments and constructive, useful suggestions.

SPECIFIC COMMENTS 1. Title has “the changing needs”, but it is not very clear to me what is changing. Does the change refer to more diverse background of students? Or is it related to changing job market? Please explain it more explicitly in the introduction or conclusions.

–>By changing needs we were referring to the a) changing diversity of students, b) changing needs of the job market, and c) changes within the discipline of hydrogeology that manifest in hydrogeologic pedagogy.

We have changed the title to "TEACHING HYDROGEOLOGY: A REVIEW OF CURRENT PRACTICE" to keep this more in line with the content of this article. However, we do still wish to acknowledge the changing demands on some hydrogeology instructors. On p.3 we now include a comment on the struggle between addressing the desire for courses with a more interdisciplinary nature versus covering the basics well (lines 71-76).

2. I would like to see the “punch lines” more clearly stated in the conclusions. What are the main messages of this review, and what are the recommendations? Do the authors recommend the iterative approach as the essential aspect of hydrogeology instruction? Or, do they see the use of student-collected data as the essential aspect?

–>We have added three key punch lines to the conclusions which are important to the future teaching of hydrogeology. Also we now include a statement emphasizing these points in the Introduction. The idea of using an iterative approach is mentioned in the abstract and the idea that there are only a few key topics is further emphasized in the

HESSD

9, C1606–C1612, 2012

second paragraph of the conclusion.

3. The authors suggest that it is important to have a balanced approach integrating class-room teaching, laboratory exercise, and field data collection. I believe that very few hydrogeologists would disagree with this point, and many of them probably have thought about the same thing. An important question, then, is what has prevented many instructors from implementing the integrated approach? Some discussion on the challenges in the integration of the three components will be useful.

–>Many instructors likely try to accomplish too much (cover too much material) in a short period of time. This is becoming even more challenging now that the discipline is becoming more relevant to other disciplines (as we discussed in the intro). This is not to say that an integrated approach is not possible or even desirable. It may be that to effectively do this, only the main topics should incorporate aspects all three elements.

This type of integration is difficult because of a lack of resources and a struggle with focus. It is hard to figure out which topics are important to cover and just how to integrate them. Some projects are good for integrating many topics but some inevitably get left out. Is it acceptable to gloss over or skip a few things? The survey results suggests what topics instructors should focus on.

Generally, it will be the field component that is likely missing from the ideal integration we propose.

Data collection is time consuming – good data are important for teaching, particularly at the undergraduate level. There is nothing more frustrating to a student than when their data do not conform to what the theory suggests.

Collection of appropriate field data is easier to accomplish in some locations than others. Some universities have financial resources to develop their own field sites and others do not, even if appropriate sites are available.

Seasonality can also be a factor in some locations. Hydrogeology courses taught dur-

HESSD

9, C1606–C1612, 2012

ing the winter may not allow for the same type of field exercises as those in other times of the year. This is often true of many other Earth science courses and there is competition to avoid these winter courses in many departments.

Scheduling these exercises during field schools can help but it can be difficult to integrate these experiences with lecture material. Field schools often struggle to demonstrate and teach a variety of techniques that may not always relate to each other in obvious ways. The level of integration of ideas will vary depending on the sites available.

Challenges related to the incorporation of integrating field instruction components are now further discussed on p. 5 and 6. These involve lack of appropriate field sites, resources and timing. Problems with using data collected by students in other aspects of a course are discussed on p.15 and p.16. As pointed out by the reviewer, this seemingly simple approach may not actually be simple. We now point out that data collected in the field may not be readily analyzed using the theories learned in an introductory course. Other approaches such as demonstrations, supplementing data collected by students and supplying student's raw data are now discussed.

4. Figure 3 lists the crucial topics to be covered in an introductory physical hydrogeology course, based on the 2005 survey. I would be very interested in finding out if these had changed during the few decades prior to 2005. If the authors want to talk about "flowing with the changing needs" in this paper, it will be very useful to look at a similar list from the courses taught in 1970's and 1980's. It will be difficult to compile a list from many samples, but the authors could obtain lecture notes (probably handwritten) from a few universities that had undergraduate courses in hydrogeology and examine the contents. Some examples I can think of are University of Waterloo, University of Minnesota, and University of Wisconsin- Madison. Could the authors contact graduates from these or other universities who took hydrogeology courses in 1970's and 1980's?

–>We agree that the method suggested by the reviewer would provide interesting re-

HESSD

9, C1606–C1612, 2012

Interactive Comment

sults but this would be a substantial task. Instead, we have done a brief review of hydrogeology textbooks produced over the past several decades. The topics covered in these textbooks have not changed substantially and are very similar to the topics in the 2005 survey. We now mention this on p. 6.

A quick survey of textbooks from the last 50 years (looked at Todd, Davis and DeWiest, Freeze and Cherry, Fetter, Domenico and Schwartz, Deming, Fitts, Hiscock) suggests little change in the topics covered. We think this relates back to the idea that certain topics are essential and that others are optional. We also noticed that most of the optional topics in textbooks tend to be more focused on geology, contaminant transport and more advanced traditional topics. Even in more recent books there is very little on ecosystems, source water protection or sustainability, which seem to be the buzzword type topics lately. We assume that these are being taught but don't know how to document this other than doing a huge survey.

5. Page 1126, line 6. I would say that software-generated contours are not only "not inherently accurate", but also less accurate. This is because there is no room for human intervention based on the knowledge of topography, geology, presence of surface-water features, land use, etc. I would like to see this point made more clearly.

–>We agree and have made this change.

6. Page 1130, line 1. I certainly see a strong merit in using the real data collected by students themselves. However, there is also a pedagogical merit in using the appropriate data that bring out the fundamental principles more clearly than messy data collected by the students. For example, for the pursuit of real data, one may be tempted to conduct a slug test in a water-table well at a convenient location. Interpretation of such data will require an elaborate mathematical analysis using non-linear equations, or numerical simulator. Would this be a more pedagogically meaningful exercise than providing the data set (still real, but not done by students) collected from a properly designed slug test? Is there a merit in teaching the students how to design a proper slug

HESSD

9, C1606–C1612, 2012

test? Perhaps, using both (clean and messy) data sets may be ideal? A discussion on the advantage and disadvantage of using student-collected data will be useful.

–>We struggle with these issues ourselves. We often wonder if it is worth the time to have students spend the hours in the field doing something that isn't really that intellectually challenging. There is merit in seeing how it works and getting the hands on experience but is that how you want to spend your 3 hour lab for a week? Is that time better spent showing a video of slug test collapsed down to a few minutes and devoting more time to theory and analysis? We have usually leaned towards focusing on theory and analysis with data supplied. Some employers would probably disagree with this approach but we don't believe it is the role of universities to train field technicians.

Data control is an important issue here as well. This is where frustration comes in and the exercise can end up missing the mark. It is certainly an important lesson for a student to find out that theories don't always translate well to field data but that may not be too helpful in a first try. Students can be left with the feeling that theory is pointless because it doesn't actually work. Providing data also gives the opportunity to show a range of outcomes where tests work and where they do not. Ownership is certainly a problem with this approach and most students do seem more engaged when they get out in the field.

This is now dealt with on p. 15 and 16 and is discussed in our response to the reviewer's comment #4.

7. Figure 3. Should the title of the horizontal axis be "respondents", not "applicants"? Same applies to supplementary figures.

–>We have made these changes.

8. Figure S1. The figure subtitle in Page 2 should start with (f), not (e). The scale for horizontal axis for the figures in Page 2 should be "0, 20, . . ., 80, 100", not "0, 25, . . ., 100".

HESSD

9, C1606–C1612, 2012

–>We have made these changes.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/9/C1606/2012/hessd-9-C1606-2012-supplement.pdf

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