

Interactive comment on “Teaching groundwater dynamics: connecting classroom to practical and field classes” by V. Hakoun et al.

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Reply to Anonymous Reviewer comments

Reviewer comments

This paper addresses the issue of how to move from classical classroom teaching to modules that promote active learning, which are well-known for considerably enhancing student performance when implemented in relevant ways. A main contribution of this work is to show example evidence of well-working active learning packages within a key field in hydrogeology (groundwater dynamics).

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The paper is generally well-written and interesting, although some parts are unclear and could be improved. In particular, before publication, I would like to see that some of the key concepts are further explained and clarified (points 1-3 below), that the discussion section is extended (point 4) which could considerably improve the paper, and that part of the introduction is changed to fit with the contents of the paper (point 5).

→ **Thank you for these very constructive comments that helped clarify the manuscript.**

Reviewer comments

1) One of the key points of the presented approach is to maximize integration between class components, as stated in key point (ii) and illustrated in figure 2. The following issues would need clarification: (a) How is integration defined? For instance, do the arrows of Fig. 1 (that attempts to explain the concept) mean that the result from one module are used in the other, and/ or does it rather mean that many modules are run in parallel, e.g. with mutual feedbacks in an iterative manner? Please also check notation: The word "iterative loop" (and not integration) is not used when referring to Fig. 1 for the first time (p. 1076, row 26). (b) Why should integration be maximized? (c) Please check consistency of notation used in key point (ii) and Figure 2: The term "Lecture classes" are used in the latter but not the former.

→ **These issues are discussed below :**

a Integration was used intending to define the association of the three class components and the support one provides to the others through, for instance, transfers of both knowledge/skills and data/results. These mutual transfers between each class component are illustrated on Fig. 1 by the arrows.

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b In our opinion, integration should be maximized as it helps improve the experiential learning context by the links and feedbacks it creates in between the class components.

c We agree and changed the notation in key point (ii) so it matches Fig. 2.

In the revised manuscript, the following corrections were added:

a We corrected the key points of the pedagogical scheme in the revised version of the Introduction. These key points define the integrated pedagogical scheme, they are : (i) groundwater flow processes topics are addressed iteratively into the three class components (lecture class, practical class, field), (ii) a main thread is used to support feedbacks between the three class components, (iii) a pedagogical approach that promotes active learning strategies, in particular using original practical classes and field experiments. Details on the integrated hydrogeology pedagogy as proposed by Gleeson et al. (2012) were added in Sec. 2 in order to explain the concept illustrated on Fig. 1. In Section 3, the terms "iterative loop" were replaced by "integrated pedagogy" to allow notation consistency. Figure's 1 caption was modified to express the mutual feedbacks between the class components.

b key point (ii) was modified as presented above in point a.

c the notation in key point (ii) was corrected : "classroom" was replaced by "lecture classes" so it matches the notation of Fig. 2. This correction has also been applied throughout the text.

Reviewer comments

2) Could the implementation of iterative loops between classroom teaching (section 3.2) and practical classes (section 3.3) be exemplified more concretely?

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→ **More concretely, the implementation of iterative loops between classroom teaching and practical classes can be exemplified as follow :**

- 1. Classroom : introduction to groundwater flow topics related to aquifer settings and hydraulic properties. Aquifer's types and settings are exemplified by: porous, fractured, karstified and confined or unconfined aquifer examples. Boundary conditions and common flow equations such as Darcy's law can also be presented. Application exercises involve for instance gradient, flow calculations, drawing and analysis of equipotentials with -if needed- teacher supervision.**
- 2. Practical class : taking the example of the rectangular tank apparatus, students set up the experiment (imposed pressure boundaries) and measure local pressure heads and outflow. Groundwater flow processes are interpreted based on equipotential and velocity field maps builded from measured data. Outflow is calculated assuming an equivalent homogeneous hydraulic conductivity. More complex numerical activities are tackled afterwards.**
- 3. Classroom : lecture is oriented on topics related to flow toward a pumping well. For instance topic such as well test analysis methods and associated analytical solutions are explained in this class. Exercises focus on well test interpretation solutions, solving methods and well's protection area that are illustrated in the two other class components.**
- 4. Practical class : with the circular tank aquifer analog, students will set and perform various pumping and injecting tests during the practical class. Experimental results are interpreted with use of the theory and methodology seen in the classroom.**

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This iterative loop example was added in the revised manuscript at the end of Sec. 3.4 (Practical classes) after both lecture and practical classes activities were presented.

Reviewer comments

3) In section 2, bullet "2", it says that the practical experimental classes aim to (iv) use the data gathered in the field. But was this done? Figure 2 suggests otherwise, as does the text on p. 1077, lines 1-2.

→ **Section 2 presents an ideal teaching framework. In such case, field data should be interpreted with practical classes activities. In the presented course example, because of the university's time schedule, field data can unfortunately not be used in practical classes.**

In the revised version of the manuscript, we added to Sec. 3 (example course) that this adapted version of the integrated pedagogy allows to implement the specific teaching goals described in Sec. 2 (ideal course) with the exception of the use of field data in practical classes. A new paragraph on possible improvements of the pedagogical scheme (see Reviewer comment n° 4 below) was added to the Discussion section (Sec. 4). This new paragraph includes a comment on possible improvements of the feedbacks between practical classes and field activities.

Reviewer comments

4) The discussion section outlines possible improvements mentions introducing physical models and improving the apparatus and its use. However, a discussion on possible improvements of the pedagogical scheme in the light of state-of-the art knowledge is not included. This would be interesting and useful to have in the discussion, since the pedagogical perspective is strong in the other parts of the paper. Possible fields

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of improvement are exemplified in (a) and (b) below. (a) Formative assignments have been shown to greatly enhance student learning. They imply that feedback is given to various assignments, such that the student can make improvements throughout the course. In the present scheme, group reports on the practical classes (p. 1078, row 7-8) and the field class (p. 1079, rows 19-20) are due 15 days after the end of the course. Could the design of exams and/ or assignments be modified, to better facilitate relevant feedback, including written feedback? (b) There are several difficulties related to evaluation of group assignments, including e.g. assessing individual contributions. How has the evaluation of the group assignment worked in the course, and is there room for improvement?

→ **We agree with Anonymous Referee that a discussion on possible pedagogical scheme improvements was missing in the discussion section.**

a Formative assignments are implemented in the present course scheme with classical homework assignments associated to classroom correction (in lecture class). Improvements in the formative assignments could be indeed conducted by modifying the current form of already implemented assignments such as the group reports. To allow the students get written feedbacks on their work, group reports evaluation may be divided into two assignments : a formative assignment (due before the end of the course) and a summative assessment (due after the end of the course). This can be implemented in the course for instance with online feedback systems and electronic work submission (Hatzia Apostolou and Paraskakis, 2010; Hartford, 2007).

b It is true that assessing individual contributions through group assignments is a delicate process (Johnston and Miles, 2004). In the actual form of the proposed course, group reports are meant as a summative assessment. The identification of individual contribution in group assignments

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may be improved for instance by (i) introducing identified tasks that should be addressed individually and (ii) combining group average and individual marks.

As suggested by Anonymous Referee the "Discussion" section 4 was modified in the revised version of the manuscript. "Improvement in the proposed pedagogical scheme" was added as a new point to the list of possible improvements. A paragraph resuming the two aforementioned suggestions of improvement was added to the discussion.

Reviewer comments

5) In the first part of the introduction (stating the general problem), the stated scientific challenges in the field of hydrogeology do not match the considered course contents well. The paper outlines main challenges as understanding impacts of global change and providing inputs in societal discussions. However, the presented teaching modules do not address connections to societal discussions, and possible relations to global climate change are rather indirect. Quite different modules would be needed to improve awareness and skills to meet such challenges (e.g. in coupled hydro-climatic modelling, etc). The presented modules are designed to give a better process understanding of groundwater dynamics and well testing. It would clearly help the reader if more direct advantages of improving such knowledge would be pointed out upfront in the abstract and introduction (such as local and regional hydrogeological change assessments, issues related to water supply, impacts of other infrastructure, etc).

→ We acknowledge that the statement of the general problem can appear rather confusing as the scope of this paper is the teaching of groundwater flow processes. It would be indeed clearer if the suggested specific advantages would be directly pointed out instead of broader related topics.

We corrected both the abstract and the introduction of the revised manuscript. The
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following suggestions : assessment of local and regional hydrogeological change and water supply issues were added instead of the too broad challenges that were previously presented.

References

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