INVITED COMMENTARY

HP TODAY

HYDROLOGICAL PROCESSES
Hydrol. Process. **21**, 1789–1792 (2007)
Published online 18 May 2007 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.6766

Taking the pulse of hydrology education

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Received 18 March 2007
Accepted 19 March 2007

Progress in the hydrologic sciences has been hampered by a lack of synthesis across the diverse yet narrow disciplinary backgrounds within which most hydrologists are educated. As part of an effort to analyse, synthesise, and unite hydrologic education across a large number of institutions, our group commenced an online survey with contributions from 158 university hydrology educators. This survey provides a first step towards better understanding how hydrology is currently taught and indicates how teaching materials and instructor preparation could be improved. The survey has shown that there is little commonality in hydrology education resources and that many instructors are using customized, original materials. Participants spent considerable time preparing their lectures using multiple resources, and noted a wide variety of textbook choice, without any dominant selection. Respondents taught relatively small classes (10–15 students), mainly at the graduate level. Survey participants were predominantly from the USA, with about one-third teaching in engineering departments and one-quarter teaching in earth science departments.

Background

Hydrology is the study of the occurrence and the movement of water, in all its forms, on Earth. Hydrology has evolved from a mainly problem-driven, applied engineering discipline to one of the building blocks of the geosciences and environmental sciences without losing its focus on real world applications. Hydrologists investigate the distribution and spatio-temporal variation of water, as part of the global water system across a wide range of spatial and temporal scales. Such studies often include socio-economic aspects in their analysis. The complexity of hydrologic investigations has increased over time because of the necessary inclusion of chemical and biological aspects of the hydrological cycle to address topics such as water quality and ecosystem function.

As the demands on current and future hydrologists have changed, the concern arises that hydrology training has lagged behind necessary preparation for both research and application. There is evidence of hydrology as a science becoming more interdisciplinary, evolving in its focus due to new scientific findings, computational and technical advances, and new linkages to other disciplines. This is supported by the results of a recent (unrelated) survey about integrated water resources management in the USA, which found that 86% of 600 survey participants think that the greatest educational need is in the area of *watershed hydrology and modeling* (Bourget, 2006). Demands for an interdisciplinary approach to hydrology education were voiced over 15 years ago (Nash *et al.*, 1990; Eagleson *et al.*, 1991). Today, educators are increasingly challenged to find or develop up to date educational materials. These challenges are not confined to academia as federal agencies are also seeking employees with broad interdisciplinary skills. Hydrology has evolved from a discipline, dominated by advancements of individual scientists, towards an interdisciplinary field, in which major advancements are likely to come from groups of hydrologists (and other scientists) who pool their expertise to tackle complex tasks (examples include: prediction in ungauged basins (PUB) initiative,

Sivapalan (2003) and Wagener *et al*. (2004)); or the Consortium for the Advancement of Hydrological Sciences (CUAHSI) initiatives currently underway). This trend is also evident in the success of interdisciplinary groups or centers addressing problems of much greater complexity than previously possible (for an example in hydrology see Sorooshian *et al*., 2002). Hydrology educators, however, are necessarily influenced by their background and their expertise when designing hydrology classes and therefore require new educational tools and resources to educate the next generation of interdisciplinary hydrologists. In the light of continuing changes within the field, discussions amongst hydrology educators regarding educational approaches and materials should be an important activity. The first step in building consensus and identifying differences in what constitutes core education in hydrology begins with examining the current state of hydrology education, who is teaching, in what department/disciplines, and with what materials.

To understand the diversity of hydrologists and hydrology education, we looked for data surveying the background of hydrologists and hydrology education, but could only find older surveys for the USA, which showed a reasonably even distribution of hydrologists' backgrounds between engineering and science disciplines (e.g. Eagleson *et al*., 1991). Therefore, we recently initiated a new survey to obtain current information to characterize hydrology education.

Survey Outline

A purposefully short survey was designed to collect information about hydrology educators' background, how they teach, and course characteristics. An 'additional comments' box was available for suggestions/opinions on how hydrology education could (or should) be improved or regarding what current problems/limitations exist.

Survey Results

Survey participant characteristics

A total of 158 participants contributed to the survey. The vast majority of these participants teach at institutions in the USA (71%), while the remaining participants teach mainly in Europe. The distribution of the participants' teaching assignments is 35% in engineering departments, 24% in earth science departments, 11% in environmental science, 7% in natural resources, 5% in geography and 18% in other departments (e.g.hydrology and water resources, agriculture. etc.).

When asked which department granted them their highest degree, 43% of the respondents stated engineering and 23% earth science departments; 9% have environmental science degrees, 8% have a natural resources degree, 5% have a degree in hydrology, and 12% have other degrees. The survey participants were well mixed between junior and senior hydrology educators with highest degrees being obtained in years ranging from 1968 to as recently as 2006. About one-third of the participants received their degree before 1990.

Class Characteristics

Most hydrology classes included in the survey are taught at the graduate level (75% of the participants teach graduate level courses), 60% of respondents teach an undergraduate level course, and 34% teach a course for both undergraduate and graduates. On average, 39% of the participants teach more than one hydrology class per year. The distribution of typical class sizes shows that most of the classes are on the order of 10–15 students (54%) (Figure 1(a)). Classes larger than 50 students seem to be the exception (9%). About 50% of the participants have taught their hydrology class more than 5 times (Figure 1(c)), suggesting again that survey participants included both young and established educators.

Participants described their classes as fitting into one of four categories (Figure 1(b)): general hydrology (43%), surface water hydrology (30%), groundwater hydrology (17%), and water resources management (10%). Not surprisingly, surface water hydrology classes are mostly taught in engineering departments (50% of all surface water hydrology classes), while groundwater hydrology classes are mostly taught in earth science departments (58%). Water resource management classes are taught equally in all departments and general hydrology classes are predominantly taught in Earth Science (22%), Engineering (30%) and all other departments (26%).

Class Material and Preparation Time

When asked whether they use a textbook in their class, and if so which one, participants listed a staggering 52 different textbooks used in their courses. However, 39% of the 158 participants stated that they are not using a textbook as an in-class resource. Most textbooks were mentioned only a few times. The most popular textbooks were by Dingman (2002, 10%), Fetter (1994, 10%), and Hornberger *et al*. (1998, 7%). There was no preference for a particular textbook within the specific areas of hydrology. Fetter (1994), for example, was used 30% outside the field of groundwater hydrology. The range of textbooks used was particularly large for general hydrology courses suggesting that opinions on content and approach vary widely. The selection of an appropriate textbook is a difficult task, as can be seen from that fact that 40% of the participants who use textbooks stated that they have been using more than two primary textbooks since they started teaching their hydrology class. This excludes changing to a newer edition of the same textbook.

DOI: 10.1002/hyp

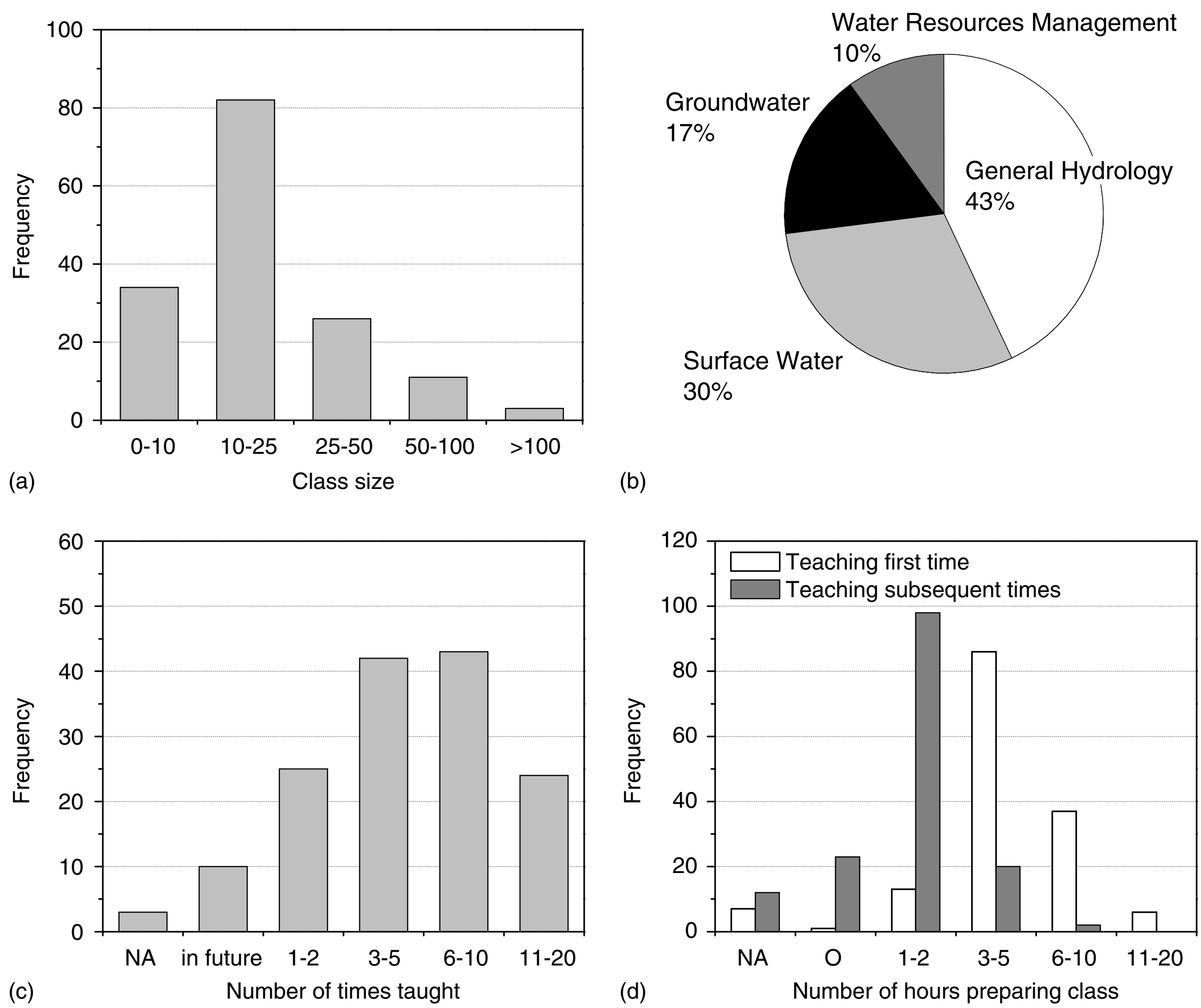

Figure 1. (a) Frequency distribution of hydrology class sizes as indicated by the survey participants. (b) Class designation provided by survey participants when asked about how to best describe their class. (c) Frequency distribution of number of times participants have taught their class. (d) Frequency distributions of class preparation time when participants taught the class for the first time, and preparation time when subsequently teaching the class (NA = no answer provided)

With respect to class preparation, most participants reported spending 3–5 h to prepare for 1 h of class time when they taught the course for the first time (Figure 1(d)). Most respondents still spend 1–2 h of preparation when teaching the course subsequently.

The survey also asked educators to estimate the proportion of class materials from different sources (primary text, secondary texts, peer-reviewed articles, government reports, and independently developed materials). In contrast to our expectations, independently developed material is used slightly more frequently as a primary source than a textbook. A quarter of all classes utilize mainly (>50%) independently developed material, while only 20% of all classes derive their material mainly from a primary textbook. Secondary texts and peer-reviewed articles are much less frequently used (less than 20% of the classes rely on more than 20% of content from these sources). Governmental reports are the least used source for preparing hydrology classes (over 60% of respondents state no use of governmental reports).

Summary

As a group of young hydrologists, we conducted a short, online survey to understand some of the main characteristics of current hydrology education and its educators. The survey provided a very interesting view on the great diversity found in hydrology education and suggests that *while an education with a common basis is desirable, it is clearly not available at the moment. Hydrology educators are challenged to identify common principles, core knowledge, and approaches that should be included, in addition to areas where clear consensus is lacking*. This lack of consistency may be contributing to slow progress in hydrologic science since each hydrologist's definition of what a hydrologist should know depends on their education and background. Kirchner (2006) and Bloeschl (2006) discuss in separate papers that advancements in hydrological science will likely come from synthesis of different approaches, from 'collision' of theory and data, and from better communication. Hydrology education is clearly one way to facilitate this communication.

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Additional information about the Research and Education Advancement through Cooperative Hydrology (REACH) group, which initiated this survey can be found as an online supplement to this article on the survey website. All the data collected are freely available and interested parties are invited to approach any of the authors to discuss the issue of hydrology education further. The survey can be found at http://www.ideal.forestry.ubc.ca/markus/survey.asp, as well as the data underlying the analysis presented here. The survey will remain open to new respondents.

Acknowledgements

We would like to thank the following individuals and organizations who supported the survey and/or our education efforts in general: the International Association of Hydrological Sciences (IAHS; Pierre Hubert and Arthur Askew), CUAHSI (Rick Hooper and Jon Duncan), the Office of Hydrologic Development of the National Weather Service (NWS; Gary Carter), the American Water Resources Association (AWRA; Dave DeWalle), and the International Environmental Modeling and Software Society (IEMSS; Giorgio Guariso and Andrea Rizzoli), the Modeling and Simulation Society of Australia and New Zealand (MSSANZ) and the Journal of Environmental Modeling and Software (EMS) (Tony Jakeman).

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