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Project Title
IPython Notebooks on Landscape Hydrology: Synthesizing Theory and Applications with Interactive Code

Project Team
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Audience
The primary audience for this material will be students in *Hydrology* (570.353), *Landscape Hydrology and Watershed Analysis* (570.412), and a new course on *Watershed Contaminant Transport* to be offered in Spring 2015. All three classes are open to seniors and graduate students, and 570.353 is a required course for the Environmental Engineering majors. The other two are electives that fulfill technical elective requirements.

Pedagogical Issue
Several core components of these three courses require students to draw on abstract mathematical concepts regarding the theory of convolutions and probability and apply them to data analysis and modeling of the movement of water and solutes in the landscape using custom programming scripts in MATLAB, R, or Python languages. This three-way connection (theory-application-code) has proved extremely difficult, even though students have (or are expected to have) covered most of the mathematical and coding fundamentals in previous classes. Students report having difficulty developing a synthetic, intuitive appreciation of how the theory relates to real-world problems (rather than being a list of equations to be regurgitated at exam time). While they could develop that appreciation by writing simple scripts that implement the theories and interact with real data, many are hesitant or are scared off by a perceived “steep learning curve” associated with coding.

Solution
We will create a set of interactive online notebooks that cover the mathematical fundamentals and transport theories and allow students to interact with bite-size snippets of code that demonstrate the application of these theories using real hydrologic and water quality data. The Python language has emerged as a particularly useful platform for teaching non-computer-science applications of programming through the development of the IPython Notebook (http://ipython.org/notebook). These notebooks combine text, graphics, interactive media and Python code in a web page that can be accessed through a browser. The Notebooks can be created using a simple rich-text markup language and do not require specialized web development skills. These notebooks will serve as learning tools for students working individually or collaboratively in groups.

Assessment Strategy
The assessment strategy will consist of two components, one providing continuous feedback and improvements, and the other asking students to evaluate the efficacy of the notebooks relative to the more traditional problem sets delivered in the course.

For the first component, each notebook will include a section where students can provide feedback and evaluation of their learning experience with that particular notebook. They will be asked to indicate the parts of the notebook that were the most useful, the least useful, and an estimate of the time that was required to complete the exercises. This feedback will be used to continuously improve the notebooks, weeding out ineffective elements and providing more details and interactive content as needed.

Towards the end of the course but prior to the final exam, students will be asked to compare their learning experience with the notebooks with the more traditional problem sets used to teach other course components. This self-reported experience will be compared to their actual relative performance in these different components in the final exam to determine whether the interactivity actually generates increased understanding or simply the perception of it.

Faculty Statement

Scripting languages like Python, R and MATLAB have become extremely user-friendly and powerful tools for engineers and scientists but are not generally integrated into STEM curricula. I would like to see students using them to better understand how the (sometimes fairly abstract) mathematical concepts on the blackboard can come alive when they are placed into a computational model and fed real-world data. However, I have had limited success in getting students (apart from those who already have significant coding experience) to see that they already have many of the skills they need.

Each notebook created by this project will cover a discrete learning module and include pedagogic text, multimedia (such as embedded YouTube videos of hydrologic events), example Python code (and the plots generated by the code, which are embedded automatically), and exercises and problem sets where students can check their understanding by writing their open python code snippets and see the output results immediately. I hope this project will serve as a pilot example for other faculty interested in expanding the interactive computational and data analysis components of their teaching in a way that does not require a steep learning curve.

The technology fellow involved in this project spent part of last semester in an independent study with me coming to grips with some of the most challenging material that will be taught in these classes, related to the use of probability distributions to represent solute transport through the landscape. She excelled at this, and I would like to channel her enthusiasm and new-found knowledge into tools that can help other students gain the deep understanding she has. We will work together over the summer to develop the pedagogic content, and she will get up to speed on the IPython Notebook framework. Over the Fall semester we will have weekly meetings to complete each module and arrange pilot tests in the Fall *Hydrology* 570.353 class. The full deployment will be in the Spring 2015 *Watershed Contaminant Transport* class. I will be primarily responsible for developing the pedagogic text, and the fellow will be primarily responsible for constructing the notebooks and curating multimedia components. We will work together to develop the interactive code components and problem sets. I expect the fellow to work approximately 150-200 of the allotted hours over the summer and the remainder over the following Fall semester. I will be solely responsible for deploying the content in the Spring semester class.

After the completion of the fellowship and over the coming years, I will refine these notebooks and expand the content, with the eventual intention of developing an on-line learning tool to teach new theoretical developments in watershed solute transport my research group has been developing. The challenges the students face in learning these concepts are also the challenges many other scientists in

my field face when confronted with new theoretical frameworks, so a tool like this can greatly expand the impact of our research.