Hydrol. Earth Syst. Sci. Discuss., 9, 2569–2599, 2012
www.hydrol-earth-syst-sci-discuss.net/9/2569/2012/
doi:10.5194/hessd-9-2569-2012

Hydrology and Earth System Sciences Discussions

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib[1], Y. Ma[2], D. Williams[2], H. Sharif[3], and F. Hossain[4]

[1]Department of Civil Engineering, University of Louisiana at Lafayette, P.O. Box 42991, Lafayette, LA, 70504, USA
[2]Center for Innovative Learning and Assessment Technologies (CILAT), University of Louisiana at Lafayette, P.O. Box 42051, USA
[3]Department of Civil and Environmental Engineering, University of Texas at San Antonio, USA
[4]Department of Civil and Environmental Engineering, Tennessee Technological University, USA

Received: 31 January 2012 – Accepted: 4 February 2012 – Published: 28 February 2012

Correspondence to: E. Habib (habib@louisiana.edu)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

HydroViz is a web-based, student-centered, highly visual educational tool designed to support active learning in the field of Engineering Hydrology. The development of HydroViz is informed by recent advances in hydrologic data, numerical simulations, visualization and web-based technologies. An evaluation study was conducted to determine the effectiveness of HydroViz, to examine the buy-in of the program, and to identify project components that need to be improved. A total of 182 students from seven freshmen and junior-/senior-level undergraduate classes in three universities participated in the study over the course of two semesters (spring 2010 and fall 2010). Data sources included homework assignments, online surveys, and informal interviews with students. Descriptive statistics were calculated for homework and the survey. Qualitative analysis of students' comments and informal interview notes were also conducted to identify ideas and patterns. HydroViz was effective in facilitating students' learning and understanding of hydrologic concepts and increasing related skills. Students had positive perceptions of various features of HydroViz and they believe that HydroViz fits well in the curriculum. The experience with HydroViz was somewhat effective in raising freshmen civil engineering students' interest in hydrology. In general, HydroViz tend to be more effective with students in junior- or senior-level classes than students in freshmen classes. There does not seem to be obvious differences between different universities. Students identified some issues that can be addressed to improve HydroViz. Future adaptation and expansion studies are under planning to scale-up the application and utility of HydroViz into various hydrology and water-resource engineering curriculum settings.

1 Introduction

Several national review reports have stressed the need to improve undergraduate engineering hydrology education (NRC, 1991; Nash et al., 1990; Wagener et al., 2007;

Howe, 2008; Ledley et al., 2008; Loucks, 2008; CUAHSI, 2010). Improvements have been recommended in two areas in particular: (1) introducing and rejuvenation of hydrologic data and observational components in the undergraduate hydrology curriculum, and (2) using numerical simulation models to facilitate students' learning of fundamental spatial and temporal hydrologic processes. In response to such recommendations, the current study develops a hydrologic learning tool that is based on three main instructional strategies: (1) learning with data and simulations, (2) embedding technical contents within real-world hydrologic systems, and (3) using web-based geospatial visualization technologies to support the implementation of desirable educational enhancements. These instructional strategies are well supported by existing education research and have been tested in a variety of related science disciplines (e.g., Dori et al., 2003; Denniston, 2005; Hickey et al., 2003; Kolodner, et al. 2004; Yadav and Beckerman, 2009; Zia, 2005; Winn, 2006; McGrath and Brown, 2005; Libarkin and Brick, 2002); however, their full potential has not been exploited in the field of engineering hydrology education.

The current study reports on the implementation and evaluation of a pilot hydrologic education system (called HydroViz; http://hydroviz.cilat.org/hydro/) that is informed by the instructional strategies discussed above. It supports technology-enhanced instruction with data, visualization, and simulations that are embedded in real-world hydrologic systems. The overall goal of HydroViz is to capitalize on recent research advances in hydrologic data and numerical simulations to rejuvenate the education of hydrology in undergraduate engineering programs and other related disciplines.

2 Hydro-data and model simulations in HydroViz

To facilitate students' learning through real-world applications, we developed the HydroViz tool for a local mid-size watershed (Fig. 1) located in the vicinity of the University of Louisiana at Lafayette campus. The Isaac-Verot (IV) watershed has an area of 35 km^2 Isaac and is a sub-drainage area of the Vermilion river basin, which drains into the Gulf of Mexico. The watershed is frequently subject to frontal systems, air-mass thunderstorms, and tropical cyclones with annual rainfall of about 140 to 155 cm and monthly accumulations as high as 17 cm. The main soil type in the watershed is silt loam with low to medium drainage capacity. Land-use in the watershed is composed of urban areas, cropland, pasture and some forested areas. Due to its low-gradient topography, the watershed has unique and challenging hydraulic and hydrologic characteristics that are caused by the combination of tidal effects and extremely low overland slopes and can often experience reverse flow during rainstorms and periods of storm surge (Habib and Meselhe, 2006).

The watershed is represented in HydroViz using three main sets of information: in-situ observations, geospatial datasets, remote-sensing data, and model simulations. The in-situ data are available from a suite of hydro-meteorological sensors that were deployed in the watershed through previous research efforts. These sensors included 13 dual-gauge tipping-bucket rainfall stations, gauges, acoustic streamflow gauges at the watershed outlet and at four interior locations, a volumetric soil moisture sensor, a disdrometer for collecting raindrop size distribution, and a total weather station. Besides in-situ rain gauges, HydroViz also includes rainfall information based on two remote sensing techniques, radars and satellites. These data sources were included in HydroViz to introduce the students to the wealth of information provided by weather radars and satellites in terms of the large spatial coverage and high temporal resolution of rainfall storms. Radar-rainfall data over the watershed were acquired from the Stage IV dataset (Habib et al., 2009) produced by the US National Weather Service (NWS). The Stage IV data has a spatial resolution of $\sim 4 \times 4\,\mathrm{km}^2$ and is available every hour. The satellite-rainfall data in HydroViz was acquired from the global CMORPH product (Joyce et al., 2004) which has an approximate spatial resolution of $\sim 8 \times 8\,\mathrm{km}^2$ and a temporal frequency of 30 min.

Geospatial data on topography and soil and vegetation types in the watershed were gathered and integrated into HydroViz. Elevation data was acquired through the US Geological Survey National Elevation Dataset (NED; http://ned.usgs.gov/) in

HESSD
9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.

three different resolutions: 1 arcsec (∼30 m) 1/3 arcsec (∼10 m), and 1/9 arcsec (∼3 m). The three resolutions are incorporated into HydroViz to allow students to analyze the topographic variations in the watershed and understand the impact of data resolution on hydrologic analysis and predictions. Soil type data was gathered from the US Department of Agricultural (USDA) Natural Resources Conservation Service (NRCS) (http://soils.usda.gov/survey/geography/) based on two sources: the Soil Survey Geographic (SSURGO) database, and the State Soil Geographic (STATSGO) database. Land-Use and Land-Cover (LULC) coverage maps were acquired and integrated into HydroViz based on historical and more recent datasets from the US Geological Survey (USGS) website (http://eros.usgs.gov). Using historical and recent maps students can investigate the effect of urbanization and land-use change on flooding in the watershed. Other datasets, such as stream hydrography, channel surveys, and digital raster graphic (DRG) topographic maps were also embedded into the HydroViz tool to support a full description of the watershed site.

The hydrologic simulation component of HydroViz is built using a distributed hydrologic model to allow for physical and spatially detailed representation and simulation of important rainfall-runoff processes in the watershed. The Gridded Surface Subsurface Hydrologic Analysis modeling system (GSSHA; Downer and Ogden, 2004) was used to generate numerical physically-based, spatially and temporally distributed simulations of basic hydrologic processes over the watershed (e.g., rainfall distribution and interception, overland water retention, infiltration, evapotranspiration, two-dimensional overland flow, one dimensional channel routing, and flow in the unsaturated zone). A $25 \times 25\,\text{m}^2$ Cartesian grid (Fig. 1) was used to represent the different watershed topographic and hydrologic properties such as surface roughness, soil parameters, and vegetation characteristics. A full description of the model setup, calibration and validation for this watershed is available in Habib et al. (2008). A set of rainfall-runoff simulations and application scenarios were performed using the GSSHA model to populate the HydroViz tool with various outputs on the response of the watershed in the form of streamflow time series at the watershed outlet and at interior locations; and time series

HESSD
9, 2569–2599, 2012

of spatially distributed fields of overland runoff, water depth, infiltration rates, cumulative infiltrated water, and soil moisture. These simulations were performed for an actual rainfall event, Tropical Storm Matthew, which swept across South Louisiana for several days (7–10 October 2004) and resulted in widespread flooding.

3 HydroViz software

The design of the HydroViz software is driven by the following educational requirements and functionalities: web-based accessibility, ease of dissemination, highly-visual and interactive capabilities and the ability to integrate the geospatial data and spatio-temporal model simulations described above. The intent is to provide authentic and hands-on inquiry-based activities that can improve students' learning. To fulfill these requirements, HydroViz was built as a browser-based, web-accessible system that leverages the power of freely available geospatial and visualization resources (http://hydroviz.cilat.org/hydro/). HydroViz employs the free Google Earth Plug-in and its JavaScript API to enable presentation of geospatial data layers and embed them in web pages that have the same look and feel of Google Earth (see Fig. 2). Google Earth offers the ability to place and visualize hydrologic technical information on a 3-D model of the Earth, which facilitate students' interactive and visually supported learning. The HydroViz software uses various programming techniques such as Cascading Style Sheets (CSS) and html, Google Earth API, Keyhole Markup Language (KML) and JavaScript codes. The Cascading Style Sheets (CSS) and html describe the look and formatting of each HydroViz web page. With the aid of Google Earth API, it was also possible to create customized buttons and panels for students to interact with and display the data. This software design allows the user to run the tool on a typical desktop computer with Internet access after a free Google Earth (GE) web browser plugin is installed. Within the HydroViz setting, students can use Google Earth navigation capabilities to explore the watershed and use the embedded inquiry-based investigations and the supporting layers of hydrologic information. The HydroViz interface (Fig. 2)

HESSD
9, 2569–2599, 2012

is divided into 3 areas: (1) Google Earth in the main display, (2) the educational content and educational tasks on the right side, and (3) layers and tools at the bottom of the interface. As the user turns various layers on or off or uses the measuring tools, JavaScript code makes calls to the Google Earth API which in turn communications with the Google Earth Plug-in. Layers in Google Earth are defined in KML language, a tag-based file format that defines the content to be displayed in Google Earth.

4 Learning modules in HydroViz

To facilitate the introduction of HydroViz in classrooms, a total of 13 educational modules have been designed and embedded into HydroViz (Table 1). The modules range from basic activities (e.g., exploring watershed characteristics) to advanced analysis of field data and model simulations. Each module is self-contained and all instructions, guidance and technical questions are embedded within the same screens that show the watershed and its visual displays. These modules were designed using an actual rainfall event, Tropical Storm Matthew, which swept across South Louisiana for several days (7–10 October 2004). Table 1 provides a list of these modules; the reader is referred to the HydroViz web tool (http://hydroviz.cilat.org/hydro) for a full description of each module and the student activities embedded into it:

The modules can be introduced to the students at different stages within a single course, or a subset of the 13 modules can be used across different classes. Each module starts with an introduction to the technical subject followed by a set of activities that the students need to complete. The activities are interactive and inquiry-based and include investigative tasks as well as quantitative and qualitative analyses.

5 Implementation and evaluation of HydroViz

HydroViz has been implemented and evaluated in 7 undergraduate courses at the developing institution and two additional independent institutions. The following sections

HESSD
9, 2569–2599, 2012

provide a detailed description of the methods and the data sources that were used to evaluate the effectiveness and educational value of HydroViz.

5.1 Evaluation methods

An improvement-focused evaluation model (Posavac and Carey, 2003) informed the evaluation of HydroViz. This model focuses on improving the program by identifying and addressing the issues early and continuously throughout the program. A mixed method research approach (Chatterji, 2005) guided our data collection. Quantitative survey data and a homework assignment helped determine the effectiveness of the program. Qualitative survey question and interviews helped explain why and how the software worked or failed to work in order to inform improvement. This evaluation was both formative and summative in nature. The summative aspect focused on project effectiveness. The formative aspect examined the buy-in of the program and investigated program components in order to improve the project.

5.2 Evaluation questions

The following evaluation questions guided the evaluation.

1. How effective is HydroViz in facilitating students' learning and understanding of hydrologic concepts and increasing related skills?

2. What are students' perceptions of various features and characteristics of HydroViz?

3. What are students' perceptions of HydroViz as a part of the curriculum?

4. How effective is HydroViz in developing freshmen engineering students' interest in hydrology as a subject area?

HESSD
9, 2569–2599, 2012

5. Do students in different classes and universities differ in their learning of the hydrologic concepts and perceptions of HydroViz?

6. What can be done to improve HydroViz?

5.3 Participants

A total of 182 students and 6 instructors in three universities participated in the evaluation study over the course of two semesters (spring 2010 and fall 2010). The courses included two senior-level *Engineering Hydrology* classes, one senior-level *Water Resources* class, and four freshmen-level *Introduction to Civil Engineering* classes (Table 2).

5.4 Data sources

Homework Assignments: HydroViz contains a set of 13 learning modules designed to cover different topics in hydrological curriculum (e.g., watersheds and sub-watersheds, classification of land-use land cover, soil types, land elevation, field equipment, rainfall measurement analysis, rainfall measurement using remote sensing techniques, and analysis of runoff/stream flow observations). A set of questions are embedded within each module for which the students have to record their answers and observations based on the activities performed. At the end of each module, the students save their reports in template files furnished to them within HydroViz and submit them to the instructor. Students' answers in these homework assignments were compiled and used to guide the evaluation analysis.

Online Surveys: an online student survey was used to examine students' perceptions of software. It is a 17-item, 5-point Likert scale instrument that presents 17 statements to students. For each statement, students chose from one of the following answers, "Strongly agree," "Agree," "Neither agree nor disagree," "Disagree," and "Strongly disagree." The survey includes six items on students' perceptions of whether the software contributed to their understanding of certain hydrologic concepts. For example, students were given the following statement "The HydroViz project contributed to my understanding of the concept of watersheds and sub-watersheds." For students in the junior/senior level engineering hydrology class, the instrument includes an item to examine their perception of whether HydroViz improved on current teaching tools/methods typically used in hydrologic engineering courses. For students in the two freshmen level Introduction to civil engineering classes, there are two items that investigate their perception of whether the tool was useful in introducing basic hydrologic concepts and increasing their enthusiasm for the subject of hydrology. The instrument also includes seven items related to their perceptions of various features and characteristics of HydroViz. In addition, the survey includes a question on whether the tool fits well with the curriculum and a text field for students to enter any comments that they may have.

Informal Interviews: notes from informal interviews with students in an engineering hydrology class serves as another data source. The interviews include discussions of issues and areas for improvements.

5.5 Data collection procedures

HydroViz was introduced and evaluated in a total of seven undergraduate courses at the University of Louisiana at Lafayette (UL Lafayette; where HydroViz was developed) and two other independent universities (University of Texas at San Antonio, UTSA; Tennessee Tech University, TTU). In each of these classes, the instructor first presented the HydroViz tool to the students. The presentation includes a brief introduction on how to install the Google Earth plug-in and how to navigate and use the tool. Students were required to complete the tasks embedded within each module in HydroViz and answer the questions and submit them as a homework assignment. In spring of 2010, the HydroViz modules were assigned towards the end of the semester and the students were given a period of two weeks to complete the activities. In fall 2010, the modules were assigned incrementally within the semester. The numbers of modules

HESSD
9, 2569–2599, 2012

assigned to the students varied by course type and semester. In Table 3, blank cells show that the modules are not assigned to a class. In some classes (e.g., TTU senior hydrology class), the instructor selected certain modules that overlapped with the course syllabus and used HydroViz to emphasize and evaluate students' learning of specific topics covered in the course. In other senior classes (e.g., UL senior hydrology class), the instructor chose to cover all modules to introduce students to other topics that are not typically covered in the course. In the freshmen-level classes, instructors assigned most modules in the spring 2010; but decided in the subsequent semester to assign only introductory modules, which are more appropriate for freshmen students. In some classes, the assignments contribute to the grades that students receive for the class. In some other classes, the assignments were not part of the grading structure for the course. Once students completed and submitted their assignments, they were also given an online survey to complete. Some of the participating professors also conducted informal interviews with students once they completed the assignment.

5.6 Analysis of evaluation data

To answer question 1, "How effective is the HydroViz software in facilitating students' learning and understanding of hydrologic concepts and increasing related skills?", students' HydroViz homework assignments were graded and descriptive statistics were calculated for all the sections. In addition, descriptive statistics were calculated for six survey items that ask students' perceptions of how well HydroViz contributed to their learning.

To answer question 2, "What are students' perceptions of various features and characteristics of HydroViz?", descriptive statistics were calculated for seven survey items related to this question. Students' comments and informal interview notes were also analyzed to identify ideas and patterns.

In order to answer research question 3, "What are students' perceptions of HydroViz as a part of the curriculum?", descriptive statistics were calculated for two survey items

HESSD
9, 2569–2599, 2012

related to this question. Related students' comments and informal interview notes were also analyzed to identify ideas and patterns.

To answer question 4, "How effective is HydroViz in developing freshmen engineering students' interest in hydrology as a subject area?", descriptive statistics were calculated for two survey items related to this question. Related students' comments and informal interview notes were also analyzed.

To answer question 5, "Do students in different classes and universities differ in their learning of the hydrologic concepts and perceptions of HydroViz?", descriptive statistics were calculated for all survey items answered by students.

To answer question 6, "What can be done to improve HydroViz?", students' comments and informal interview notes were also analyzed to identify ideas and patterns.

6 Evaluation results

1. How effective is HydroViz in facilitating students' learning and understanding of hydrologic concepts and increasing related skills?

HydroViz was effective in facilitating students' learning and understanding of hydrologic concepts and increasing related skills as indicated by students' homework assignments. Table 3 shows that an average of 66–85 % of the students understood the key concepts and increased their skills. It seems to be more effective for students in the senior-level engineering hydrology or water resource engineering courses. An average of 69–91 % of them showed competency for these concepts. Concepts in the latter modules seem to be more difficult to grasp than those in the other modules. The percentages of students who received full or almost full scores for the last four modules were lower than the previous ones.

Table 4 shows that an average of 10–32 % of students did not complete certain modules assigned by the teachers. Junior/senior students performed better where the highest incompletion rate for a module is 30 %, whereas for freshmen, up to 48 % of

HESSD
9, 2569–2599, 2012

them did not complete a module. The completion rates for the last three modules are lower than the other ones.

The survey results seem to be consistent with the analysis of homework assignment (see Table 5). Of all the participants, an average of 67–87 % of students agreed or strongly agreed that HydroViz contributed to their understanding of the hydrologic concepts. This was particularly true with the students in the senior-level courses, in which 78–100 % of them strongly agreed or agreed that HydroViz contributed to their understanding of various concepts. Freshmen were less positive. About 52–88 % of the students in freshmen classes from two universities strongly agreed or agreed that HydroViz contributed to their understanding of various concepts. About 81 % of the freshmen strongly agreed or agreed with the following statement: "I found HydroViz useful in introducing basic hydrologic concepts."

2. What are students' perceptions of various features and characteristics of HydroViz?

Students had positive perceptions of various features of HydroViz (Table 6). Of all the participants, 79–93 % strongly agreed or agreed that they liked the various features and characteristics of HydroViz shown in Table 6. Students in the senior-level courses were slightly more positive. In these courses, the percentage of students who strongly agreed or agreed that they liked various features of the tool ranged from 83–97 %, yet the percentage of students in the freshmen course who strongly agree or agree that they like various features of the tool range from 75–90 %. Students commented that they like the tool because it is hands-on and it presents the technical subject within a real-world context.

3. What are students' perceptions of HydroViz as a part of the curriculum?

Overall, students have positive perceptions of HydroViz as a part of the curriculum (Table 7). About 85 % of the students in the senior-level courses strongly agreed or agreed with the following statement: "I find that HydroViz improves on current teaching tools/methods typically used in hydrologic engineering courses." Almost all of them

(96 %) strongly agreed or agreed that HydroViz fits well with the curriculum. The freshmen in the civil engineering introduction course found the tool less relevant. About 63 % of them strongly agreed or agreed that HydroViz fits well with the curriculum.

4. How effective is the HydroViz software in developing freshmen engineering students' interest in hydrology as a subject area?

The experience with HydroViz was somewhat effective in raising freshmen civil engineering students' interest in hydrology (Table 7). About 57 % of the freshmen strongly agreed or agreed with this statement: "As a new freshmen civil engineering student, I found HydroViz useful in increasing my enthusiasm for the subject of hydrology." Several freshmen civil engineering students commented that the tool was eye opening for them.

5. Do students in different classes and universities differ in their learning of the hydrologic concepts and perceptions of HydroViz?

In Tables 3–7, it is clear that in general, students in senior level classes received better scores and had higher completion rates for HydroViz homework assignments and reported more positive perceptions of HydroViz than students in freshmen classes. There does not seem to be obvious differences between different universities.

6. What can be done to improve HydroViz?

Students identified some issues that can be addressed to improve HydroViz. Many students commented on the heavy workload. The HydroViz assignment required a lot time to complete. In addition, for some classes the timing of the project was not optimal because it was the end of the semester and students had commitment for assignments and finals for other classes. They wished that they had more time for the project. They said that they could enjoy the project more if they had more time. Table 4 shows that the average percentages of students who did not complete the tasks increased for the last several sections of the assignments. Students suggested that the instructor should introduce HydroViz early on in the semester and present them in smaller chunks to the students as they go through the semester. In addition, the tool should include indication of the scope of the project, including the total numbers of screens and tasks as well as their current progress in completing the tasks. Further, students suggested that the tool allow the user to jump or navigate to a certain screen without having to go through every screen.

Reading and interpreting the instructions and questions seemed to be an issue that lowered the grade for some students. For example, one of the first questions that students needed to answer in the assignment was to identify the state and city where the watershed was located. A few students provided the city name but did not mention the state. This is a simple task that one would expect that all students could complete correctly. Problems like this were somewhat common throughout the assignment. Some students did not read or answer the entire questions or had slightly different interpretation of the questions. Some did not see some questions as questions. Some others changed question numbers, reworded the questions, or deleted some parts. A student even turned in their assignment as one paper without sections. Several students commented that the questions need to be better clarified and more direct instructions should be provided on what questions students should answer and what are expected of them.

Some freshmen did not think that the content was particular relevant to their specific engineering field. Some of them thought that the project was too long and challenging for them. A simplified version of HydroViz might be more appropriate for this group of students. One suggestion was that the tool includes a demo that shows the overall functionality of HydroViz with some examples of the activities and expected results/outcomes. One of the challenges for some students was the required use of Excel in the assignment. Instructions on how to graph in Excel would be helpful to these students. The tasks for the last few set of questions seemed to be particularly challenging. More guidance or instructions might be needed to improve students' learning.

HESSD
9, 2569–2599, 2012

A couple of minor technical issues were identified. For example, a line tool was provided in HydroViz to allow students to measure length and area. Students asked for improvement of the tool that allows for more flexible use of the tool and accurate calculation. Another area that can be improved is the downloading of the rain gauge data. At the time of the evaluation, students had to click on each rain gauge on the map to download the data. Students requested that all the rain gauge data to be downloaded at one time.

7 Summary, discussions and future work

HydroViz is a web-based, student-centered, highly visual educational tool designed to support active learning in the field of Engineering Hydrology. The technical design of HydroViz is based on integration of hydrologic data and numerical simulations into a web-based system that leverages the strength of Google Earth to provide authentic and hands-on activities to improve learning. The development of the HydroViz system focused on achieving three main outcomes: (1) facilitating students' learning and understanding of basic hydrologic concepts and increasing related observational and data analysis skills (students learning outcome), (2) development of hydrology learning modules that are adaptable and easy to transfer to other institutions (community building outcome), and (3) development of improved knowledge on how web-based techniques for geospatial navigation, visualization and data publication and analysis can be used to improve undergraduate hydrology education (knowledge base outcome).

The current study indicated that HydroViz was effective in facilitating students' learning and understanding of hydrologic concepts and increasing related skills. The evaluation shows that HydroViz led to effective learning and positive perception. The learning modules embedded within HydroViz were successfully implemented in senior-level engineering hydrology courses at three independent institutions, and their potential for increasing freshmen's interest was tested in introductory civil engineering classes. The web-based, visual and spatial navigation tools used in HydroViz were identified as the most attractive and effective features that appealed to both students and instructors.

HESSD
9, 2569–2599, 2012

We found that successful implementation of HydroViz requires the consideration of many factors. As a web-based tool that can run on any web browsers, HydroViz was designed for easy dissemination. The only requirement is to download a free Google Earth (GE) web browser plugin. In addition, the instructions and the technical questions are embedded within the same screens that show the watershed and its visual displays. However, we found that contextual variables might have impacted the effectiveness of HydroVoz. This is a common issue with educational innovations. A program might prove to be effective in small-scale testing; yet it may not be successful when implemented in other context. Typically, contextual variables may contribute to an inconsistent performance. Reducing these variables might lead to more positive results. In our case, the evaluation drew our attention to some contextual variables that we need to communicate to the instructors when the tool is used in other institutions. For example, how and when HydroViz is used was a significant factor impacting the performance of students in this evaluation study. In some classes, the tool was introduced toward the end of the semester. Students had very limited time to complete all the activities when they were overwhelmed by projects and finals from other courses. Heavy workload and timing of the project led to negative attitude for students in some classes. In addition, some instructors assigned HydroViz activities without presenting the concepts in class. This might have also negatively impacted the implementation of HydroViz. Therefore, based on first-hand experience and recommendations from the instructors who were involved in the current HydroViz evaluation study, when adapting HydroViz for use in other universities, we might provide suggestions to other instructors on when to introduce HydroViz and how to break down the tasks so that the workload is appropriate and students may better digest the materials. In addition, we believe that HydroViz should be used as supplementary materials to existing curriculum of hydrology. The instructor should present some hydrologic concepts in the existing curriculum and then use HydroViz to provide more hands-on activities and practice. Better integration of HydroViz with existing hydrology curriculum will improve student learning.

HESSD
9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.

HydroViz was much more effective for students in the engineering hydrology class rather than the freshmen introduction to civil engineering class. This is not surprising. HydroViz was originally designed for engineering hydrology class. We suspected that the tool might be somewhat challenging for freshmen engineering students to use, but we wanted to find out whether the tool or part of the tool could serve as an introduction to hydrology and whether it could attract freshmen to the subject of hydrology. We found that HydroViz has great potential for this audience. The tool increased the enthusiasm for half of the freshmen and broadened their understanding of civil engineering. Even though HydroViz was challenging to some freshmen, most of them still learned the key concepts. The evaluation provided suggestions for us to create a simplified version of HydroViz and customize it for freshmen engineering students. It identified concepts or tasks that might be too challenging or irrelevant to the freshmen and areas that we could more guidance in the tool. Video demos of how the tool is used can be recorded to serve as a tool to recruit students into the field of hydrology.

It seems that HydroViz has more potential than the current evaluation indicates. We believe that the results will be more positive if the assignments are improved by clarifying the questions, breaking down some of the activities to make the tasks more focused and to deliver them in smaller chunks. Lower scores and completion rates of the last three or four modules suggest that they are more challenging than other modules. Providing more guidance with the use of video tutorials, templates for data entry, and example solutions might help improve student learning. In addition, we expect higher scores for the homework assignments if they are in the grading structure for the class and more students turn in the assignments. After this evaluation study, our team has improved HydroViz by clarifying the questions, providing more guidance, refining navigation and interface design. These efforts would further improve the effectiveness of the tool so that it could be used successfully with minimum support from the instructor.

The evaluation results were rather similar across the three institutions involved in the evaluation. Students in TTU and USTA demonstrate similar level of learning of the hydrologic concepts and perceptions of HydroViz as compared to students in UL

HESSD
9, 2569–2599, 2012

Lafayette, where the tool was originally developed. This indicates that it is quite promising to disseminate HydroViz and use it in engineering hydrology courses in other institutions across the country. Finally, we would like to point out that the recent implementation of HydroViz has resulted in an actual adaptation case by one of the independent testing institutions which decided to adapt HydroViz design and functionality and develop a completely new application for one of their own local watersheds. The results of this ongoing experiment will provide important feedback on how to enhance and facilitate the adaptability of future expanded versions of HydroViz and the development of other similar applications. The authors are inviting other interested users of HydroViz to participate in potential adoption and adaptation testing studies. The development codes that were used to develop HydroViz (Cascading Style Sheets (CSS) and html, Google Earth API scripts, Keyhole Markup Language (KML) and JavaScript codes) are available upon request from the authors and can be customized to develop parallel HydroViz versions for other specific applications. The results of the current evaluation study will guide future further development of HydroViz and lead to expanding it to encompass a variety of applications that cover various concepts and fields that are of interest to hydrology and water resource education. The overall lessons learned from this research indicates that educational developments that are based on embedding the scientific content within a real-world physical context, such as that illustrated in HydroViz, have a great potential for transforming the education of hydrology and for inspiring future generations of hydrologic researchers and practitioners. Finally, it is pointed out that the authors, in collaboration with educators and researchers from other universities are working on developing an expanded version of HydroViz that will cover three large-scale ecosystems (Coastal Louisiana, South Florida and the Everglades, and the Great Salt Lake basin in Utah). Each of these systems will be embedded into a HydroViz-like design to be used as case-based student-centered learning environments that present unique hydrologic concepts and physical settings.

HESSD
9, 2569–2599, 2012

Acknowledgement. Support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No DUE-0737073, and by the National Science Foundation's Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) program under Award No DUE-1122898. The authors acknowledge the participation of students at the University of Louisiana at Lafayette, the University of Texas at San Antonio and Tennessee Technological University for their contribution towards evaluation and improvement of the HydroViz tool.

References

Bourget, P., G.: Integrated water resources management curriculum in the United States: results of a recent survey, J. Contemp. Water Res. Educ., 135, 107–114, 2006.

Chatterji, M.: Evidence on "what works": an argument for extended-term mixed-method (ETMM) evaluation designs, Educ. Res., 34, 14–24, 2005.

CUAHSI: Water in a Dynamic Planet: a Five-Year Strategic Plan for Water Science, the Consortium of Universities for the Advancement of Hydrologic Science, Inc., Washington DC , available at: http://www.cuahsi.org/docs/stratplan/CUAHSI-5yr-StrategicPlan.pdf, last access: 26 February 2012, 2010.

Denniston, K. J.: "Successful Pedagogies", Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education, Proceedings of a conference by the American Association for the Advancement of Science, April 2004, Washington D.C., Crystal City, Va., available at: http://www.aaas.org/publications/books_reports/CCLI/, last access: 26 February 2012, 2005.

Dori, Y., Tal, R., and Tsaushu, M.: Teaching biotechnology through case studies-can we improve higher order thinking skills of non-science majors, Sci. Educ., 87, 767–793, 2003.

Downer, C. W. and Ogden, F. L.: GSSHA: model to simulate diverse stream flow producing processes, J. Hydrolog. Eng., 9, 161–174, 2004.

Howe, C.: Preface to a creative critique of US water education: Universities Council on Water Resources., Journal of Contemporary Water Research and Education, 139, 1–2, 2008

Habib, E., Malakpet, C. G., Tokay, A., and Kucera, P. A.: Sensitivity of streamflow simulations to temporal variability and estimation of Z-R relationships, ASCE J. Hydrol. Eng., 13, 1177–1186, 2008.

Habib, E., Larson, B., and Graschel, J.: Validation of NEXRAD multisensor precipitation estimates using an experimental dense rain gauge network in South Louisiana, J. Hydrol., 373, 463–478, 2009.
Hickey, D. T., Kindfield, A. C. H., Horwitz, P., and Christie, M. A.: Integrating curriculum, instruction, assessment, and evaluation in a technology-supported genetics environment, Am. Educ. Res. J., 40, 495–538, 2003.
Kolodner, J. L., Owensby, J. N., and Guzdial, M.: Case-based learning aids, in: Jonassen, D. H., Handbook of Research for Educational Communications and Technology, 2nd edn., Lawrence Erlbaum Associates, Mahwah, NJ, 829–861, 2004.
Ledley, T. S., Prakash, A., Manduca, C. A., and Fox, S.: Recommendations for making geoscience data accessible and usable in education, Eos, 89, 291, 2008.
Libarkin, J. C. and Brick, C.: Research methodologies in science education: visualization and the geosciences, J. Geosci. Edu., 50, 449–455, 2002.
Loucks, D. P.: Educating future water resources managers, J. Contemp. Water Res. Educ., 139, 17–22, doi:10.1111/j.1936-704X.2008.00014.x, 2008
Posavac, E. J. and Carey, R. G.: Program Evaluation: Methods and Case Studies, 6th edn., Prentice Hall, Upper Saddle River, NJ, 2003.
McGrath, M. B. and Brown, J. R.: Visual learning for science and engineering, IEEE Comput. Graph., 25, 56–63, 2005.
Nash, J. E., Eagleson, P. S., Phillip, J. R., and van der Molen, W. H.: The education of hydrologists (Report of the IAHS-UNESCO Panel), Hydrol. Sci. J., 35, 97–607, 1990.
National Research Council: Opportunities in the Hydrologic Sciences, National Academy Press, Washington, D.C., 348 p., 1991.
Wagener, T., Weiler, M., McGlynn, B., Gooseff, M., Meixner, T., Marshall, L., McGuire, K., and McHale, M.: Taking the pulse of hydrology education, Hydrol. Process., 21, 1789–1792, 2007.
Winn, W. D., Stahr, F., Sarason, C., Fruland, R., Oppenheimer, P., and Lee, Y.-L.: Learning oceanography from a computer simulation compared with direct experience at sea, J. Res. Sci. Teach., 43, 25–42, 2006.
Yadav, A. and Beckerman, J. L.: Implementing case studies in a plant pathology course: impact on student learning and engagement, J. Nat. Resour. Life Sci. Educ., 38, 50–55, 2009.
Zia, L. L.: "Web-enabled Learning Environments", Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education,

April 2005, Crystal City, Va., Advancing Science, Serving Spciety (AAAS) report, Washington, DC 2005, available at: http://www.aaas.org/publications/books_reports/CCLI/, last access: 23 February ,2012.

HESSD
9, 2569–2599, 2012

E. Habib et al.

Table 1. Summary of HydroViz learning modules (see http://hydroviz.cilat.org/hydro for details).

Module	Title	Brief description
Module 1	Getting Acquainted with the Watershed	Introductory session to familiarize students with the watershed, its geographical/physical characteristics.
Module 2	Exploring Land-Use Land-Cover (LULC) Coverage Map	Students identify how many LULC classes exist in the watershed, identify which LULC class is dominant, assess main changes between recent/historical LULC.
Module 3	Exploring Soil Coverage	Students use two soil-type layers to perform analysis on soil characteristics and estimate basic properties that control watershed response (e.g., saturated hydraulic conductivity, porosity).
Module 4	Exploring Land Elevation	Students examine the watershed topography and drainage patterns, examine differences between different resolutions (1, 1/3, and 1/9 arcsec).
Module 5	Exploring Field Equipment	Students explore different hydro-meteorological sensors; activate links that provide description and animations on their operation mechanism; and download and analyze sample data .
Module 6	Working with a Real Rainfall Storm	Students work with Tropical Storm Matthew that passed over the watershed on 7–10 Oct 2004; read news articles describing the storm impact; compare satellite images (prior and post-storm) and identify flooded areas; download and analyze in-situ rainfall data during the storm.
Module 7	Analysis of Rainfall Measurements during Storm Mathew	
Module 8	Measuring Rainfall Using Remote Sensing Techniques	Students explore rainfall estimates from satellites and radars during tropical storm Matthew; perform quantitative and graphical analysis to compare satellite and radar estimates versus ground rain gauges.
Module 9	Analysis of Streamflow Observations due to Storm Mathew	Students examine streamflow observations during Storm Mathew; generate time-series plots of streamflow data and corresponding rainfall; estimate runoff peaks, time-to-peak and total runoff volume; runoff-rainfall ratios.
Module 10	Runoff Analysis using Curve Number	Students apply the Curve Number (CN) method to estimate runoff depth during Storm Matthew; analyze effect of land-use scenarios and antecedent moisture conditions; apply TR55 method to estimate runoff depths under different distribution of impervious areas.
Module 11	TR55 Graphical Method	
Module 12	Setting up a Hydrologic Model	HydroViz introduces students to different steps necessary for building a distributed hydrologic model.
Module 13	Hydrologic Model Simulations	Students evaluate results on model calibration and compare model-predicted versus observed hydrographs; visualize spatial fields of model simulations on different rainfall-runoff processes.

HESSD
9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.

Table 2. Participating class information.

Course title	University	Level	Semester	Number of participants
CIVE 101 Introduction to civil engineering	UL Lafayette	Freshmen	Spring 2010	20
CIVE 101 Introduction to civil engineering	UL Lafayette	Freshmen	Fall 2010	38
CIVE 429 Hydrology	UL Lafayette	Senior	Spring 2010	20
CEE 4420 Engineering hydrology	Tennessee Tech	Senior	Fall 2010	14
CE 1301 Introduction to civil engineering	UT San Antonio	Freshmen	Spring 2010	29
CE 1301 Introduction to civil engineering	UT San Antonio	Freshmen	Fall 2010	43
CE 4603 Water resources engineering	UT San Antonio	Senior	Fall 2010	18

HESSD
9, 2569–2599, 2012

Table 3. Could you please write a caption for this table?

	Watersheds and Sub-Watersheds	Land-Use Land Cover	Soil Type	Land Elevation	Field Equipment	Rainfall Data	Rainfall Measurement Analysis	Measuring Rainfall Using Remote Sensing Techniques	Analysis of Runoff/Stream flow Observations
Overall Average	85 %	72 %	70 %	69 %	74 %	73 %	68 %	66 %	N/A
Senior Class Average	82 %	77 %	69 %	72 %	78 %	91 %	85 %	87 %	69 %
Freshmen Class Average	87 %	68 %	70 %	65 %	71 %	64 %	51 %	56 %	N/A
CIVE 429 SP	83 %	92 %	95 %	90 %	96 %	91 %	90 %	87 %	70 %
CE 4603 FA	81 %	70 %	67 %	69 %	N/A	N/A	N/A	N/A	N/A
CEE 4420 FA	N/A	69 %	44 %	57 %	59 %	N/A	79 %	N/A	68 %
CIVE 101 SP	81 %	63 %	65 %	57 %	59 %	57 %	46 %	51 %	N/A
CE 1301 SP	98 %	77 %	83 %	73 %	83 %	70 %	55 %	61 %	N/A
CIVE 101 FA	81 %	63 %	63 %	N/A	N/A	N/A	N/A	N/A	N/A

HESSD

9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.

Table 4. Percentages of students who did not complete a set of tasks.

	Watersheds and Sub-Watersheds	Land-Use Land Cover	Soil Type	Land Elevation	Field Equipment	Rainfall Data	Rainfall Measurement Analysis	Measuring Rainfall Using Remote Sensing Techniques	Analysis of Runoff/Stream flow Observations
Average	10 %	20 %	24 %	24 %	24 %	20 %	32 %	32 %	28 %
Senior Average	13 %	21 %	30 %	25 %	22 %	1 %	16 %	13 %	28 %
Freshmen Average	9 %	20 %	17 %	24 %	25 %	30 %	48 %	41 %	N/A
CIVE 429 SP	10 %	5 %	5 %	6 %	4 %	1 %	10 %	13 %	27 %
UTSA 4603 FA	16 %	30 %	30 %	25 %	N/A	N/A	N/A	N/A	N/A
CEE 4420 FA	N/A	27 %	55 %	43 %	40 %	N/A	21 %	N/A	28 %
CIVE 101 SP	10 %	26 %	27 %	31 %	41 %	35 %	53 %	47 %	N/A
UTSA 1301 SP	1 %	14 %	8 %	17 %	9 %	25 %	42 %	35 %	N/A
CIVE 101 FA	15 %	19 %	17 %	N/A	N/A	N/A	N/A	N/A	N/A

HESSD
9, 2569–2599, 2012

HESSD
9, 2569–2599, 2012

Table 5. Percentage of students who agree or strongly agree that HydroViz contributed to their understanding of various hydrologic concepts.

	Watersheds and Sub-Watersheds	Land-Use & Soil-Type Coverage	Hydrologic Field Sensors	Spatial Variability of Hydrologic Variables	Uncertainty in Measuring	Rainfall Runoff-to-Rainfall Ratio	(Freshmen Only) Basic Hydrologic Concepts
Average	87 %	84 %	82 %	67 %	76 %	81 %	81 %
Senior Average	97 %	96 %	100 %	78 %	82 %	81 %	N/A
Freshmen Average	80 %	75 %	70 %	60 %	72 %	N/A	81 %
CIVE 429 SP	100 %	96 %	100 %	82 %	96 %	89 %	N/A
CE 4603 FA	91 %	91 %	N/A	N/A	N/A	N/A	N/A
CEE 4420 FA	100 %	100 %	100 %	73 %	67 %	73 %	N/A
CIVE 101 SP	88 %	75 %	69 %	56 %	88 %	N/A	87 %
UTSA 1301 SP	72 %	72 %	88 %	72 %	72 %	N/A	74 %
UTSA 1301 FA	83 %	76 %	52 %	52 %	57 %	N/A	78 %
CIVE 101 FA	78 %	78 %	N/A	N/A	N/A	N/A	83 %

Table 6. Percentages of students who strongly agree or agree that they like various features of HydroViz.

	Embed-ding Google Earth	Realistic Representation	Integrated System	Interact with HydroViz to Extract Data	Questions are Integrated with Google Earth	Data and Modeling Skills are not Required	Encouraging Independent Exploration
Overall Average	91 %	93 %	89 %	86 %	80 %	79 %	83 %
Senior Average	96 %	97 %	93 %	95 %	83 %	86 %	88 %
Freshmen Average	87 %	90 %	86 %	79 %	79 %	75 %	79 %
CIVE 429 SP	96 %	100 %	96 %	100 %	86 %	86 %	100 %
CE 4603 FA	91 %	91 %	91 %	91 %	82 %	91 %	91 %
CEE 4420 FA	100 %	100 %	93 %	93 %	80 %	80 %	73 %
CIVE 101 SP	94 %	100 %	88 %	75 %	69 %	69 %	75 %
CE 1301 SP	76 %	76 %	80 %	80 %	72 %	64 %	76 %
CE 1301 FA	85 %	88 %	88 %	82 %	91 %	82 %	85 %
CIVE 101 FA	94 %	94 %	89 %	78 %	83 %	83 %	78 %

HESSD
9, 2569–2599, 2012

HESSD
9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.

Table 7. Percentages of students who strongly agree or agree with some statements in the survey.

	(Seniors only) HydroViz improves current teaching methods in engineering hydrologic courses	(Freshmen only) HydroViz increases my enthusiasm for the subject of hydrology	(All students) HydroViz fits well into the curriculum of this course
Overall average	85 %	57 %	78 %
Senior class average	85 %	N/A	96 %
Freshmen class average	N/A	57 %	63 %
CIVE 429 SP	96 %	N/A	96 %
CE 4603 FA	73 %	N/A	91 %
CEE 4420 FA	87 %	N/A	100 %
CIVE 101 SP	N/A	63 %	63 %
CE 1301 SP	N/A	46 %	52 %
CE 1301 FA	N/A	59 %	76 %
CIVE 101 FA	N/A	61 %	67 %

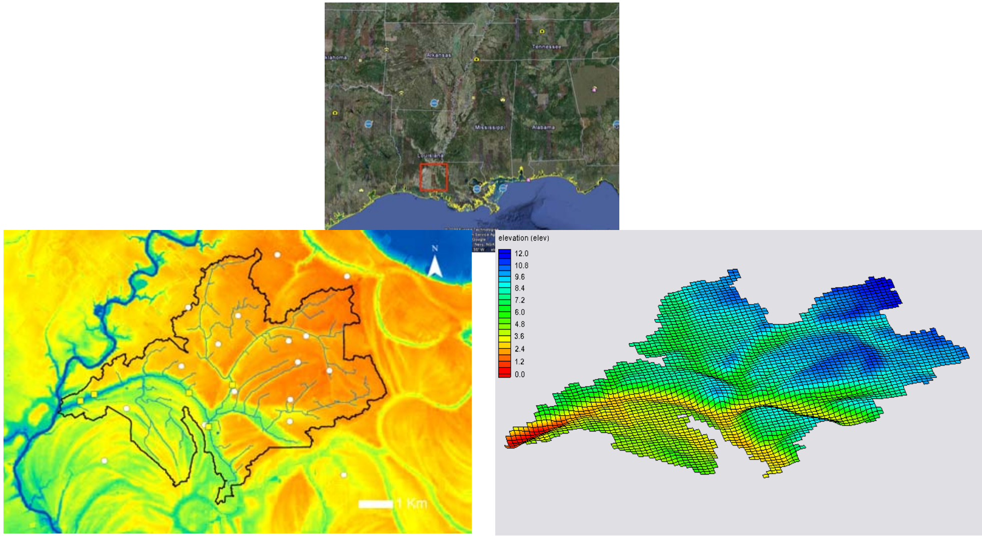

Fig. 1. Location map of the Isaac-Verot Experimental watershed used in the HydroViz tool. The lower left panel high-resolution topography of the watershed and the locations of different rainfall streamflow sensors. The lower right panel shows the 25 km computational grid used to develop the GSSHA hydrologic model for the watershed.

HESSD
9, 2569–2599, 2012

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◀| |▶
◀ ▶
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

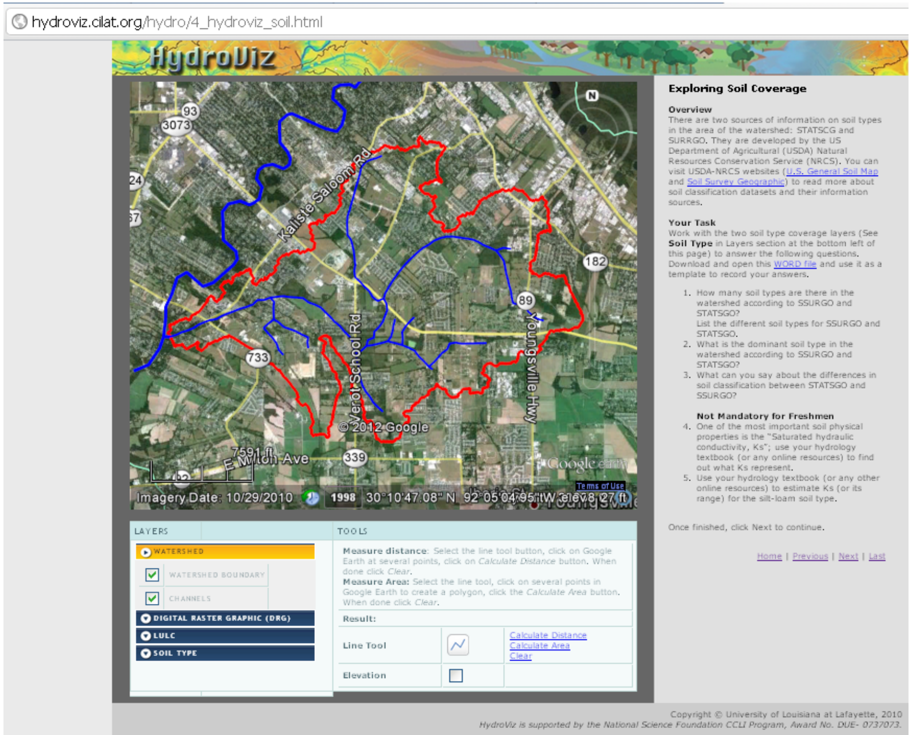

Fig. 2. HydroViz Interface showing: (1) Google Earth in the main display, (2) the educational content and educational tasks on the right side, and (3) layers and tools at the bottom of the interface.

HESSD
9, 2569–2599, 2012

HydroViz: evaluation of a web-based tool for improving hydrology education

E. Habib et al.