A GOOGLE-EARTH BASED ENGINEERING EDUCATION TOOL FOR PLACE-BASED LEARNING OF HYDROLOGIC CONCEPTS USING A CAMPUS WATERSHED AND WI-FI CONNECTIVITY

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Abstract

Hands-on learning is regarded as one of the most effective ways to improve and stimulate student learning in engineering education. However, there are many disciplines in engineering that are not as amenable to 'hands-on' in the traditional sense of "*bringing a sample tool from the laboratory or taking students to the hands-on laboratory*". One such discipline is 'Engineering Hydrology', a typical senior-level elective course in most undergraduate civil engineering curriculum. For gaining the highest level of student learning in such a course, it is almost impossible to implement hands-on activities in class on a frequent basis since the subject of the topic (Hydrology) is often a larger-than-classroom watershed involving topics such as rainfall-runoff transformation, land use/land cover, terrain features and complex instrumentation that are difficult to be replicated in a smaller laboratory. The conventional approach to incorporating 'hands-on' learning concepts for such a course has therefore been to organize field trips that consume significant time away from regular lectures due to the detailed planning that is needed for a successful execution. This paper describes the adaptation of a Google Earth-based Hydrology education tool for place-based and hands-on learning on hydrology concepts using a campus watershed. With several decades of high resolution image of the earth's surface, Google Earth has now evolved to a powerful tool for visualization, analysis and learning of environmental concepts that are spatial and geographic in nature. HydroViz is one such Google Earth-based tool, developed by a team of researchers at University of Louisiana at Lafayette, which allows student-driven active learning of hydrology concepts. By leveraging a campus watershed located very close to the classroom at Tennessee Technological University (TTU), HydroViz adaptation allowed for a hands-on and place-based learning experiencing for students without the need for time-consuming field trips. By using Wi-Fi internet connectivity, students applied the adapted tool while located inside the campus watershed to pose key hydrology questions and seek answers in a hands-on manner that would otherwise not be possible in the classroom. In essence, the adapted tool was successful in fulfilling the notion that – *when you cannot bring the watershed to the classroom, bring the classroom to the watershed.*

Keywords: Hydrology, Google Earth, Place-based Learning, Wi-Fi, Hands-on Learning.

Introduction

Hydrology is the study of the occurrence and distribution on water in nature in the form that is often known as the 'water cycle'. Given that earth's water is always in movement, hydrology is that discipline that allows the water cycle (also known as the 'hydrologic cycle') to be quantitatively studied for the water resources on, above, and below the surface of planet Earth. In the civil engineering curriculum, hydrology is a key topic on water resources engineering that many senior level under-graduate and graduate students choose to specialize on. This topic also forms the cornerstone of many engineering infrastructure projects such as reservoir, dams, irrigation systems where engineers often need to ask '*how much water is naturally available?*' and compare the answer to these projects' standard objective question of '*how much water is required*?' Similarly, hydrology topics also allow operation and management of natural and man-made systems, such as wetlands, lakes, irrigation systems, rainfall harvesting schemes and drainage networks. To provide students with an engineering perspective, a hydrology course typically breaks up the study of the water cycle into components such as processes (rainfall, surface runoff, infiltration, evaporation, transpiration, groundwater flow), instrumentation (rainfall and stream flow gages, weather stations) and landform features (land use, land cover, terrain, soil type and elevation). Figure 1 shows an overview of the major processes of the water cycle deemed important to the engineer for design or operations of a water resources system.

Due to the nature of the topic, the instruction of hydrology poses an interesting challenge. If the goal is to achieve the highest level of student learning, then the format for instruction should be active and student-driven involving a strongly interactive component of hands-on learning. For example, if a student is expected to understand the concept of infiltration and the role played by soil properties and land use, it is most beneficial for him/her to 'go out' in the field and conceptualize the soil's ability to absorb rain water as a function of real-world constraints such as soil type, land use, terrain, rain rate etc. If a student is expected to physically grasp the role of topographic limits or the watershed divide in 'capturing' the rainfall as runoff to the outlet, it is highly beneficial for the student to observe the terrain and elevation features in the real-world to be convinced 'intuitively' of the flow patterns during a storm event using basic knowledge of fluid mechanics. Because of such needs for showcasing the 'real world' to students, hydrology is one such discipline in engineering that is not as amenable to 'hands-on' in the conventional sense of "*bringing a sample tool from the laboratory* " as are other topics in civil engineering such as 'concrete design', 'structural mechanics' or even simply 'fluid mechanics'.

Thus, for gaining the highest level of student learning in such a course, it is almost impossible to implement hands-on activities in the class on a frequent basis since the subject of the topic is often a larger-than-classroom watershed involving phenomena such as rainfall, runoff, land use, flow dynamics, instrumentation and terrain. A miniature laboratory version of a watershed, while useful for a basic introduction, will never mimic the real-world natural transformation and distribution of water in the water cycle. The only option left therefore is to organize field trips to distant watershed that consume a

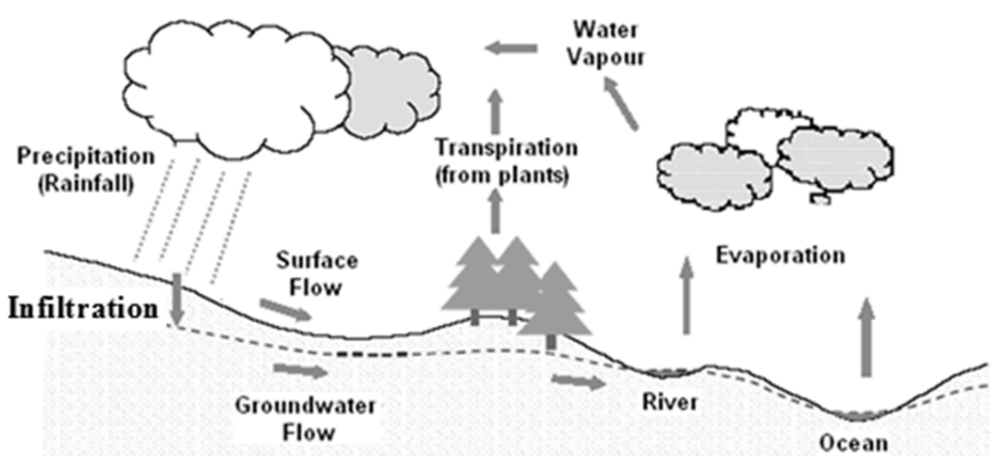

Figure 1. Overview of the major processes of the water cycle that are important to the engineer for design and operations of water resources systems.

significant amount of time from regular lectures due to the detailed planning needed for a successful execution.

This is where a 'compromise' option may yield the benefits of a field trip without the level of logistic planning that is normally associated with traditional field trip by leveraging the latest technological advancements and wireless (Wi-Fi) internet connectivity. The compromise option is based on the notion that –*when you cannot bring the watershed to the classroom, then bring the classroom to the watershed.* Such a compromise concept would require a campus watershed located very close to the classroom (to avoid having to plan field trips) such that students can be taken 'out there' as frequently as needed. Consequently, various lecture modules and course topics could be delivered 'on site' in the form of hands-on demonstration and query based learning.

Such a concept is often called place-based education[3]. Place-based education is often hands-on, project-based and always related to something in the real world. For example, students embarking upon a study of the Hoover Dam, might interview the engineers and staff who now oversee the dam's operations and maintenance. While place-based education has a long heritage in the social science education, it has seen little application for engineering education, particularly in water resources engineering[9]. With the recent and easy availability of broad-band Wi-Fi on campus and mobile computing enabled portable computers (such as tablet PCs or iPAD), an internet-based GIS (Geographic Information Systems) software tool that visualizes a real-world watershed can be a potential candidate for place-based education and hands-on learning of hydrology. For example, students can operate the software tool during class periods 'out on the field' on campus in coordination with the instructor using their portable devices[7]. Various topics on hydrology that are embedded as teaching modules of such a GIS software can then be instructed to students in the active learning format for the whole watershed as the 'classroom'. This would give students a chance to observe the cause-and-effect relationships of the watershed dynamics and properties, which would otherwise not be possible with conventional hands-on activities. Such cause and effect relationships (e.g. rainfall-runoff transformation, drainage patterns during a storm or stream flow regimes) are usually taught in a hydrology class through 'second-hand' (i.e., passive) examples explained on the classroom board.

This paper describes the adaptation of a Google Earth-based Hydrology education tool for place-based and hands-on learning of hydrology concepts using a campus watershed located very close to the Department of Civil Engineering at Tennessee Technological University (TTU). With several decades of high resolution image of the earth's surface, Google Earth has now evolved to a powerful tool for visualization, analysis and learning of environmental concepts that are spatial and geographic in nature. HydroViz is one such Google Earth-based tool, developed by a team of researchers at the University of Louisiana at Lafayette, which allows student-driven active learning of hydrology concepts. By leveraging a campus watershed located very close to the classroom and internet connectivity, HydroViz adaptation pushed boundaries of the hands-on learning to a place-based environment. This was done by adapting the Google Earth-based HydroViz for the local campus watershed. The paper elaborates the software aspects of the adaptation procedure followed by a brief place-based implementation of the tool.

The paper is organized as follows. An overview of the Google-Earth Hydrology education tool called HydroViz that has been developed by a team at University of Louisiana at Lafayette (led by Dr. Emad Habib; see [5],[11] . The next section provides a summary of the campus watershed that was used for adaptation of HydroViz for place-based learning. This is followed by the software procedure for creating the necessary geographic information layers to represent each aspect of the watershed process or concept. Finally, we briefly cover the experience of implementing the adapted tool on the campus watershed and the conclusions of the study.

Hydroviz

HydroViz is a web-based, student-centered, highly visual educational tool designed tosupport active learning in the field of Engineering Hydrology. The development of HydroViz is afforded by recent advances in hydrologic data, numerical simulations and visualization and web-based[5]. The original version of HydroViz was implemented in several hydrology-related courses offered in three different universities. The evaluation[11] indicated that educational developments that are based on embedding scientific contents within a real-world context with visual and interactive functionality have a potential for improving the education of hydrology and inspiring future generations of hydrologic researchers and practitioners. The motivation for creating HydroViz is embedded in several national review reports that stressed the need to improve undergraduate engineering hydrology education[8],[10],[4],[2]. The common thread in the recommendation of these recent reports is the introduction of hydrologic data and observational components and numerical simulation components to simulate fundamental hydrologic process in the undergraduate hydrology curriculum.

HydroViz is a hydrology 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 components. HydroViz leverages 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. These design features significantly facilitate the dissemination and adoption of HydroViz by any interested educational institutions regardless of their access to data or computer models. Figure 2 provides a schematic for the overall architecture of HydroViz tool developed by Habib et al.[5].

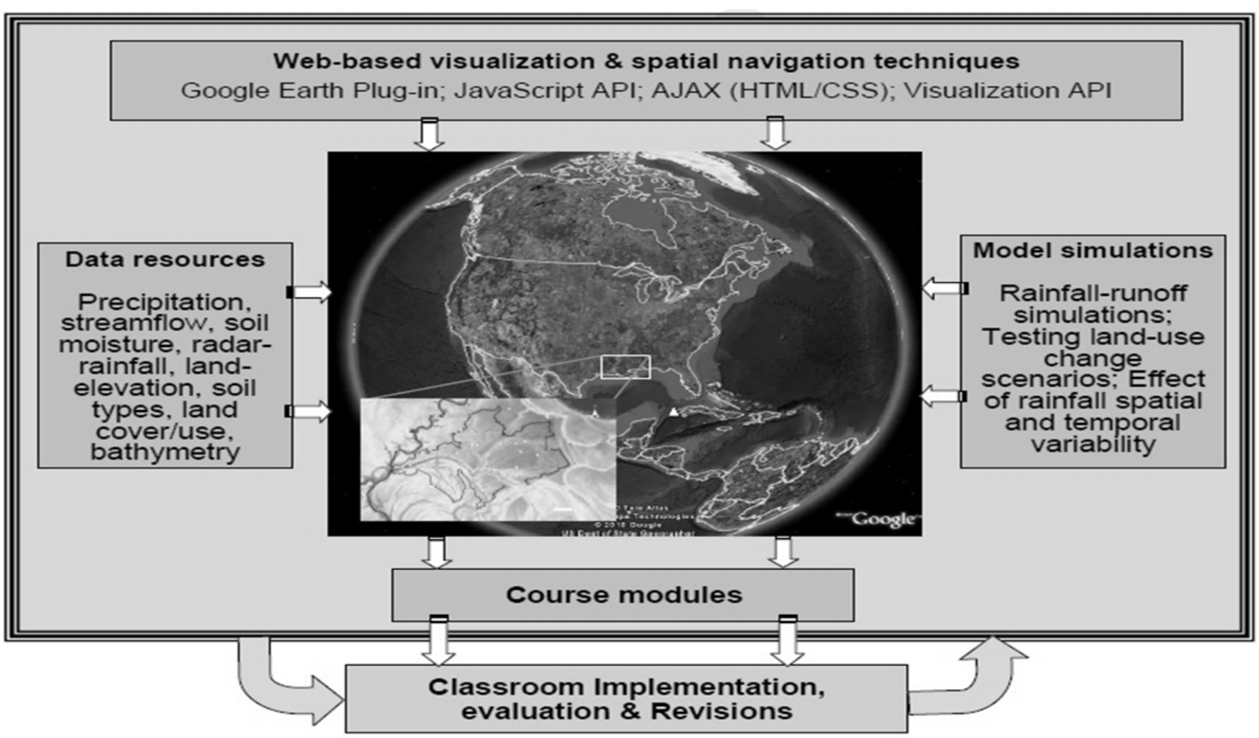

Figure 2. Overall architecture of HydroViz developed by Habib et al.[5] depicting the various inputs and modules. (*figure reprinted with kind permission from Habib et al. (2011)*)

Besides being freely accessible to a wide user community, Google Earth offers the ability to place and visualize hydrologic technical information on a 3D model of the Earth, which subsequently can facilitate students' interactive and visually supported learning. Within a HydroViz setting, students can use Google Earth navigation capabilities to explore the watershed, either on their own or by using the embedded inquiry-based investigations and the supporting layers of hydrologic information.

To facilitate classroom usage, HydroViz is laden with a set of classroom educational modules (each addressing a specific topic of hydrology) that can be used sequentially within different stages of an engineering hydrology curriculum. HydroViz is primarily designed to be used in junior/senior/graduate level courses on hydrology, water resources engineering, or other related subjects. A simplified version of HydroViz can be also used in basic-level courses that focus on introducing new engineering and earth science students to basic hydrologic concepts. The HydroViz hydrologic observatory, in the original version developed by Habib et al.[5] is for an actual watershed called Isaac-Verot (IV) which is located in south central Louisiana and is part of the Vermilion River basin that connects to the Vermilion Bay of the Gulf of Mexico. This is an experimental site located in the proximity of the campus of the University of Louisiana at Lafayette. For further details on HydroViz, the reader is referred to Habib et al.[5], Ma et al.[11] and the HydroViz website at http://HydroViz.cilat. org/hydro/. In the current study, we present an application of this learning model and how it was adopted for a different watershed located on campus at TTU to facilitate place-based learning of hydrology concepts. Figure 3 provides a screenshot of the front page of HydroViz once the student user activates the index GIS layer.

The TTU Campus Watershed Used for Adaptation of Hydroviz

Like the original HydroViz software, the adapted HydroViz hydrologic observatory is also developed for an actual watershed called the 'Boiler-Plant' (BP) watershed which is located right on TTU campus about 100 yards from the classroom where Hydrology courses are instructed (Figure 4). This is an urban and experimental site being monitored mainly for developing low impact development (LID) strategies to minimize storm runoff. As part of an EPA-driven directive to explore ways for creating more pervious landscape to reduce peak stormwater flow, TTU recently embarked on a LID study to understand the campus-wide rainfall-runoff relationship by installing instrumentation for rainfall and runoff monitoring.

The BP watershed has an area of about 0.125 km^2 and is basically a zero-order catchment with no streams or creeks running through it. As an urban watershed, its outlet is the storm drainage man-hole (near Boiler Plant; Figure 4) that collects the generated storm runoff and passes on to the storm sewer network leaving campus. The BP watershed is a low-gradient watershed where urban land use and land cover plays vital role in runoff prediction. The terrain elevation in the watershed, with reference to mean sea level, ranges from approximately 1131 ft near the outlet to 1157 ft at the catchment divide. There are two main soil types in the BP watershed: Christian Loam and Mountview Silt Loam. The landuse is composed mainly of urban areas with some cropland, pasture and grassland areas.

Adaptation of Hydroviz for TTU (Boiler Plant) Watershed

Unlike the original IV HydroViz, the number of topics on hydrology that the BP watershed allowed for a real-world rendition was smaller. The specific topics were:

1) General features of the watershed such as the watershed divide, location of outlet, areal size etc.
2) Land use and Land cover.
3) Soil coverage.
4) Elevation (terrain).
5) Instrumentation for rainfall and flow measurement.

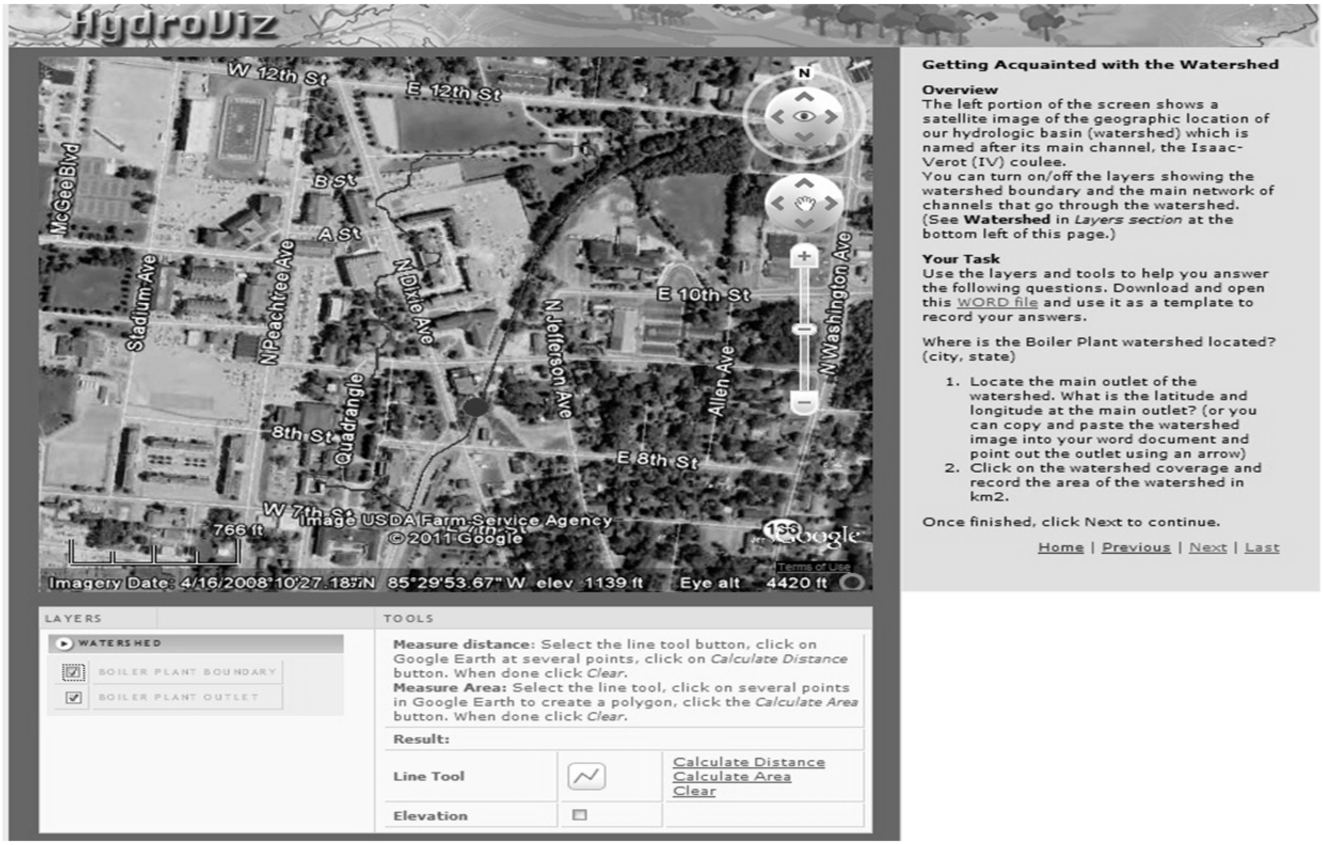

Figure 3. Screenshot of HydroViz showing the typical front page that is on display when the student user activates the tool. Note: the GIS layer of watershed boundary and outlet is 'turned' on using the bottom panel. The above screen shot is the adaptation for TTU from the original version developed by Habib et al. (2011) and is available online at: http://HydroViz.cilat.org/hydroTN/index.html).

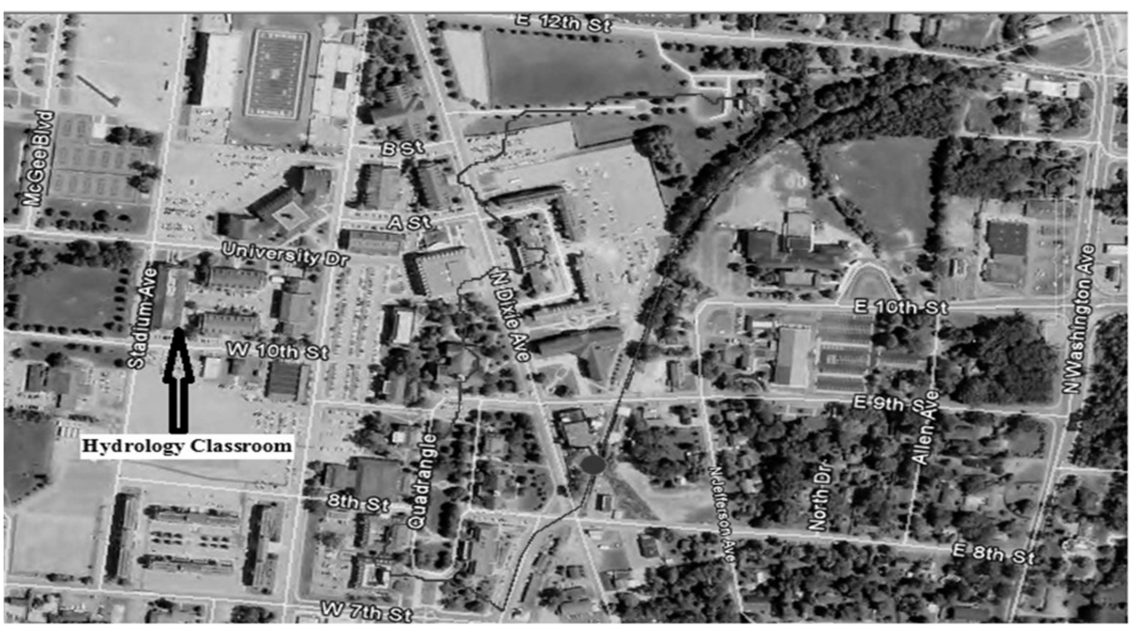

Figure 4. The Boiler Plant (BP) 'urban' watershed on TTU campus that was adapted for HydroViz. The red circle donates the watershed outlet in the form of a man-hole that collects the generated storm runoff and facilitates entry to the storm sewer network leaving campus.

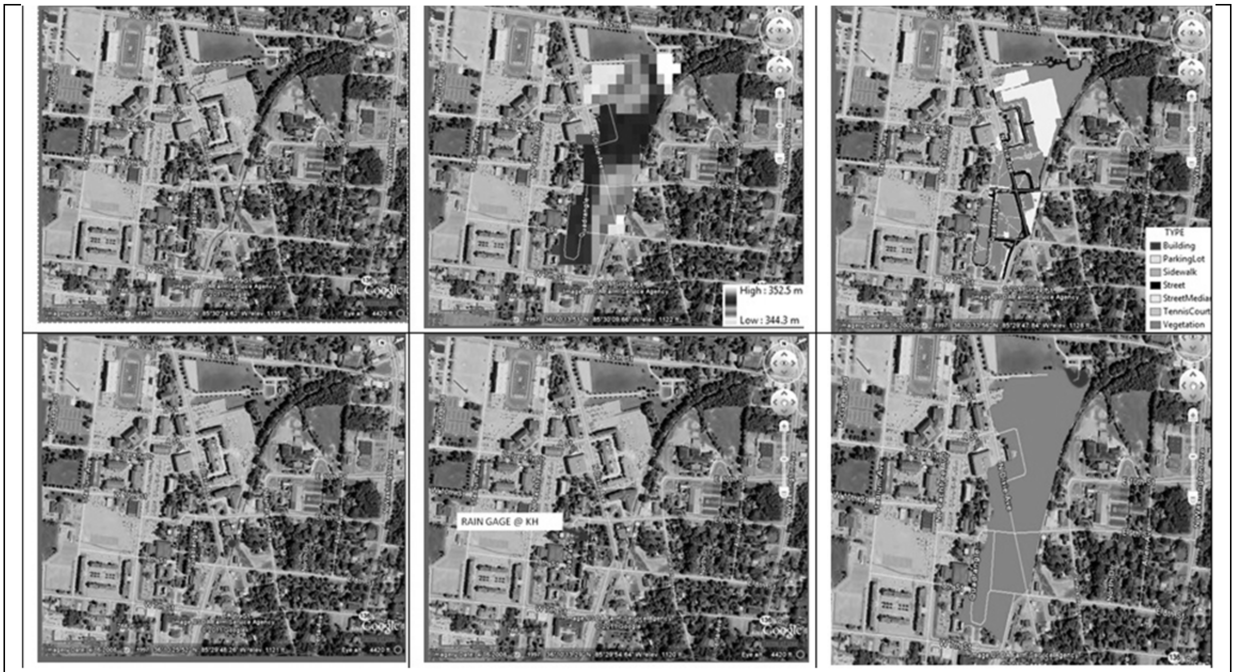

Figure 5. The six GIS layers on TTU BP watershed rendered as Google Earth KML files for display in HydroViz-TTU adaptation. Each layer in a panel represents a hydrology topic. From upper left (clockwise): General watershed boundary, elevation/terrain, land use/land cover; watershed outlet, instrumentation and soil coverage.

6) Runoff modeling using Curve Number (CN) method.

Each topic constituted at least or more GIS layers digitized using arcGIS^{TM} as a vector or raster dataset for visualization in Google Earth from the hydrologic data. Once the GIS layers were created, a Keyhole Markup Language (KML) version was created using the software called Google Earth Pro^{TM}. Unlike Google Earth, which is mainly for visualization and display of geospatial data, Google Earth Pro provides additional capabilities such as mapping large GIS datasets and calculating areas with a polygon or circle. In this step, each GIS layer (in the form of shape files) was converted to KML files for display on Google Earth (and eventually on HydroViz). The next step involved the web visualization of the BP watershed KML files using Javascript API in the same manner as the original HydroViz described in Habib et al. [5]. The software architecture remained the same as the original HydroViz. The reader is referred to Habib et al. [5] for the details of the software. Hereafter, a basic overview of the web visualization of the KML files on Google Earth is provided.

The main look of HydroViz (shown in Figure 3) is created using Cascading Style Sheets (CSS) and Hyper Text Markup Language (HTML). In addition, the use of Google Earth API allows for the creation of customized buttons and panels for student users for interactive display of geospatial data. The HydroViz interface (see an example in Figure 3) is divided into 3 panels: (1) Google Earth Display (left panel), (2) Student user driven the Educational Component (right panel) comprising hydrology topics, and (3) customized layers and tools (bottom panel). As the student user reads the content (right panel) they may need to turn layers on or off to conduct measurements using the bottom panel. During this step, JavaScript code makes calls to the Google Earth API which in turn communications with the Google Earth Plug-in of left panel for user-driven display. As mentioned earlier, the layers in Google Earth are defined in Keyhole Markup Language (KML), which is a tag-based file format that defines the content to be displayed in Google Earth. Figure 5 summarizes the six KML file- images (each pertaining to a specific hydrology topic) that were used for the adaptation of HydroViz for BP watershed (hereafter called 'HydroViz-TTU').

Implementation of Hydroviz-TTU for Place-Based Learning

On October 20, 2011, senior-level students enrolled in CEE4420 –Engineering Hydrology that is taught by author – Faisal Hossain – were taken out to the BP watershed for a testing of the concepts of place-based learning using the adapted HydroViz software. There were a total of 18 students, divided into four groups of not more than 5 members. Each student or a group had at least one hand held device for accessing the broadband Wi-Fi internet connectivity on campus. These devices comprised laptop/notebook (PC and Mac), Apple iPAD and Smartphones (Google Android, or iPhone).

The trip to BP watershed was considered part of a regular class and not a field trip since it was on campus premises (thereby also avoiding the necessary liability issues and logistic planning). The class period spanned 85 minutes. During this class period, the goals for place-based learning were as follows:

1) To survey in person (for each student) the boundaries of the watershed and get an idea of the areal extent and its divide.

2) To explore the terrain and elevation to get an idea of the drainage patterns for storm runoff during a storm.

3) To reconcile the findings in #2 with the location of the watershed outlet (which was also an objective for identification in person).

4) To explore the land use/land cover and physically investigate the soil type differences.

5) To verify the level of detail, scale and uncertainty in the representation of geospatial data displayed on HydroViz-TTU.

It was found that HydroViz-TTU allowed a successful place-based learning experience of above 5 objectives within a single class period through the use of Wi-Fi. Given the size of the BP watershed (~0.125 km^2), each group was able to 'scope' the watershed boundary points in about 10-15 minutes to get a 'feel' of the watershed dimensions. Students frequently checked the HydroViz-TTU display to navigate through the watershed and check in-situ for hydrologically relevant items (such as soil type or land use/land cover). Although detailed exercises (contained in each of the HydroViz-TTU module) were not attempted in a place-based learning framework on the first attempt, students gained a real-world appreciation of the general concepts of a watershed, divide, terrain and flow patterns that would have otherwise been very difficult to render in a traditional classroom environment. Additional place-based lectures can therefore allow students to pursue query-based learning in the context of the BP watershed. For example, in the immediate aftermath of a storm event, students could check if the runoff generation was different for the two specific soil types that comprised the watershed without the need for a field trip. Nevertheless, a few suggestions for improvement of future place-based learning classes emerged from the first round of implementation. These are:

1) Use of laptop/notebooks are usually unwieldy for place-based learning as it was found difficult to watch the display while hold the device and investigate physically the details on location. More portable and hand-held devices such as smart phones and compact iPADs were found much more user-friendly for such place-based learning.

2) Even with campus wide broadband Wi-Fi to access Google Earth, there were several small 'pockets' of poor or no connectivity. To ensure continuity in the implementa-

tion of place-based learning, students or groups should have backup hard copies of the key Google earth KML files for geo-spatial data.

3) If the class is divided into groups, each group should be accompanied by a teaching assistant or be connected through two-way radio with the instructor to coordinate and complete the class in a timely manner.

Conclusion

Hands-on learning is regarded as one of the most effective ways to improve and stimulate student learning in engineering [1]. However, as discussed in detail earlier, engineering hydrology is one such discipline in engineering that is not as amenable to 'hands-on' in the traditional sense of "*bringing a sample tool from the laboratory or taking students to the hands-on laboratory*." Thus, for gaining the highest level of student learning in hydrology, it is almost impossible to implement hands-on activities in class on a frequent basis since the topic of hydrology involves concepts such as rainfall-runoff transformation, land use/land cover, terrain features and complex instrumentation that are difficult to be replicated in a classroom laboratory. This paper presented a 'compromise' option based on the notion that –*when you cannot bring the watershed to the classroom, then bring the classroom to the watershed.* Such a compromise concept requires a campus watershed located very close to the classroom (to avoid having to plan field trips) such that students can be taken 'out there' as frequently as needed within a class period. The paper then described the adaptation of a Google Earth-based Hydrology education tool for place-based and hands-on learning on hydrology concepts using the campus watershed. With several decades of high resolution image of the earth's surface, Google Earth has now evolved to a powerful tool for visualization, analysis and learning of environmental concepts that are spatial and geographic in nature. HydroViz is one such Google Earth-based tool, developed originally by a team of researchers at the University of Louisiana at Lafayette[5], [11] which allows student-driven active learning of hydrology concepts. Both the original HydroViz and the new adapted version are web-based and can be fully accessed at http://hydroviz.cilat.org/. By leveraging a campus watershed located very close to the classroom at Tennessee Technological University (TTU), HydroViz-TTU adaptation allowed for a hands-on and place-based learning experiencing for students without the need for time-consuming field trips. By using Wi-Fi and broadband internet connectivity, students were successful in applying the adapted tool while located inside the campus watershed to pose key hydrology questions and seek answers in a hands-on manner that would otherwise not be possible in the classroom. The implementation of HydroViz in a place-based learning setting revealed that while the advances in technology made the concept feasible for instruction of hydrology, there are nevertheless some logistic hurdles. Key hurdle seemed to be on the size of the device for running the HydroViz-TTU tool. In addition, it was also found that hard copy documents of HydroViz software should be retained to ensure continuity in the learning experience in zones where internet Wi-Fi connectivity is poor or non-existent.

As a future extension of this work, HydroViz-TTU will now be attempted of all its lecture modules in a place-based framework. Also, the tool will be explored for an enhancement to display dynamic data embedded in the KML files (such as a time series of land use/land cover change or climate change from Google Earth Engine or of hydrologic model simulation). We hope to report on our findings sometime in the future on these aspects.

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References

1. Aziz, El-Sayed (2011). Teaching and learning enhancement in undergraduate machine dynamics, *Computer Applications in Engineering Education*, vol. 19(2), pp. 244-255 (DOI: 10.1002/cae.20306).

2. CUAHSI (2010). Water in a Dynamic Planet: A Five-year Strategic Plan for Water Science (http://dx.doi.org/10.4211/ sciplan.200711).

3. Davidson-Hunt, I. and R.M. O'Flaherty (2007). Researchers, Indigenous Peoples, and Place-Based Learning Communities, *Society and Natural Resources*, vol. 20(4), pp. 291-305.

4. Gant, C.L. (2008). A Creative Critique of U.S. Water Education. *Journal of Contemporary Water Research and Education*, vol. 139.

5. Habib, E., Y. Ma, D. Williams, L. Qin and Y. Liao. (2011). HydroViz: A Web-Based Hydrologic Observatory for Enhancing Student Learning in Engineering Hydrology Courses: (I) Conceptual Design and Software Description, *Advances in Engineering Education* (in review; available online at: http://HydroViz.cilat.org/ hydro/publications/HydroViz_Part%20I.pdf).

6. Howley, A., M. Howley, C. Camper, H. Perko. (2011). Place-Based Education at Island Community School, *The Journal of Environmental Education* vol. 42(4).

7. Mosqueda, G., M. Ahmadizadeh, S. Tangalos, D. Moore-Russo. (2011). Internet-based instructional resource exposing middle school students to structural and earthquake engineering, *Computer Applications Engineering* Education, (DOI: 10.1002/cae.20357).

8. NRC (1991). Opportunities in the Hydrologic Sciences, National Academy Press, Washington, D.C., 348 p.

9. Smith, G. A. and D. A. Gruenewald. (2007). Place-Based Education in the Global Age: Local Diversity, 1st Edition, Routledge (ISBN: 0805858644).

10. Wagener, T., Weiler, M., McGlynn, B., Gooseff, M., Meixner, T., Marshall, L., McGuire, K. and McHale, M. (2007). Taking the pulse of hydrology education. *Hydrological Processes*, vol. 21(13), pp. 1789-1792.

11. Ma, Y., E. Habib, and D. Williams. (2011). HydroViz: A Web-Based Hydrologic Observatory for Enhancing Student Learning in Engineering Hydrology Courses: (II) Implementation and Assessment Results, Advances in Engineering Education (in review; available online at: http://HydroViz.cilat.org/hydro/publications/HydroViz_Part%20II.pdf).

Biographical Information