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# Evaluating the Usefulness of Virtual 3-D Lab Modules Developed for a Flooding System in Student Learning

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# Evaluating the usefulness of virtual 3D lab modules developed for a flooding system in student learning

## Introduction

High intense rainfall causes floods. Flooding in vulnerable river systems results in huge property damage. Proper understanding of watershed hydrology and river flow hydraulics is essential to flood plain management and mitigation. As a part of the civil engineering curriculum, students learn about these concepts. In STEM education, students need to spend extra time and effort after their college education to connect the knowledge gained through classroom instruction to the practical applications required within their careers. It is very difficult to create a lab module for a severe flooding scenario. However, new technological developments have made this possible. This research work is intended to transfer knowledge to practice for civil engineering students to learn flood modeling as part of water resources engineering education which uses recently developed interactive 3D simulation. The suitability of interactive 3D models for such difficult situations is supported by the research literature (e.g., Lee *et al*. 2007 [[1]]). Further, the usefulness of these modules in learning was evaluated using a systematic study at three universities by an education expert.

## Flood Modeling and its importance

Flood modeling is considered to be the most important task by US Army Corps and Federal Emergency Management Agency (FEMA) for designing remedial alternatives, floodplain delineation for flood insurance FEMA (2001) [[2]] rate maps and flood mitigation works. In most civil engineering programs, it is not economically viable to develop a physical laboratory setup to simulate flood scenarios involving levee breaches, structure and pumping station failures. Thus, a computer simulation-based modeling approach is proposed. Further, slow and gradual changes occurring in land use patterns and global climatic conditions do not happen over observed short time periods (e.g., a month to 10 years). However, land use and climate disturbances can dramatically change the response of the watershed system during severe weather conditions that may induce flooding.

## System considered

In this research study, a virtual 3D lab module was created for a watershed called the Little Calumet River System, located in Indiana (Figure 1). Hart Ditch is the main tributary to this river. Hart Ditch flows north and confluences with the east-west flowing Little Calumet River. From that confluence point, water goes both east and west. The western arm drains to Lake Michigan through Cul-de-sac canal. The eastern arm drains to Lake Michigan through Burns Ditch. Covering both urban and rural areas, this system was very severely flooded during the 2008 storm Ike. US Army Corps constructed a levee system for more than 20 miles inside the Indiana territory to mitigate the flood. As this system has several essential components and flood mitigation work, this system was chosen for the 3D model development.

Flood model development was done in stages. As this effort is a data intensive process, through undergraduate senior design projects, watershed data such as landuse data, soil data, cross section survey data, details of flood control structures and Manning's friction factor n were obtained. These data were obtained through field survey and published data from agencies such as USGS, USDA, US Army Corps and Little Calumet River Commission. Using HEC HMS model (HEC HMS 2010) [3], watershed rainfall – runoff simulation model was created. Five different severe rainfall events were simulated and using USGS flow observation data (USGS station 05536190), runoff hydrographs were compared and the model was fine-tuned and calibrated. Chandramouli and Karim (2015) [4] provide more details about the hydrologic modeling steps.

After satisfactory calibration of the hydrologic model, the hydraulic model for the river system was created using HEC RAS (HEC RAS 2010) [5]. Both HEC HMS and HEC RAS software were developed by Hydrologic Engineering Center, US Army Corps and are available in the public domain. Hydrographs results for each storm were obtained from HEC HMS and were used as input to the HEC RAS model. The HEC RAS model simulates the flow hydraulics in a channel and the unsteady simulation created using this model provides stages (water surface elevations) with respect to time in different cross section locations. A screen shot of that model is given in Figure 2.

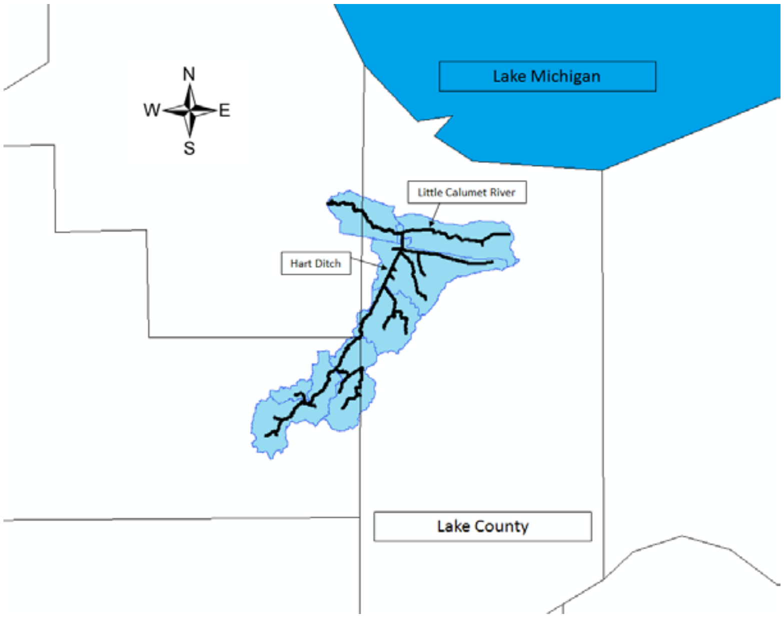


**Figure 1: Hart Ditch Watershed in Northwest Indiana**

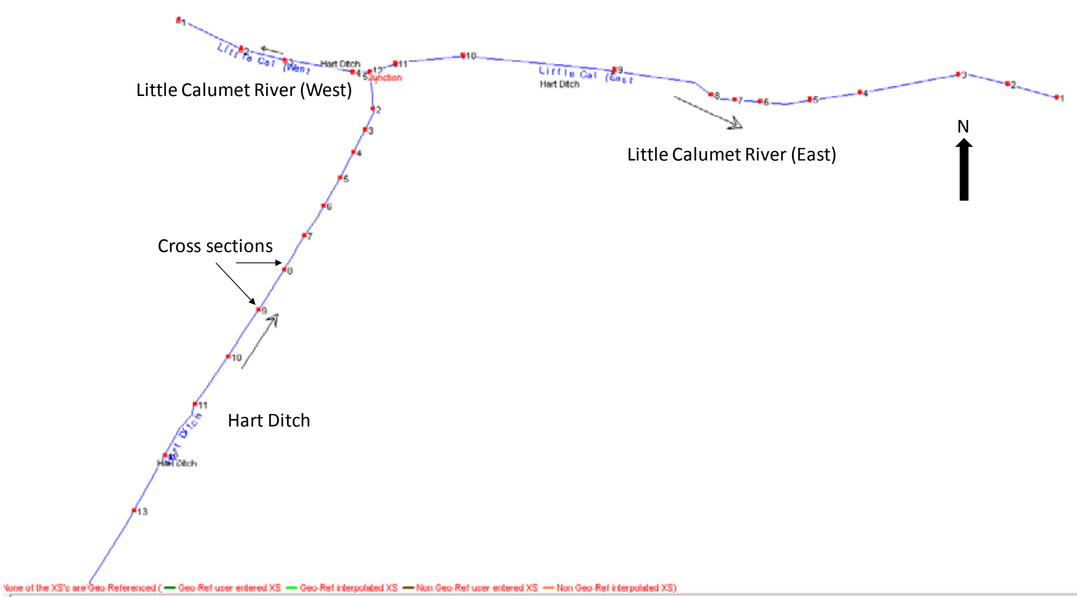


**Figure 2. HEC RAS Model – Cross sections location in Hart Ditch and Little Calumet River**

After calibrating the HEC RAS model using USGS flow and stage observations, stages at different cross sections were documented in hourly time steps. These results were used in developing the virtual 3D model.

The virtual 3D model for the river system considered was developed at the Center for Innovation through Visualization and Simulation (CIVS) at Purdue University Calumet. The virtual 3D model was developed in the Unity 3D platform. This 3D model is very user-friendly. Users can document the HEC RAS model results for different storms and take them to the 3D domain and study the flood inundation. Figure 3 provides the screen shot of the 3D model.


**Figure 3. Virtual 3D Model Developed in Unity 3D Platform**

**Evaluation Steps**

Advantages of virtual 3D modules were documented in the literature. The richness of the scenarios presented in the virtual module also provides students with an authentic context within which to situate their learning. Consistent with constructivist views of learning, Lave and Wenger (1991) [6] argue that learning is most effective when knowledge is presented within the context it will be used, what is known as situated learning. The virtual 3D module used in this project supports effective learning by providing students with the ability to manipulate a model of reality to help make connections between various concepts and theories necessary to solve real-world problems.  Recent literature supports the use of virtual reality models to help in situated learning (e.g., Messner *et al.*, 2003 [7], Sampio *et al.*, 2011 [8], Johnston and Whatley 2006 [9], Creem Regehr [10]). Lee *et al.*, (2007) [11] indicated the advantages of using virtual reality simulation for war like environments which can mimic in real time a life-like experience for a medical team attending to injured soldiers. So based on these studies, in this research, it was hypothesized that the students who learn the flood modeling and flood plain mapping with the aid of the virtual 3D modules would learn better than those who did not use such technology. To evaluate this, the virtual 3D models discussed previously was used in the civil engineering curricula at four universities, as listed in Table 1.

**Table 1 provides the courses used for collecting the data from different schools.**

| **Name of the school** | **Course** | **Data collection held during** |
|---|---|---|
| Purdue University Calumet | CE34200 Hydrology and Hydraulics | Spring 2013 (base line), Spring 2014, Spring 2015 |
| Florida Atlantic University | CWR 4202 Hydrologic Engineering | Fall 2014 and Spring 2014 (baseline)<br>Fall 2014,Spring 2015, Fall 2015 |
| University of Kentucky | CE 341 Intro to Fluid Mechanics | Fall 2014 and Spring 2014 (baseline)<br>Fall 2014,Spring 2015, Fall 2015 |
| University of District Columbia | CVEN 325 Hydrology and Hydraulics | Fall 2014, Fall 2015 |

The 3D module was used in CE 34200 Hydrology and Hydraulics course as a lab module at Purdue Calumet. CIVS at Purdue Calumet has a theater with CAVE system to run the 3D model. Students did the lab work in this theater. Simultaneously, at three other universities namely University of Kentucky, Florida Atlantic University and University of District Columbia, the lab module was used. In those schools, a computer model with 3D glasses were used. For the

University of Kentucky, since the evaluation was done for basic fluid mechanics course, a virtual 3D movie was also created to give basic introduction. However, for the analysis presented here, the data from University of Kentucky were not included. A separate analysis is being done and this analysis is not yet complete.

**Method**

A quasi-experimental design was used to evaluate the interactive modules' effectiveness. Student performance on the module of instruction related to flood modeling, management, and mitigation was assessed *before* implementation of the virtual lab module and compared to student performance in the same courses once the virtual 3D lab modules had been integrated. Similarly, students' perceptions of the instructional approach and materials was assessed with students experiencing instruction prior to implementation of the 3D lab modules and with students in classes where the 3D modules were implemented.

**Pre-/Post Test to Assess Student Learning**

Learning was assessed with a pre-test at the start of the instructional unit where the virtual lab modules would be implemented, and a post-test at the end of the instructional unit. The same pre- and post-tests was administered to students in each course once the 3D lab modules were implemented. The pre-test was composed of 13 objective, multiple choice questions related to floodplain modeling and management. Some questions asked students to interpret graphic representations of river systems and/or complete calculations in order to select the correct response. There are two instances where students are asked to provide written explanation in relation to the questions asked. The post-test is of the same format with minor modifications made to parameter values in problems, areas of a graphic to interpret, etc.

**Questionnaire to Assess Student Perceptions of Learning**

Students' learning experiences and their attitudes toward the instruction and instructional materials was also assessed in each course prior to and after implementation of the 3D lab modules. In courses where the 3D modules have not yet been implemented, students were asked to complete a questionnaire containing 21 objective items and 1 open-ended item. Participants are asked to indicate their level of agreement on a Likert-type scale for 14 items related to their experience in, perceptions of, and satisfaction with the unit of instruction. Students were also asked to indicate their overall understanding of floodplain analysis as well as respond to basic demographic items. The final open-ended question invited participants to share any other comments on the unit of instruction. In courses where the 3D modules was implemented, students were asked to complete a questionnaire containing 40 objective items and 1 open-ended item. All items included on the questionnaire used prior to 3D implementation are included on this survey, with minor modifications made to reflect the inclusion of the 3D modules. 21 additional items specific to the 3D modules were also added. The construction of the questionnaire was influenced by the work of Lee (2011) [[1]] who also examined the use of virtual reality to aid learning.

**Participants**

A total of 128 students participated in the study.  Forty-five students were in a control group that did not use the 3D modules, while 83 students were in the treatment group that used the 3D module. Among the total participants, 84% were male and 16% were female. The following research questions guided the research study:

1. Did students who used the 3D module demonstrate greater learning gains than those who did not use the module?
2. Did students who used the 3D module have more favorable perceptions of the instruction than those who did not use the module?
3. What were the perceptions of the learning experience of students who used the 3D modules?
4. For those students who used the 3D module, what factors impacted their learning and their perceptions of their learning experience?

After evaluating the pre and post tests, the results were consolidated and the basic statistics indicate the following:

**Research Question 1:**

**Table 1: For Research Question 1 – Full Dataset**

| | | N | Mean | SD |
|---|---|---|---|---|
| No 3D | Pre-test | 25 | 11.76 | 2.50 |
| | Post-test | 25 | 11.76 | 2.20 |
| 3D | Pre-test | 61 | 12.20 | 2.08 |
| | Post-test | 61 | 12.45 | 2.24 |

**Inference:** Repeated measures ANOVA was used to compare pre-/post-test scores of those who used the 3D module and those who did not. No significant differences were found in pre-/post-test gains between the groups

This analysis was refined to focus on the 10 test items that required higher-order thinking skills (application and analysis). The results are presented in Table 2.

**Table 2: For Research Question 1: With higher order thinking skills**

| | | N | Mean | SD |
|---|---|---|---|---|
| No 3D | Pre-test | 10 | 7.60 | 1.26 |
| | Post-test | 10 | 6.70 | 2.21 |
| 3D | Pre-test | 51 | 6.37* | 1.70 |
| | Post-test | 51 | 7.08* | 1.35 |

**Inference:** Those who used 3D module demonstrated greater learning gains from pre- to post- than those who did not us the 3D module.

**Research Question 2:**

There were no significant differences between the perceptions of the learning experience between groups. It needs further analysis.

**Research Question 3:**

Students using the 3D modules generally had favorable opinions of their learning experience. Of the 61 students who used the 3D module and completed the questionnaire, the vast majority agreed or strongly agreed with numerous statements indicating favorable perceptions. For example, 93% of respondents indicated that they enjoyed learning about floodplain analysis. Over 85% felt the 3D lab module was easy to use, they enjoyed interacting with it, and learning with it was fun. 88% of respondents reported that their use of the 3D lab module enhanced their learning of floodplain analysis, and 90% reported that it helped them link new knowledge with previous knowledge. At the end of the unit of instruction, 94% of respondents rated their understanding of floodplain analysis as outstanding or good.

**Research Question 4:**

For this question, by focusing on age, engagement, comfort with technology and type of technology, inferences were derived. In general, with age, perceptions of learning experience did not vary significantly. Engagement factor indicated increased enjoyment in majority of the group. Participants felt comfortable with 3D modules.

**Conclusions**

Using SPSS, a statistical software tool, the data were analyzed and the present results indicate the following:

1. Students who used the 3D module performed better on questions requiring application of knowledge than students who did not use the 3D module.
2. There is an improvement in the student learning when they use 3D module. However, use of the 3D module itself did not appear to significantly impact students' perceptions of their learning experience. It needs further analysis.
3. Students who used the 3D module rated their experience with the module highly.
4. The vast majority of participants who used the module described the lab module as interesting and enjoyed interacting with it.
5. The vast majority of participants who used the module felt that the 3D lab module enhanced their learning and helped them to link new knowledge with previous knowledge.
6. The majority of participants who used the module were satisfied with the 3D lab module and would like the opportunity to use 3D technology to learn about other topics.

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