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Outcome-based Evaluation of Environmental Modelling Tools for Classroom Learning*

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The effectiveness of the use of Web-based modelling systems in classroom teaching to enhance student learning is difficult to evaluate. The traditional 'control group' (e.g. students not using computer models and their interfaces) is not feasible due to the intrinsic complexity of environmental issues and the many processes simulated by the computer models, which would be almost impossible to replicate without model use and relying solely on hand calculations.. The evaluation procedure described here was applied to an honours first-year class having students with excellent academic histories. Web interfaces for two environmental computer simulation models (GRASIM and L-THIA) were used. The subject matter focused on key environmental topics including water management and pollution control. Pre- and post-tests were administered for each modelling exercise to test students' learning in three categories: quantitative, qualitative and idea-eliciting. Significant improvements in test scores were observed for both quantitative and qualitative learning categories. An evaluation triangle was designed to visualize the changes in the three learning categories for the pre- and post-test scores. The exercises were deemed helpful by participating students in enhancing their understanding of the subject matter. The proposed outcome-based procedure showed great potential in objectively testing the effectiveness of Web-based modelling tools in undergraduate education, albeit that more testing on larger class size is needed to further substantiate the observed improvement. Designs of the pre- and post-test questions are also important for accurate evaluation and must take into account students' academic demography as well as the topics being taught.

Keywords: multimedia teaching; teaching evaluation; learning tools; enhanced learning

INTRODUCTION

NATURAL RESOURCES and environmental engineering are intrinsically multi-disciplinary and hence should be viewed and taught as such. The so-called sustainable solution of environmental problems has driven environmental engineers and society at large to address natural resources and environmental issues from a systems perspective [1, 2]. College education can be one of the key strategies for fostering systems thinking and skills for future management professionals. Computer aided learning has played an essential role in environmental engineering education in this respect [3] and has been put into use in many universities around the world [4, 5, 6]. Specifically, computer modelling can be an invaluable tool in conveying the systems concept that is the core of current industrial solutions to farming and environmental problems such as non-point source (NPS) pollution [7]. In a review of computer mediated learning in higher education, Jong *et al.* [4] noted that the most popular form of computer aided learning in science and engineering is simulation using models.

The ubiquitous reach of the Internet and the explosion of the associated World Wide Web (WWW) technologies made the Web-based teaching paradigm flourish in many engineering disciplines, mostly in delivering educational material in multimedia formats including text, sound and video [8, 9, 10, 11, 12]. The importance of employing computer models in promoting students' systems thinking was clearly stated by Grant [1] as 'the only way to deliver the systems message effectively' and that 'we need to explore additional ways *of providing modelling apprenticeships to a wider audience'*. This clearly outlined the need for the combination of the two powerful tools, i.e. the WWW and computer simulation models. However, as noted previously by Gunn *et al.* [13], interactive online modelling systems are still lacking in environmental engineering education and curricula. Also, much remains to be done in its integration with students' learning processes to form a cohesive educational environment [14].

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Another challenge that this work addresses is the evaluation of the teaching effectiveness of modelling tools, since there have been few published works that provide a means for the evaluation of the perceived advantages in using comprehensive computer models in teaching environmental engineering classes. The main obstacle is that the traditional way of comparing a 'treatment' group (or the group that uses computer modelling tools) vs. the 'control' group (or the group that doesn't) was found to be almost impossible in targeted environmental classes.

Past Web-based modelling efforts have resulted in developing Web interfaces for complex environmental simulation models such as the Grazing Simulation Model (GRASIM) [15, 16], GLEAMS [17] and the Long-Term Impact Assessment (L-THIA) model [18]. These systems and related educational materials have been used to improve student understanding of complex natural resource systems in a number of undergraduate classes [19]. The tools developed allow educators in the natural resources area to bring real-world experiences into the classroom. Discussions with students indicate that these Web-based models are useful in the classroom for understanding the complex mosaic of interactions that are characteristic of natural resources and agricultural systems. These experiences were documented previously [19, 13].

Through the course of teaching and curriculum development involving these models, attempts were made to evaluate their intended effectiveness in various engineering classes by comparing test scores between a control group using traditional class lectures against a group that uses the Web-based modelling tools. It was noted that due to the intrinsic complexity of natural resource and environmental quality issues, it was often not feasible for the control group to complete a case study of equal complexity without using the computer models. Additionally, although limited tests indicated a preference for modelling systems in students' understanding of basic concepts, often the test results were inconclusive. Lastly, these modelling systems have not been used in classes that are tailored towards undergraduate students from majors outside science and engineering disciplines. Hence, these modelling tools were applied in an introductory environmental engineering class catering to novice students, and the effectiveness of these tools in improving student learning was evaluated using an outcome-based approach.

The outcome-based assessment and evaluation process has been advocated by the Accreditation Board for Engineering and Technology (ABET) that mandates its use in universities for accreditation purposes. It is the basis for the outcome-based learning (OBL) paradigm that focuses on design and teaching using 'a learner-centred results-orientated system founded on the belief that all individuals can learn' [20]. According to Spady and Marshall [21], 'outcomes are clear, observable demonstrations of student learning that occur after a significant set of learning experiences' and that these demonstrations can reflect students' learning in three categories, i.e. knowledge, its application and students' motivation/confidence to demonstrate skills. This new paradigm differs from the traditional teaching mantra of 'these are the skills/topics that you should know' and brings more responsibility to the educator to allow him/her to work with developers of educational tools to custom design teaching material to maximize student's learning. This new paradigm was the inspiration behind the development of the evaluation method used in this study.

It follows that the assessment in OBL is not a simple memory test. It is important to explore new and efficient assessment/evaluation methods to test the acquired skills/knowledge by the students in a more comprehensive fashion, in which challenging tasks are used to allow a student to improve his/her thinking, researching and analysing abilities on the subjects taught. Accordingly, the objectives of this paper are to:

(1) present an outcome-based procedure to evaluate the effectiveness of environmental models to improve student learning;
(2) apply the outcome-based evaluation procedure to evaluate the effectiveness of the two environmental models (GRASIM and L-THIA) in undergraduate learning.

EDUCATION MATERIAL AND PROCEDURES

The Web-based interface developed for the GRASIM and L-THIA models was used in this project to administer the modelling exercises. Through the interface, students can quickly prepare model input files, run the simulations and review model results in both text and graphic formats through a series of interactions in the browser. Supporting multimedia educational material including case studies serving as tutorials for the models were also developed detailing the model theoretical and operational aspects. The two modelling systems were used in the curriculum of an introductory environmental engineering course for students in their first year of university enrolment.

The GRASIM model

GRASIM is a tool used to assess the economic and environmental impact of pasture management. Grazing systems are naturally cross-disciplinary and interrelated among several areas of science, including whole farm planning and total human and natural resource management. GRASIM is a grazing simulation model that links all components of the pasture system. It allows a user to obtain a better understanding of the pasture system and to determine management strategies that will yield more efficient utilization of pastures.

It predicts standing biomass, herbage nutritional quality and nutrient leaching under pastures, and it generates information suitable for estimating the financial and environmental consequences of alternative dairy management strategies, including partial mechanical harvest in the context of the year-round feed needs of the dairy herd. Storage/harvest needs and year-to-year variability can also be evaluated. In addition, the model evaluates the effect of stocking rate on supplementation of the amount of harvested feed.

GRASIM is equipped with a mechanistic general use crop model that can be calibrated for a variety of crops. It accounts for carbon, nitrogen and water budgets in the pasture environment. GRASIM data requirements include minimum and maximum daily temperatures, daily rainfall, average daily solar radiation, soil physical properties, grass growth parameters, soil nitrogen transformation coefficients and initial levels of soil water and soil nitrogen. The coefficients used in GRASIM computations carry physical meaning and can be measured. Unlike functional or empirical model parameters, these measurements do not change with geographic location and growth environment. GRASIM executables and documentation are available at the WWW site: http://pasture.ecn.purdue.edu/~grasim/

GRASIM has been validated and proved to perform well under field conditions [16]. In addition to its technical merits, it provides a better understanding of systems thinking and how one component of a system affects the others. GRASIM offers students in soil and water quality curricula a dynamic, easy-to-use tool that can assess the effect of various parameters of productivity and on environmental impact of pasture use. The model can also evaluated the effect of management parameters on biomass quantity and quality, and nutrient flow to the environment. Weather databases (solar radiation, precipitation, and temperature) are stored on the server on which the model is located. Choice of the location of interest results in the selection of appropriate weather files, default soil properties and other model-required data from the database.

The L-THIA model

The L-THIA model estimates long-term average annual runoff for different land use types in a watershed based on long-term climate, soils and land use data for that area. By using more than 30 years of daily precipitation data in the daily direct runoff calculation with the United States Department of Agriculture Soil Conservation Service (SCS), which is now the Natural Resources Conservation Service (NRCS), curve number (CN) method, L-THIA estimates the long-term average impact, rather than an extreme year or storm event impact. It also provides comparative impact assessments of land use change in terms of annual average non-point source pollution loadings by multiplying event mean concentration (EMC) data with daily direct runoff. The EMC data were introduced to estimate non-point source (NPS) pollution loading from non-urban and urban areas [22]. The L-THIA model was written in the 'C' programming language, and an executable L-THIA was created to run within the Web-based L-THIA via Common Gateway Interface (CGI).

L-THIA is the core hydrologic model within a locally developed Web-based Spatial Decision Support System (SDSS). For watershed management purpose, it has been chosen as it can be readily run through a network environment with readily available data considering connection speed, and model execution time and data requirements. The Web-based SDSS was presented previously [18] and used in this study. Its three main components include an interactive graphical user interface (GUI) for identification of the watershed of interest, hydrologic model (L-THIA) to calculate direct runoff and NPS loading, and GIS spatial database. The SDSS is available at the following Website: http://pasture.ecn.purdue.edu/~watergen/

Supporting materials

Apart from the detailed presentations for GRASIM and SDSS/L-THIA systems on their respective Web sites as already shown, case studies and their background information have been developed and are available at: http://pasture.ecn.purdue.edu/~water/teach/src/teach.htm/

The site includes step-by-step instruction for modelling projects. The case studies were designed to cater for students at different levels, majors and previous levels of modelling experience.

CLASSROOM USED IN THE STUDY

The modelling exercises were employed in the HONR199v class, an interdisciplinary honours programme course. The course provides first-year students with exposure to important topics on water resources management, quality and its protection. It combines field observations and data collection, laboratory analysis techniques and computer-based modelling. Students completing the course will be able to:

(1) better understand the water system and the impact on food production, land use and management on water quantity and quality;
(2) determine measures to protect this vital resource. The class was taught in the fall semester of 2003 and included eleven undergraduate students.

The class Website is at: http://pasture.ecn.purdue.edu/~honr199v/

Outcome-based evaluation

Accurate evaluation of the effectiveness of new teaching protocols is as important as the development of these learning tools. This evaluation provides educators with a tangible gauge to help adjust their teaching techniques and enhance their teaching tools.

With the modelling tools employed in this research, it is practically impossible to quantify the hydrological and biological processes without using models. By a similar token, the Web-interfaces for these models greatly simplify the otherwise cumbersome tasks of storing and organizing input data as well as interpreting and visualizing simulation results. These issues would make the use of the models by the students very difficult, if not impossible, to fit in a timely teaching schedule. Therefore, it is not possible to have a 'control group' without using computer models through their Web-interfaces. The proposed outcome-based evaluation procedure is an attempt to overcome these constraints.

The outcome-based evaluation procedure is based on the understanding of three basic organizational levels of the Web-based learning process. These levels include: developers, instructors and learners, and that the interaction and feedback among these levels are essential for improving students' experiential learning.

The effectiveness of the interactive learning process using Web-based models can be tested with the following sequential steps:

(1) Developer(s) set the learning goals in using the modelling systems and the scope of the tools that s/he develops.
(2) Course instructor(s) set learning objectives for the specific exercise in which the tool is being used.
(3) Instructor(s) develop scenario(s) for the specific learning objectives listed in step (2).
(4) Evaluator(s) (or instructor(s)) develop and conduct an instructor's survey to set the benchmark for which the students' learning outcome will be evaluated against. The survey has to be specific to the exercise scenario and in accordance with the pre- and post-test(s) listed in step (5) below.
(5) Evaluator(s) develop and conduct pre- and post-test(s) for students'/learners' evaluation and differential learning after using the modelling tools. The pre- and post-test will be specific to the exercise scenarios and matches the instructors' survey. It is desirable that the learning evaluation matches and approaches the instructors' survey. The test should cover the learning prism explained below to measure the improvement in various modes of learning, i.e. qualitative, quantitative and constructive idea eliciting.
(6) Complete an evaluation and feedback loop to the developer and instructor to improve the model and/or the scenario and the supporting material.

Learning goals

These evaluation steps are further illustrated in the section below.

The learning goals are defined to guide students towards certain topics within their teaching curriculum. Furthermore, these goals are refined according to the teaching tools available. In this study, and for water quality and watershed hydrology subjects, the following are key topics the students are expected to learn upon finishing the course:

(1) Fundamental understanding of the hydrological cycle.
(2) Fundamental understanding of overland flow runoff processes.
(3) Understanding of the non-point source (NPS) pollution and prevention.
(4) Understanding of the interaction between farm/human management practices and runoff and nutrient loadings.

Classroom modelling exercise

The two modelling systems were used and their effectiveness tested in an introductory environmental engineering class. These students were enrolled in an honours first-year programme geared toward undergraduates with excellent academic histories.

Two case studies, one for each modelling tool (GRASIM and L-THIA), were conducted during regular lab periods. Pre- and post-test questions were designed and categorized into qualitative, quantitative and idea-eliciting for each exercise. The general focus of each set of test questions was determined by the nature of the modelling system. GRASIM was used to simulate pasture-based farming practices to predict productivity and environmental impacts of grazing; L-THIA was used as a watershed hydrological simulation model to predict direct runoff and nutrient loading from various land uses. The exercise learning objectives, case study scenarios and the corresponding pre- post-test for both case studies are listed in the Appendix. These were developed in coordination by the evaluator, educator and developer. The scenarios are based on the instructors' real world experience in the field. The pre- and post-tests are designed and categorized to reflect the learning triangle introduced below.

The qualitative questions are more open-ended and test students' general grasp of the concepts. Quantitative questions are to test how exact can students remember details or how well can they handle quantitative analysis. Idea-eliciting questions are to test if students can identify the common merits of the online modelling systems by giving constructive suggestions and identifying the importance of the theoretical presentation of the modelling system in facilitating the use of these systems.

The following procedure was used in the classroom evaluation of the modelling tools:

(1) Students/learners were pre-tested to evaluate their starting point coming into the exercise (closed book test).
(2) The conceptual model of the target modelling

system was presented to show the scope of the modelling tool, components, key linkages, sinks and sources in water and nutrient budgets.

(3) A demonstration run was then conducted in class using a real scenario. The main model input/output and the online demonstration manual were presented.
(4) Real case study scenarios were presented and discussed in class.
(5) Students then solved the scenario and generated output for several runs and compiled their final output and analysis.
(6) The class was regrouped to review the lessons learned during the exercise.
(7) Post-test was conducted in class (closed book).
(8) Results evaluation and analysis to test whether the exercise achieved its goals and if not why and what can be done to improve the experience.
(9) Feedback was provided to the developers on ways to improve the learning tools.

Additional post-tests can be conducted for analysis of long-term retention of information. This is a long-term goal, and data on this aspect will continue to be collected. They might be very difficult to collect, but we believe that the long-term data are essential to address significant issues related to the impact of these tools on the decision-making skills and professional performance of students/learners. Data can be collected within the continuing improvement of the accreditation documentation and reporting. However, this issue will not be addressed in this paper.

Knowledge growth evaluation technique

After pre- and post-test scores were evaluated, the points earned for each section of the test (qualitative, quantitative and idea-eliciting) were converted into percentages so numerical comparison of the learner's understanding could be analysed from pre-model use to post-model use. An equilateral evaluation triangle (Figure 1) was designed to have its three sides graduated into uniform 0–100 scales with each side representing one of the three categories of the learning test. Visual representations of the knowledge placement before using the model were compared to placement after using the model.

Knowledge growth by the students can be visualized in two formats using the same evaluation triangle. For the first format, students' pre- and post-test scores for the three learning sections are scaled between 0 and 100. Then the score change in pre- and post-test for each category is directly drawn along the corresponding edge of the

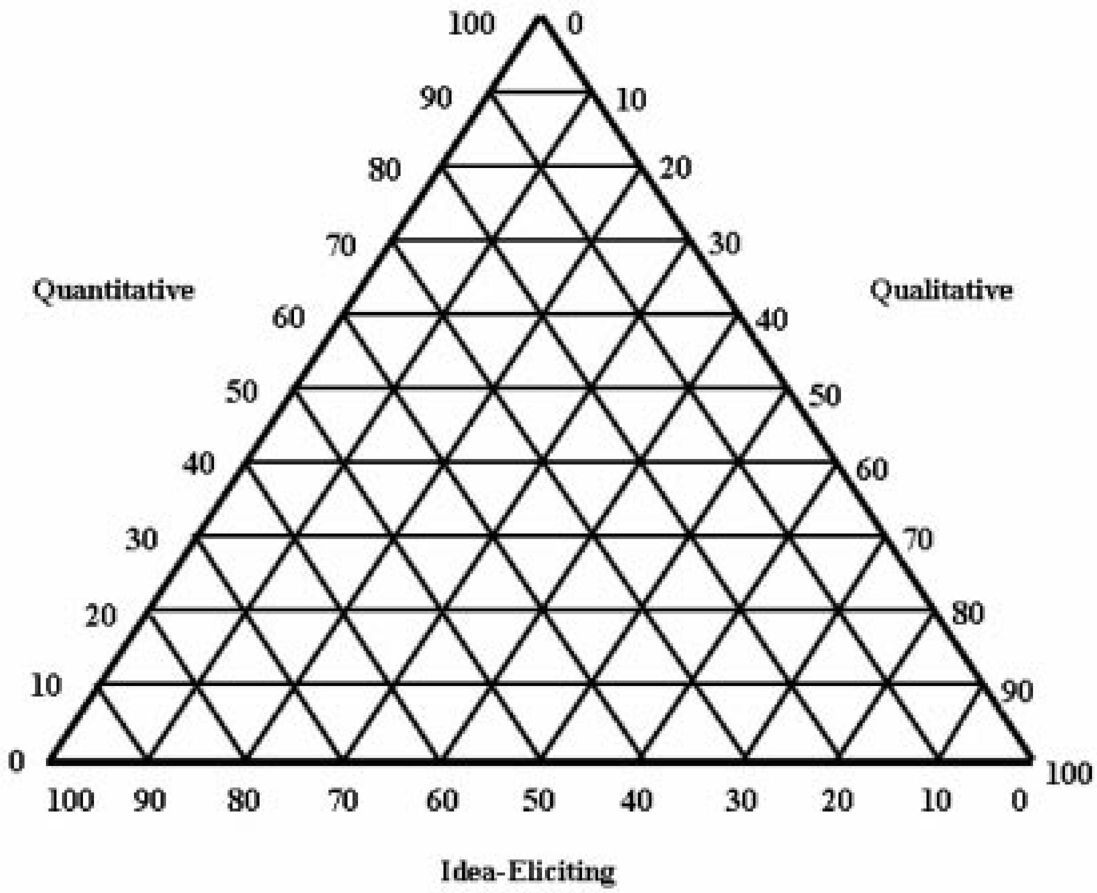

Fig. 1. Evaluation triangle for visualizing student's learning testing scores for the three learning categories: quantitative, qualitative, and ideal-eliciting

evaluation triangle in form of an arrow starting from pre-test score and ending at post-test score for each learning category. Due to the fact that the same set of questions were used for pre- and post-tests, this method gives a direct illustration of students' performance changes before and after using the modelling systems.

For the second format, students' pre- and post-test scores were normalized using the total scores on the three learning categories, hence, the score for each learning category can now be thought of as a constituent of the total performance by the students in percentage terms, which in turn correspond to the scales of the three sides of the evaluation triangle. In this format, the base of the triangle represents the initial pre-test status of the learners and the post-test results are represented in a third dimension in the form of an arrow starting from pre- and ending at post-testing status. This format provides a better view of the composite collective improvements in students' understanding of the subject under investigation as well as the application of the Web-based models.

The three sides of the evaluation triangle can be assigned to represent other forms of learning skills and any classification changes before and after the modelling exercise. The percentages will then be placed on the evaluation triangle to plot the growth of the learner as a result of that learner using the Web-based model.

RESULTS OF CLASSROOM IMPLEMENTATION

The scenarios developed and presented in the Appendix were implemented in accordance with the methodology presented above.

The design of the pre- and post-test questions for the two modelling exercises were conducted to relate the functionalities of the two models, while taking into account the students' academic background and their inexperience in using complex computer models. These questions are listed in the Appendix. The same sets of questions were used in the pre- and post-tests for the two modelling exercises. In both sets of test questions, qualitative questions were mostly open ended and designed to test students' ability to correctly interpret and explicitly use the technical terminologies in the subjects taught, i.e. pasture management (GRASIM) and watershed management for reduced long-term water quality impact (L-THIA). For the quantitative questions, students were tested against simple principles represented in quantitative terms for the GRASIM model exercise. For the L-THIA model, the core of its hydrological module for estimating runoff from various land uses was posed in the quantitative questions. Students were instructed to give more detailed description of their understanding of the model, which effectively tests students' understanding of the basics in hydrological modelling. The same open ended questions were asked as idea eliciting questions for both modelling exercises. It is assumed that students' understanding of the biological and hydrological processes as represented by the two models can give them a more detailed understanding of the modelling exercises and tasks at hand so that more pertinent suggestions can be elicited from them as for the design of the interfaces for the two models.

The pre- and post-testing scores for the two modelling exercises are shown in Figure 2. Pre- and post-test results show strong improvement in all three learning categories. Due to the fact that the same set of questions was used in pre- and post-tests and that the tests were named by all participating students, a pair-wise t-test was performed on testing scores for the three learning categories. There were significant ($a=0.05$) improvements in scores for both qualitative and quantitative sections of the tests. Statistically, significant changes were not detected for the idea-eliciting section of the tests, despite the observed more detailed responses from students in the post-testing for both modelling exercises (Figure 2(a) and (c)).

Figure 2(a) and (c) show that the magnitudes of the improvement in test scores for the quantitative and qualitative questions are greater than that for idea eliciting questions. It was the intention of the instructor/evaluator to use the idea eliciting questions to see if students could identify critical and key processes for the models involved, and at the same time elicit constructive suggestions for the development of the model interface based on such suggestions. However, none of the participating students realized the importance of the organizational needs for the modelling interface and hence rarely gave suggestions outside those mentioned in the questions, therefore leading to the lack of significant improvements in this section of the testing scores. We believe that this particular question can be reworded in order to spark more detailed response from the students. We also believe that more exposure in the subject of this course (i.e. environmental engineering) would give the students the ability to have deeper insights of the modelling system, hence more detailed suggestions. However, there was an almost unanimous consensus among participating students regarding what is the most important factor influencing the use of modelling systems, and that is the user friendliness and simplicity of the interface.

Generally, students performed better on the qualitative questions that carry an open ended nature. Previous efforts [19, 13] also showed such a trend. During grading of the pre- and post-tests, occasionally, it was noted that after the modelling exercises, students could give a more detailed account of certain processes while losing the overall picture of the whole system, of which they've already demonstrated understanding in the pre-test. This is demonstrated in the use of GRASIM

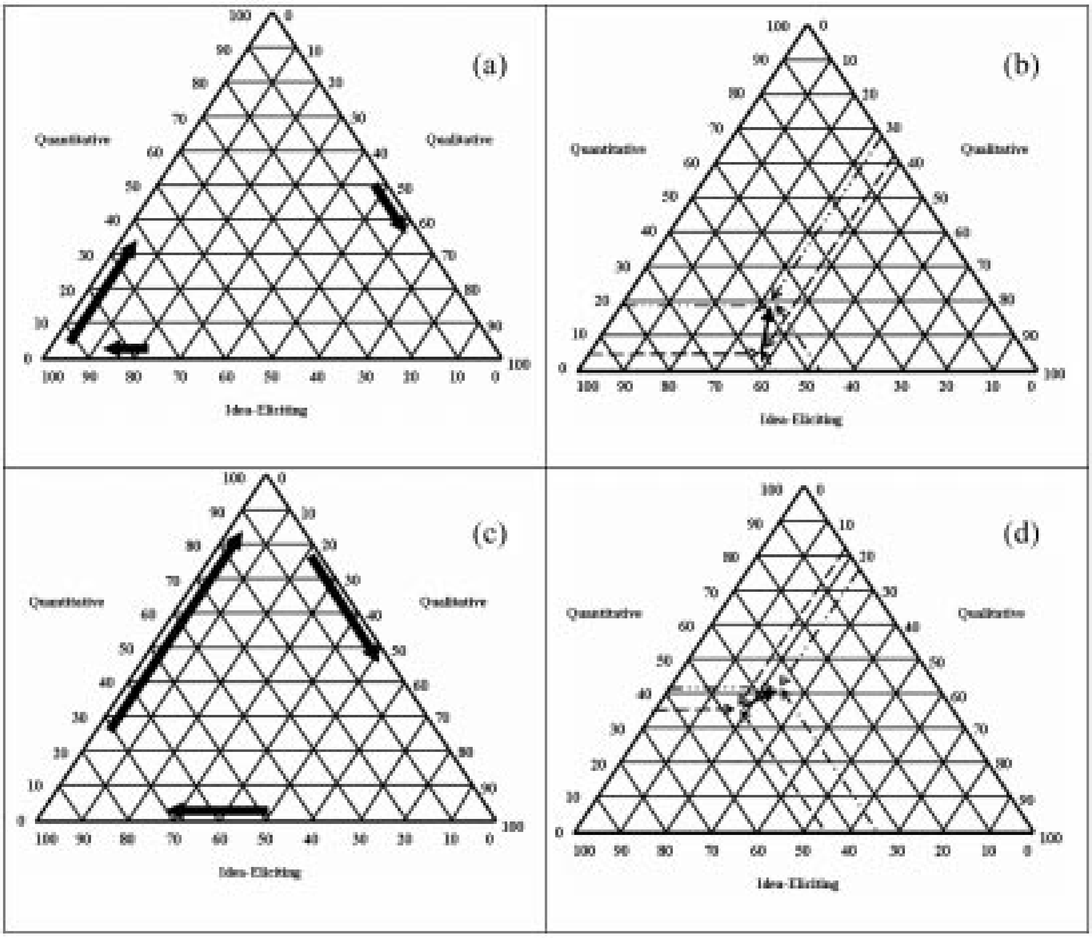

Fig. 2. Evaluation triangles show improvement in testing scores from pre- and post-tests using L-THIA (panels a and b) and GRASIM (panels c and d) online models. Panels (a) and (c) show test scores as is; panels (b) and (d) show test scores as a percentage of the total score (i.e. sum of scores from all three learning categories). In all four panels, solid black arrows indicate the change of scores/ performance from pre- (start of an arrow) to post- (end of an arrow) test

model and Figure 2(b), where it is shown that the relative footprint in students' overall understanding of the pastoral system increased for quantitative learning while it decreased in the qualitative learning due to, perhaps, the fresh exposure of numerical modelling of the system that led the students to pay more attentions to the details than the framework. We believe that longer lab periods and more guided discussion after the exercise can help students put their newly acquired quantitative skills into perspective. In both modelling exercises, it was shown that the relative presence of the idea eliciting section decreased in the overall learning experience (Figure 2 panels b and d) due to the lack of significant improvement in students' response in pre- and post-tests. This is due to combined effect of simplicity of test questions (many hints were listed in the questions) and the lack of serious thinking by the students in answering the idea eliciting questions, which were to elicit 'constructive suggestions' that would have been based on their improved understanding of the subject matter. For example, more detailed comments as to how to improve the layout of the modelling interface to enhance its presentation of the theoretical framework of the modelling system are expected from the response to these questions.

Overall, it was a consensus among students that the models are indispensable tools in dealing with farm productivity evaluation and water management. This concurs with the previous study of the effectiveness of modelling tools in engineering education [19]. Gunn *et al.* [13] also stated the dilemma in designing the case study scenarios in that complex problems cannot be solved by hand calculation, while too simple of a scenario would not merit the use of a powerful computer simulation model, hence it rendered it very difficult to compare the effectiveness of using these computer modelling system to that of traditional teaching methods without the access of a model. The outcome-based evaluation in this study intended to help evaluate student learning while using these complex environmental models.

We recognize that more testing of the Web-based modelling exercises in enhancing students' learning using the outcome-based method is needed, despite the observed effects in this study. The small class size (eleven students) in this study also warrant more testing of the proposed teaching tool and its evaluation methods in not only bigger classes but also on different levels of classes such as in junior or senior classes. Test questions would certainly need to be carefully designed and perhaps increased in quantity to test students' performance improvement more thoroughly. It is recommended that a testing question database be constructed, modularized and dynamically administered by the instructors.

The lessons learned from this evaluation exercise are very valuable in improving student learning. Feedback to the evaluator(s), instructor(s), and developer(s) is critical and should be on-going. This evaluation is not and should not be limited to short-term learning evaluation. Long-term evaluation on student learning and its impact on decision-making are ongoing.

SUMMARY AND CONCLUSION

In this study, an outcome-based evaluation procedure was developed to test the effectiveness of Web-based simulation modelling tools in improving students' understanding of key environmental concepts. Two Web-based computer modelling systems were used, GRASIM and L-THIA, to model pasture-based systems for productivity and water quality and watershed land use management for overland runoff and water quality impact assessment, respectively. Pre- and post-tests were administered before and after the modelling exercises using case studies. Test scores were compared and analyzed. The improvements were displayed using an evaluation triangle with its three sides representing each of the three learning categories used in the pre and post-tests: qualitative, quantitative and idea eliciting. The evaluation triangle proved to be very helpful in visualizing the improvements as well as the changes in the relative improvements of each learning category in the overall students' understanding and grasp of key concepts.

The following conclusions were drawn from this study:

(1) Based on the improved test scores, we note that both modeling systems could play a large role in the observed significant improvements in students' understanding of the subjects taught.
(2) During the evaluation, pre- and post-test questions need to be designed to closely relate to the subject matters being taught and to the classroom academic demography in order to accurately reflect the perceived improvement in students' understanding and skills.
(3) More tests need to be conducted on larger class sizes to substantiate the improved learning observed in this study.
(4) Model interface design aimed at ease of use and execution robustness of these models should be placed as top priorities in developing such modelling systems as indicted by the participating students.

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APPENDIX

L-THIA

1. Objective

Improve experiential learning of water quality of the water quality system while maintaining the complexity and the comprehensive nature of this system, its processes and the interaction that exist among them. Specifically, improve both qualitative and quantitative understanding of hydrological cycle and identify influential factors affecting surface runoff and nutrient loading from a given area

2. Scenario (Understanding Rainfall-Runoff Relationship using Web-based Modelling Tool)

A. Comparison of runoff quantity about different weather conditions

Rainfall amount affects directly runoff amount. However, runoff can be affected rather by rainfall intensity (how much rain has come during how long time) than by rainfall amount. Through running L-THIA for two locations in west coast and mid-west the fact can be examined.

Procedure

- Run L-THIA for Fresno County in California and Tippecanoe County in Indiana for the same land uses and hydrological soil group areas
- Land Use / Hydrological Soil Group / Fresno, California / Tippecanoe, Indiana

Land Use	Hydrological Soil Group	Fresno, California	Tippecanoe, Indiana
Commercial	B	10 acres	10 acres
Agricultural	C	45 acres	45 acres

- Compare the result for average annual runoff depth and average annual rainfall;
- Explain why Fresno has more runoff than Tippecanoe, even though Fresno has less amount of average annual rainfall than Tippecanoe.

B. Comparison of runoff quantity and pollution loading from a watershed about pre and post development land use condition

Land use change can impact runoff. Through this exercise, students can evaluate the hydrological impact due to land use change from urban sprawl. They can learn the impacts by comparison of the results between pre and post development conditions.

Problem:
Urban area in West Lafayette is growing due to urban sprawl. A watershed in West Lafayette has experienced dramatic land use changes during a past decade as shown in the table below. Evaluate the land use change impact using L-THIA based on the information including location, land use and hydrological soil group. Use the 'before development' land use as 'current' and 'after development' as 'scenario 1'.

Procedure

- Run L-THIA for Tippecanoe (West Lafayette) County at Indiana using data prepared in the table
- Land Use / Hydrological Soil Group / Before Development / After Development

Land Use	Hydrological Soil Group	Before Development	After Development
Commercial	B	2 acres	27 acres
Agricultural	C	40 acres	15 acres
Pasture/Grass	B	55 acres	20 acres
Forest	C	75 acres	35 acres
Industrial	B	3 acres	33 acres
Low Density Residential	B	4 acres	23 acres
High Density Residential	C	1 acres	27 acres

- Compare the results for average annual runoff depth between pre and post development conditions;
- Explain the reason why runoff is increased and how the urban development has affected non-point source pollution loading.

3. Pre Post test for using L-THIA model

Qualitative

Name three key factors that influence the overland runoff capacity for a given area.

Describe the relationship between total rainfall amount, rainfall intensity, and storm runoff.

Describe the difference between pre- and post- developed areas in terms of hydrological characteristics that either facilitate or hinder storm runoff capacity.

Describe major soil hydrologic groups and their hydrological characteristics, and their relationship to storm runoff generation.

What is NPS pollution? Describe the factors that would promote or impede NPS pollution.

Quantitative

What's the most popular method for overland runoff calculation?

Idea eliciting

For the purpose of promoting Web-based modelling system usage by common users, what do you think is the most important factor? (Interface user-friendliness, page loading speed, more interactive online help, or other cutting edge IT tools such as flash or animation etc).

GRASIM

1. Objective

Improve experiential learning of the management of pasture-based grazing system for maximum productivity and minimum water quality impact. The focus is the system thinking of the major components/processes and the interaction that exist among them. Specifically, improve both qualitative and quantitative understanding of agro-eco-system and identify influential factors affecting nutrient dynamic with different management practices

2. Scenario

A farmer in West Lafayette, IN wants to fertilize his pasture to improve crop growth. He is concerned about nitrogen leaching and would like to improve the fertilizer use efficiency using multiple fertilizer applications. Provide advice using GRASIM (the GRAzing SImulation Model). The Purdue extension field office recommended total fertilizer application of 200kg/ha Nitrate (N-NO3). The pasture area is 15 ha. You can compare nitrogen leached below the root zone for 1, 2, 3 and 5 applications. All simulations should have the same total amount of fertilizer. For the weather year, use 2. This year has low rainfall, only getting 75% of the yearly average. Use the default values for all other variables.

3. Pre- Post-test for using GRASIM model

Qualitative

Name the various sinks of N in the pasture system.

Name the key soil, plant, management, and weather factor that affect N loss to leaching the most.

Name the linking processes (two-way links) between the following entities in the context of nitrogen cycle:

- Soil N and plant;
- Soil N and water;
- Soil N and management.

Discuss how N dynamics (N cycle) work in the pasture system.

Quantitative
Which one is a safer fertilizer application regime?

- apply 1 lump sum of fertilizer across the a single growing season; or
- apply the same amount of fertilizer via two separate applications across a single growing season.

Relate your answer to the timing of application in terms of weather conditions.
What is the acceptable level of N concentration in water defined by EPA?

Idea eliciting
For the purpose of promoting online modelling system usage by common users, what do you think is the most important factor? (Interface user-friendliness, page loading speed, more interactive online help, or other cutting edge IT tools such as flash or animation etc).

Name a few other online modelling systems that are similar to the one you used in the GRASIM lab.

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