Hands-on experiments for teaching children about erosion, watershed management, and water resources.

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Abstract

It is well documented that children determine if they are "interested" in math and science by the time they are in middle school. Therefore, it is important to reach children at that age with fun activities that help them learn about math, science, engineering, and their environment. This paper will discuss several hands-on experiments used to teach children about erosion, run-off, pollution, watershed management, and water resources. The two primary apparatus are a river meander demonstration table and a soil erosion box. These devices were constructed using relatively inexpensive materials and could be easily replicated by other interested parties. Both are portable and have been used for outreach activities as well as on-campus instruction. The river table is a 20" wide by 48" long by 4" deep Plexiglas box filled with sand. Students are given the opportunity to interact with the model (with instruction) such that they investigate river dynamics, sediment transport, erosion, and erosion control (using model gabions, riprap, and sponges). The soil erosion box is an 18" wide by 36" long by 3" deep wood box that can be filled with various materials and placed at variable inclines. The simulated rainfall run-off and eroded sediment are caught in glass jars at the end of the box. The amount of water and sediment can then be measured and conclusions drawn by students on the effect of slope, soil type, and ground cover on erosion and erosion control techniques. These experiments have been performed by middle school, high school, and college students with degree of complexity and expectations increasing with age. Finally, this paper will also discuss the success and failures of these models in teaching children and make recommendations for implementing similar outreach programs.

Introduction

As we all know, today's children are tomorrow's engineers. Also, it is well documented that children determine if they are "interested" in math and science by the time they are in middle school. Therefore, there is a distinct need for outreach programs that are creative, fun, interactive, and interesting to improve the learning process and recruit the next generation of engineers. This was the impetus behind the "Engineering the World" outreach program developed by civil engineering professors (including the author) at Lawrence Technological University. This outreach program was developed for middle school students and featured activities that provided exposure to each of the conventional disciplines of civil engineering (geotechnical, environmental, structural, construction, surveying, and water resources). The program was held at an inner-city middle school in Detroit, Michigan. Students in the program were enrolled in sixth, seventh, and eighth grades. Enrolling in the after school program required qualification of good academic standing by the students. In addition, almost all of the students were underprivileged minorities. Classes were scheduled for 20 students, yet regular attendance was between 8 and 12 students.

The equipment described in this paper was developed for the Engineering the World Program. These two experiments (river meander demonstration table and soil erosion box) were developed in part because of the significant soil erosion and stream degradation associated with urban watersheds (although concepts taught are applicable to urban and rural environments). The Detroit Metropolitan Area is home to three highly urbanized watersheds, yet a majority of the people living within these watersheds are unaware of the impact humans have on the physical and ecological health of streams within these watersheds. There exists a distinct need to increase awareness and knowledge of these issues among the general public, specifically children.

Equipment and Experiment Descriptions

River Meander Demonstration Table

A river meander demonstration table is a 20 in. wide by 48 in. long by 4 in. deep Plexiglas box (Figure 1). The boxes are filled with a mixture of fine, medium, and coarse sand to allow the creation of three dimensional river systems. Flow through the model is accomplished by using a small submersible pump in a lower reservoir. For convenience and economics, the reservoir is simply a 20-gallon plastic storage container. Water is inserted into the upper end of the demonstration box through a small hose into a diffuser. The diffuser slows the velocity of the water to resist excessive sediment erosion at the point of entry. This allows water to enter the system more naturally instead of directly through the hose. The diffuser plate can be removed to simulate “flash” flood events that are commonly associated with urban stormwater surges. The box is set at a slight angle to facilitate gravity flow through the river system and water returns to the lower reservoir after passing through the model. The water then recirculates through the system.

The system allows students to visual various river processes including sediment transport, bank and bed erosion, river evolution, flooding, etc. The use of non-uniform sand allows students to visualize the transport of different sediment sizes as would be encountered in nature. Depending on the velocity of the water, students can see smaller grains of sediment being transported, with larger grains settling onto the bottom. Sections of the riverbed with no sediment present (visible Plexiglas) represent locations of higher shear stress due to increased velocity. Sections where sand is settling can be explained as regions of low velocity and subsequently lower shear stresses. Frequently, riverbed features such as point bars, scour holes, bank erosion, etc. are clearly visible by the students (Figure 2).

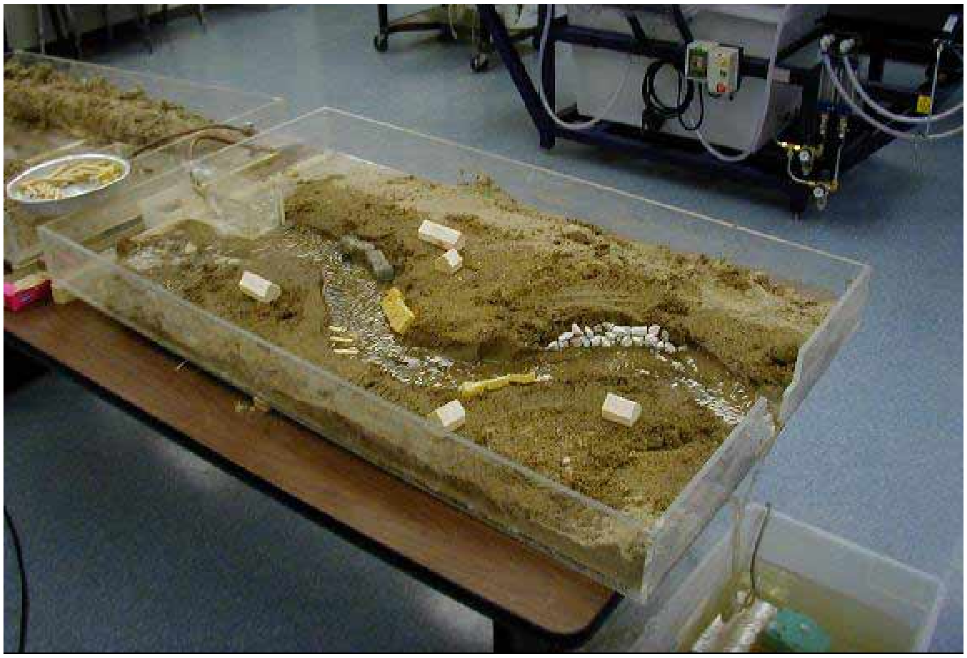

Figure 1: River meander demonstration table.

Figure 2: Bank erosion on outside bend (stabilized with gabions) and point bar on inside of bend.

As part of the project, students were asked to verbalize what they were seeing and how water flowing through the system was changing the environment. Initially, they did not use the proper terminology, but their descriptions were somewhat accurate. The system allowed students to visualize various river processes including sediment transport, bank and bed erosion, river meandering, flooding, etc. The use of non-uniform sand allowed students to visualize the transport of different sediment sizes as would be encountered in nature. Depending on the velocity of the water, students could see smaller grains of sediment being transported, with larger grains settling onto the bottom. Additionally, students had the opportunity to change their environment by adding scale features to the model such as boulders, gabions, logs, and bank vegetation. The boulders were simply small rocks; the gabions were wired baskets filled with gravel; the logs were cut dowel rods; and sponges anchored with toothpicks represented bank vegetation (Figure 3). The river model was easily changed to incorporate these features. Finally, after students were given the opportunity to alter the system, they were asked to construct a new river system and predict how it would react when water flowed through the system (Figure 4). Their success predicting at exactly where erosion and deposition would occur was marginal ,but they seemed to have an overall grasp of the process and what impact they had on the system.

Figure 3: Gabions, bank vegetation, and log vanes (note the visibility of Plexiglas bottom indicating a defined Thalweg).

Water in the reservoir periodically needs to be changed because it becomes sediment laden and very "muddy" in appearance. This feature can be used to facilitate discussions on how erosion relates to water quality. The sediment laden lower reservoir also provides students an opportunity to make qualitative observations and quantitative measurements of the amount of sediment that is lost from the system. If the lower reservoir is viewed as a downstream waterbody (for example, one of the Great Lakes) the students gain an appreciation for the ultimate deposition point for sediments eroded from the watershed.

Figure 4: Student interacting with river demonstration table.

In addition to instream model features, small houses are included with the model. Students can be asked to place the houses at various locations and then describe why those locations were chosen. This leads to discussions on floodplains and the problem with building a house too close to the river. Occasionally, a home near an eroding riverbank ends up collapsing into the river; a vivid demonstration (Figure 5). Unfortunately, students enjoy catastrophic events, so it's difficult to stress the seriousness of the event. Another option is for the instructor to place the house at different locations and ask the students to evaluate the locations.

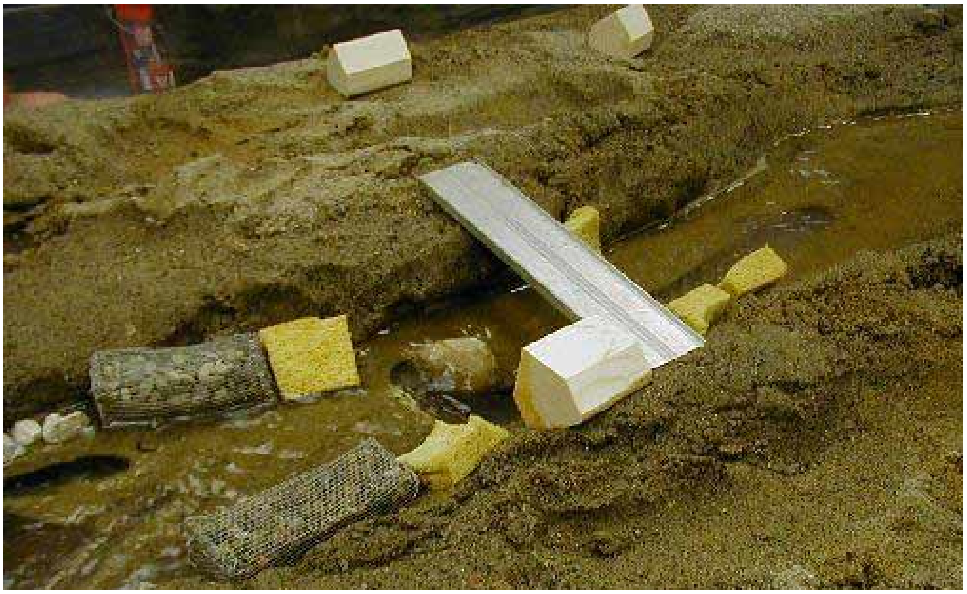
Figure 5: House collapsing into the river.

Sediment Erosion Box

The sediment erosion box is an 18" wide by 36" long by 3" deep wood box that can be filled with various materials and then set at various inclines. Rainfall is simulated in the experiment by using a watering can at the upper end of the box. The simulated rainfall run-off and eroded sediment are caught in glass jars at the end of the box (Figure 6). The amount of water and sediment collected in the glass jars can be measured to determine the amount of run-off, infiltration, and soil erosion. Students then repeat the procedure using different soil types, land cover, etc. Conclusions can be drawn on the effect of slope on erosion, effect of bed material and ground cover on erosion, water retention properties of the soil, and erosion control techniques.

Figure 6: Sediment erosion box.

There are several types of experiments that can be performed using two or more sediment erosion boxes. Additionally, there are numerous variations on those experiments. The amount of time, material, space, and quality (maturity, motivation, etc) of the student will dictate the number of experiments an individual would want to perform. The following series of five experiments indicates the range of experiments that can be performed using the sediment erosion boxes and what students should visualize from those experiments.

The first experiment investigates the effect of dry soil versus wet soil. If two boxes are set side by side, one containing wet sand or soil and the other containing dry sand or soil, students can see the effect the initial moisture content of the soil has on the run-off and erosion. Additionally, the infiltration of water on dry sand provides a good visualization of the process.

The second experiment investigates the effect of slope on erosion. The boxes are made with adjustable legs so various inclines can be established. Using the same soil type and roughly the same initial moisture content, the students can pour water on three or more inclines to see the drastic effect slope has on the amount of soil collected in the jars. Typically, doubling the slope of an erosion box filled with sand quadruples the amount of eroded material collected in the glass jar.

A third experiment investigates the effect of soil type on water retention, run-off and erosion. The boxes can be set with the same initial conditions (incline, soil amount, etc), but filled with different types of soil. For example, a good experiment would include typical topsoil, playground sand, and highly organic potting soil. These can be purchased at any gardening center for convenience. This experiment shows students that different soil types can retain different amounts of water. With some additional time, students can also relate the increased amount of organic matter to the increase of water retained.

A fourth experiment can be performed using different soil cover types. Three erosion control boxes can be set at the same incline with one box containing bare soil, one covered with grass (sod), and the third completely empty. After the same amount of water is added to the three boxes students can visualize the effect of ground cover on run-off and erosion. The box containing sod retains more water and the water that does run-off is much clearer than the box with bare soil. Additionally, less soil is eroded from the box containing sod. The final box contained no soil so nearly all of the water is collected in the jar. Students might initially be confused by this experiment but relating the third box to impermeable surfaces like parking lots and roofs is very easy. This might give the impression that the water running off from these surfaces is “clean” because no sediment is present in the jar. To avoid this misperception, a variation on this experiment is to place a little oil (even cooking oil) or road salt in the empty box to simulate pollutant run-off.

Finally, for the fifth experiment, any of these experiments can be performed with the v-notch partially or completely blocked with a sediment-retaining device. This experiment allows the introduction of erosion control devices with pieces of silt fence, geosynthetics, model gabions (mesh baskets filled with rock), etc used to retain some or all of the sediment while allowing the water to pass through.

The author has traditionally utilized these experiments in a more qualitative manner when in the K-12 environment. Students use rulers or beaker gradations to measure the “amount” of sediment in the glass jars to make comparisons between experiments (Figure 7). They also compare the volume of water captured in the jar with the amount of simulated rainfall to quantify run-off. Very few, if any, calculations are made. However, any of these experiments could be modified to be more quantitative.

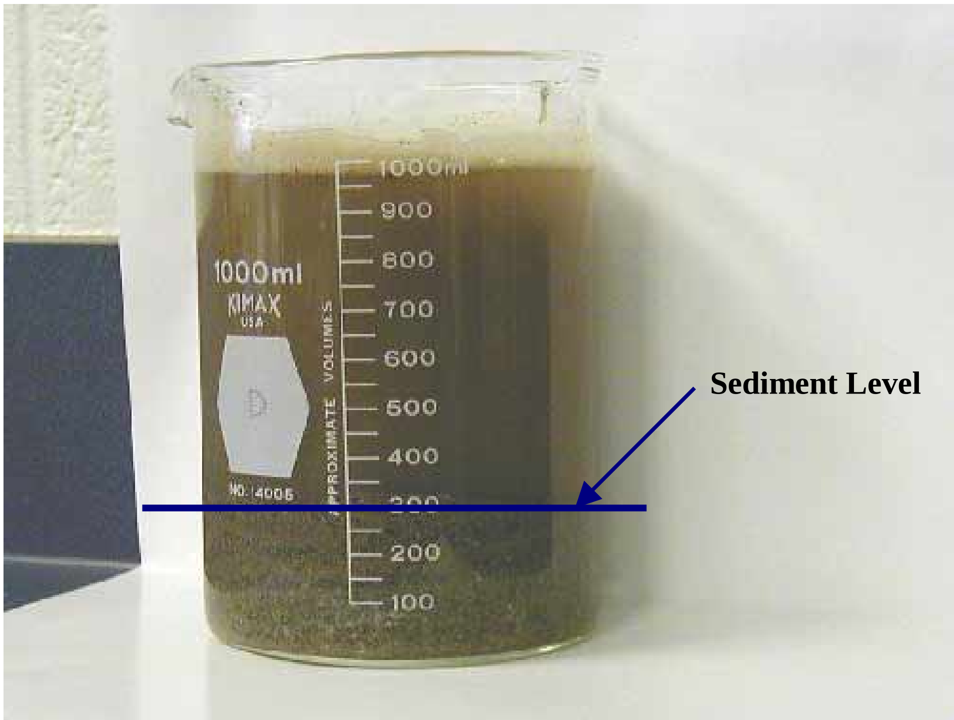

Figure 7: Collected run-off.

Summary

Since completion of the "Engineering the World" outreach program in the Spring of 2002, these experiments have occasionally been used in outreach events on Lawrence Tech's campus as well as in college classrooms. Through these formal and informal events, the experiments have proven to be a valuable tool for educating people about sediment erosion, river mechanics, and watershed processes. The biggest challenge associated with performing these experiments is maintaining student interest and determining appropriate levels of instruction. Students of all ages universally enjoy the river meander demonstration tables, but the level of learning can be categorized as directly proportional to maturity. Frequently students are not patient enough to watch the river adjust to changes implemented by them. Also, with 6 to 10 students using a table, experiments can disintegrate into a "free for all" unless activities are regulated and the instructor is actively involved (Figure 8). It is important for an instructor to lead individual shorter duration activities as part of the grander experiment. Additionally, the river tables can be viewed as "wet sand boxes" to younger or non-mature students. An instructor must not let the students "play", but instead, the students should "experiment." It was found that middle school students are very good at remembering the terminology associated with the tables (bank erosion, scour, gabions, etc) and predicting the occurrence of erosion. They can also comprehend the effect people have on watersheds and streams. However, detailed scientific information on river dynamics and watershed processes needs to be reserved for older students. The soil erosion boxes are less interactive and dramatic than the river tables and are subsequently less appealing to younger students. With middle school students, it is good to perform only a couple of experiments and not all of the activities described in this paper. The effect of slope on run-off and the effect of ground cover have proven to be the best received. Again, a more complete study of water run-off would be more appropriate for older students. As a general rule of thumb, the 3rd or 4th grade seems to be the lowest level in which genuine learning associated with these experiments occurs.

Figure 8: Students simultaneously adapting model.

General Recommendations for Outreach Programs

Challenges associated with any outreach program can include maintaining student interest, identifying appropriate level for instruction, and dealing with problematic students. A few general recommendations for outreach programs is to maintain flexibility in program organization, maintain hands-on emphasis for activities, and provide recognition to the students for their accomplishments. As would be expected, for younger children it was found that shorter activities were generally more successful. Shorter duration activities also present less risk of devoting too much time to an activity that was not at the appropriate level (either too simple or too difficult). Flexibility in program planning and delivery is also critical. It helps to be prepared for quick changes to program plans. If students are uninterested or not enthusiastic about a given activity, the lack of interest can linger and affect the atmosphere of the entire session. Sometimes the simplest activities can be the most successful at achieving student awareness of engineering principles. An instructor needs to be sure not to leave any students out of a planned activity (otherwise students might pursue potentially disruptive activities). However, it is also important to identify capable and highly interested students (so as to capture their enthusiasm and allow this to spread to the entire group). If a student or group of students is entirely unwilling to participate in the planned activities, discipline can become an issue. It is wise to have an authority figure present, such as their regular teacher. Another aid is providing recognition to the students for their accomplishments. Prizes or candy can be awarded for best designs, proper calculations, and correct answers to questions related to the subject matter. Students enjoy personal recognition and the pursuit of prizes can enhance the learning environment. However, it is important in some manner to recognize all students. An excellent option is personalized certificates distributed in an awards ceremony that indicates they completed the activity. These certificates were found to be very effective for elementary and middle school students as rewards for their learning achievements.