Using Century Old Research to Teach Fundamental Soil Science Concepts Today

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Introduction

Great advances in our understanding of soil processes have been made in the past century. What is now considered common, fundamental knowledge was once, however, cutting edge research reported in the literature of the day. It is this same fundamental knowledge that we strive to instill in students in undergraduate soil science classes and laboratories.

Putting this knowledge into the context of the historical literature can be beneficial in understanding the development of both the discipline of soil science in particular and the scientific method in general. Examples are drawn from the literature to illustrate both physical and chemical soil processes that students typically find challenging.

Laboratory exercises, incorporating readily accessible materials, can be designed in a range of complexities depending on the class level (first to fourth year). Data collection can be followed by analysis ranging from simple plotting to statistical comparison of replicated measurements on several different experimental materials.

Example 1: The Angle of Repose

The angle of repose illustrates the effects of pore water pressure and capillary action on the mechanical properties of soil. By making the connection of building sand castles on the beach, the effect of water content on the maximum attainable angle is easily visualized.

Recreating Webster's (1919) experiments and analysis neatly demonstrates the relationship between water content and the angle of repose attained in a sandy material. A natural extension of this work is to use materials of different grain (and pore) size distributions. Different versions of this experiment, ranging in complexity of both method and analysis, are performed in first through fourth year labs.

The Experiments:

- Dry sand is slowly poured onto a flat surface to form a conical heap with maximum slope angles (Fig. 1).
- Four slope angle measurements are made both for accuracy and to allow for statistical comparison, if required by the assignment. Multiple cones (and slope measurements) can be made to highlight the importance of experimental replication.
- Cones are constructed at incrementally increasing water contents. The four slope measurements on each cone tend to display greater variability as the cones become much more irregular in shape, reinforcing the importance of multiple measurements (Fig. 2).

Figure 1

Figure 2

The Results:

The data are entered in a spreadsheet, plotted and, if desired, statistical analysis and curve fitting is performed. In this case, both student derived data and data extracted from Webster's (1919) original paper are plotted and compared.

Regression analysis via a quadratic trend line generated by the spreadsheet produces both the equation of the lines and the associated R^2 values. Further analysis yields the maximum slope angles and their associated water contents (Fig. 3).

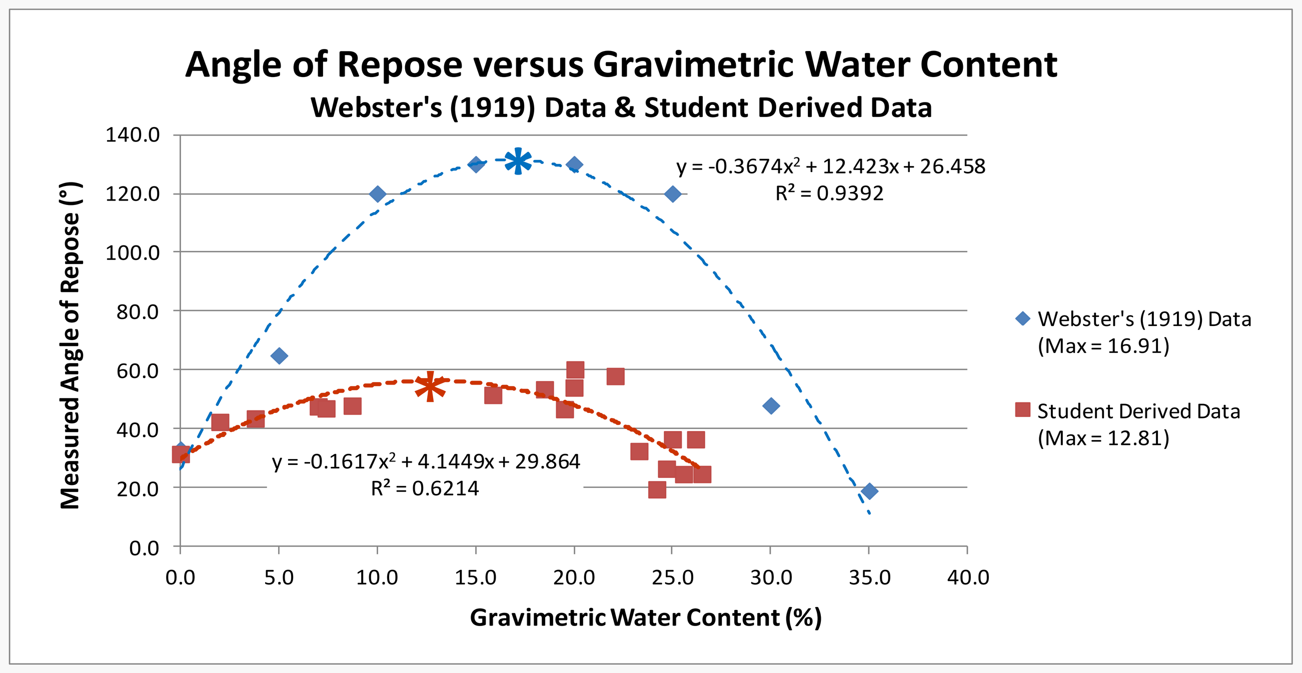

Figure 3

The Discussion & Write Up:

Discussion can center around the following:

- the effect of capillary action in generating negative pore water pressures at low water contents versus positive pore water pressure at higher water contents and the effect on slope angle
- the importance of replication during experimentation in examining the range of measured slope angles and allowing statistical analysis of derived data
- the importance of experimental design in comparing the maximum slope angles reported by Webster (1919) versus those attained by the students (e.g., Webster's angles >90°).

Example 2: Osmosis in Soils

Osmosis tends to be a difficult process for students to understand as it appears to be the opposite of the dilution process they would expect. Internet searches on osmosis yield scores of biological examples of cell walls acting as semi-permeable membranes, but these are not intuitively transferable to the same process in soil.

Although a component of the total potential of pure water in the soil (together with pressure potential, ψ_p, and gravitational potential, ψ_g), the osmotic potential, ψ_o, is often neglected in soil physics. However, in the case of moist clay soils, ψ_o may not be uniform within the soil system but rather decrease from the outside soil solution towards the clay mineral surfaces. Similarly, a gas phase in the soil allows water movement in the vapour phase while solutes remain trapped behind the gas barrier resulting in increased solute concentrations and a non-uniform ψ_o.

The experiments of Lynde (1912), Lynde and Bates (1912) and Lynde and Dupré (1915) concisely demonstrate how water flows through soil in response to a solution concentration gradient. A duplication of these experiments is currently underway in a fourth year soil physics class so, although no student data is provided, the experimental procedure will be outlined.

The Experiments:

- Tubes 1 cm in inside diameter (I.D.) and 15 cm in length are covered at the bottom with a fine wire mesh and cotton cloth.
- Clay soil sterilized by boiling in distilled water is added to the tubes and centrifuged.
- The soil solution was replaced with a 0.6M K_2SO_4 solution and the tube capped with a rubber stopper and a bent tube of 1.5 mm I.D.
- Filled tubes are placed in wide mouthed bottles filled with distilled water as in Lynde's (1912) Figure 2 (here as Fig. 4).

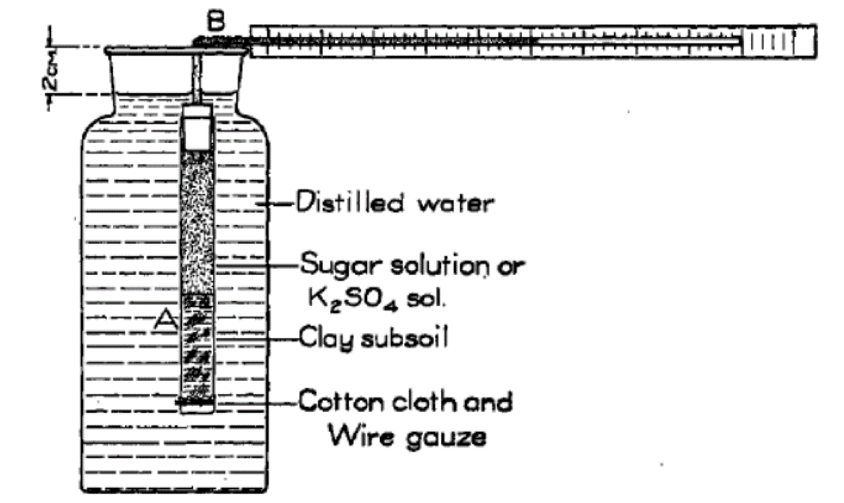

Fig. 2.—Modification of Pfeffer's apparatus. Clay subsoil acts as the semi-permeable membrane.

Figure 4

The Results:

Experiments are currently underway in an effort to reproduce the data from Lynde (1912) as shown below (Fig. 5).

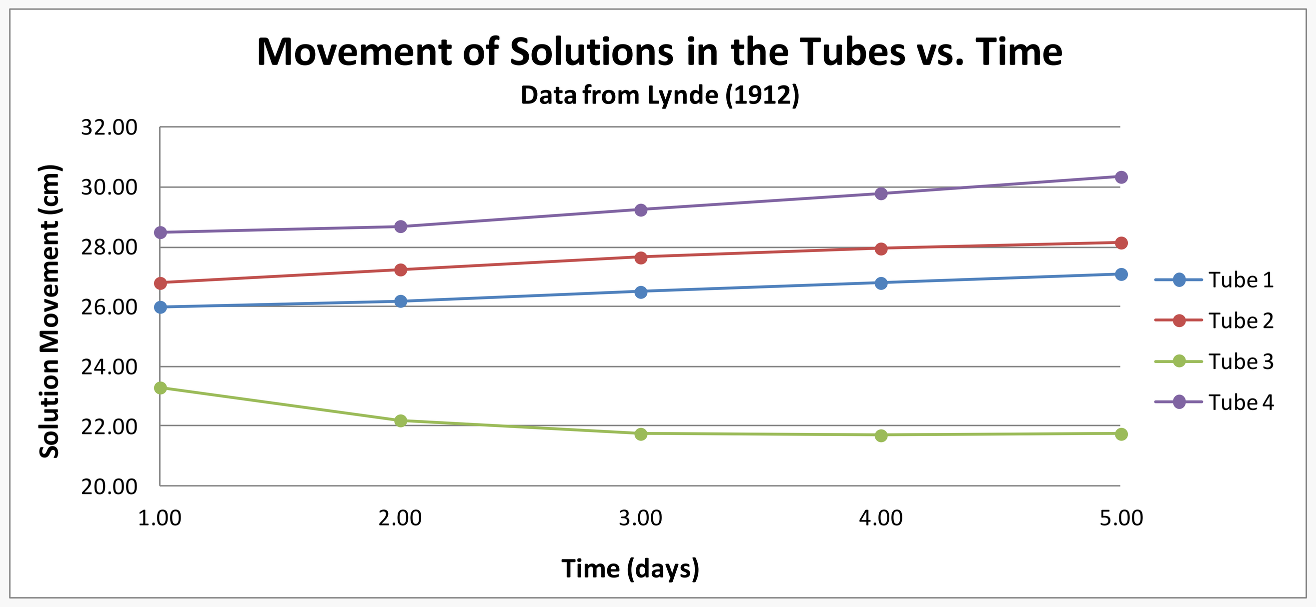

Figure 5

The Discussion & Write Up:

The written portion of this lab will involve the students explaining the results in the context of a theoretical outline of osmosis with the soil acting as the semi-permeable membrane.

Further exercises will involve the duplication of the experiments of Lynde and Bates (1912) to confirm the following:

- whether the efficiency of the soil as a semi-permeable membrane increases with the thicknesses of soil in the tubes
- whether osmotic effects increase in proportion to the temperature of the system.

Conclusions

Fundamental concepts and processes are effectively taught through the duplication of experiments performed a century ago. Advantages of this approach include the following:

- equipment requirements tend to be quite modest by today's standards.
- the time frames over which they are performed fit conveniently within the laboratory schedule of most undergraduate courses.
- the discussion of laboratory derived data in the context of the original experiments aids the understanding of both the discipline of soil science in particular and the scientific method in general.
- these fundamental experiments are easily expandable to include more complex data analysis and inclusion of additional experimental factors according to the academic level of the students.

References

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Acknowledgements

- Brock University GEOG 2P11 students for providing data:
  Mackenzie Ceci, Aaron David, Taylor Ervick, Chris Garofalo, Teigan Mallory, Martina Tepavcevic, Brent Thorne
- Chris Garofalo for supplying Figure 2
- Loris Gasparotto, Geography Department Cartographer, for graphic work

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