APPLICATION OF EDUCATIONAL AND ENGINEERING RESEARCH TO CLASSROOM TEACHING

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Abstract *— The education of engineering undergraduate and graduate students for the 21st century will be a challenge for engineering faculty members. This is due to students from diversified background, various interdisciplinary fields of study, and different resources that are available to the teachers to provide a variety of learning experiences. Engineering faculty in general devote a major part of their time to research in their individual disciplines and spend a very limited time to prepare for teaching. There is a vast amount of research carried out in the field of education. Most of the engineering teachers are not formally trained to teach. Thus they may not be conscious of this research that can provide enormous help in organizing their teaching activities. This paper discusses the synergistic use of some research contributions from the field of education and their application in classroom teaching and research. Selective examples are provided to illustrate the discussed concepts and procedures.*

Index Terms ¾ Concept maps, learning outcomes, research experience, use of taxonomy, Vee diagrams.

INTRODUCTION

Excellence in teaching does not come easily. The teacher is basically a manager or facilitator of the learning experiences of the students. Faculty members often must be proficient at both teaching and conducting research in their specialized areas. A faculty member plays two roles, as a teacher and as a researcher. These roles however, involve similar activities and skill. For example the choice of objectives of a course or research, scope and content of the course or research project, development of learning or research experience, evaluation of student learning or findings of a research experiment by an appropriate evaluation tool etc., are common in both the roles. The key to effective teaching and research are planning, organization and implementation, evaluation, and modification. Engineering teachers are not formally trained to teach. Many have not had exposure to educational psychology, curriculum development, teaching and evaluation methods. Selected research from the field of education that the authors have found useful and have applied to engineering teaching in their classroom are summarized in this paper with examples.

LEVELS OF LEARNING OUTCOME

A systematic plan for teaching of any subject normally includes the selection of learning outcomes, the choice of specific methods and media for providing instruction, and selection of a specific method of evaluation. As teachers we are interested in the learning outcomes of our students. It is known that students have different abilities, interests and expectations. Learning is the changes in student's capacity for improved performance as a result of their learning experience. Many times teachers insist that the student must learn what they see as the "necessary" coverage of a subject. The main reason for this may be that they assume their own range of knowledge as the norm for their students. The result is often undue pressure on the student. The teachers set the pace of learning by choosing the amount of material and time for its assimilation. Some students may not be able to learn quickly as intended by the teacher. They need more time to relate the new information to their previous knowledge. Thus learning takes time. Hence it may not be desirable to include and "cover" every thing as seen "necessary" by the teacher. The authors have tried to "uncover" the subject matter by emphasizing important concepts and applications. Once the students understand these salient aspects, we have provided them with a frame work that helps them to learn more on their own.

In deciding what is "important" or "necessary" to be covered, the learning outcomes or objectives aid the teacher. A learning outcome or objective is a statement of an intended result of instruction in specific terms. These help to select teaching methods and media, to create a learning environment in which the objectives can be achieved, and to ensure proper evaluation. The teacher will not know if the students have achieved an objective unless he is sure of that objective. Also, without explicit objective, the students will not know what is expected of them and hence the objectives are to be shared with students.

There are many approaches suggested by several researchers in education regarding the instructional outcomes [1,2]. Bloom's taxonomy of educational objectives has been widely accepted and used by educators. A taxonomy is a hierarchical classification system for describing and sequencing learning outcomes. As per Bloom's system there are six major outcomes (or levels) of learning in the cognitive domain. Most teaching involves some combination of the six different categories. They are briefly defined, beginning from the lowest level in the following paragraph.

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Recall involves recognition and remembering information, facts, theories, and principles. Comprehension is to understand and be able to explain specific concepts in one's own words and images rather than as memorized definitions of others. Application is using what one has learned in new and concrete situations. Analysis is thinking about what one has learned in an active way and breaking it down into its component parts. Synthesis is combining information from many different sources into a unified whole with new ideas or insights about a topic. Evaluation is using critically what one has learned so far. It is to be noted that success at the initial levels is necessary for success at higher levels. This taxonomy also helps teachers in their teaching. As teachers we have to remember and understand various concepts of the subject and use them in our classroom. We need to break the subject down into its several parts, show the relationships between them, and synthesize or put it together again. We need to evaluate or judge which part of the subject will be most useful to the student and how well we can convey the required information. Figure 1 presents an example of learning objectives (abridged version) for a basic course in geotechnical engineering. This list is given to the students on the first day of the class meeting so that they know what to expect from the course and also to help them in organizing their study. The students evaluate the teacher at the end of the semester and use the same list to judge how well the teacher has performed in enabling them to learn the material as stated by the objectives. This serves as a feedback for the teacher to improve the course and teaching, if necessary. There are also taxonomies available in affective and psychomotor domain and for problem solving. Some of these are also used selectively in laboratory, tutorials and when students work on research projects. These are not discussed in this paper, but details are available in [1].

CONCEPT MAPS

Over many years the authors have tried to formulate an integrated approach for teaching. This approach is based on Ausubel's theory of meaningful learning, Novak's theory of conceptual education, and Gowin's Vee heuristic for the structure of knowledge [3]. The main concept in Ausubel's theory is meaningful learning. To learn meaningfully, one must choose to relate new information to relevant concepts one already knows. Meaningful learning is a continuous process wherein new concepts gain greater meaning as new relationships are acquired. Thus concepts are never "completely learned" but are always relearned and modified. Learning is not an additive process, with new learning simply piling up on top existing knowledge, but is an active, dynamic process. The mental structures that store and organize learned materials can be pictured as a multi-dimensional map of interrelated ideas, with innumerable connections among stored material. In the case of people who know something of a subject, like the teacher, new information is quickly grasped in a usable form because the connections to existing knowledge

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SELECTED COURSE OBJECTIVES

1. Given the results of particle size analysis and Atterberg Limit tests on a soil sample, the students will be able to correctly classify the soil as per AASHTO and USC system with the help of appropriate classification charts supplied to them.

2. Given a flow net, the students will be able to compute correctly the quantity of seepage, the hydraulic gradient at any point and the uplift pressure exerted on the hydraulic structure.

3. Given a soil profile the students will be able to determine correctly the total pressure, pore pressure and effective stress at any point.

4. Given a soil profile, the geometry of loaded area and the type of externally applied load. The students will be able to correctly compute the stress induced at any depth in the soil mass using the stress distribution charts or tables provided to them.

5. The results of a consolidation test on a soil sample are given. The students will be able to: (a) determine the compression index and coefficient of consolidation for the soil (either by log time or square root of time method) correctly for a given stress range; (b) compute correctly the settlement due to a proposed shallow foundation (the stress distribution charts/tables are provided) or a fill, and (c) compute correctly the time rate of settlement for any given percent consolidation.

6. Given the results of a direct shear or a triaxial test the students will be able to correctly draw the Mohr-Coulomb failure envelope and determine the shear parameters.

7. Given the geometry of the slope and the relevant soil properties, the students will be able to correctly compute the factor of safety by the ordinary method of slices or simplified Bishop's method.

8. Given the data from a set of soil borings the students will be able to develop a soil profile and estimate the relevant properties of the soil from standard penetration or cone penetration tests.

FIGURE 1
LIST OF SELECTED COURSE OBJECTIVES

are numerous. The learning of a novice such as a student is slow because connections between new information and existing mental structure are very limited [4].

The learning of several parallel concepts can be facilitated by the use of "concept maps". The Concept maps are somewhat analogous to road maps in that they show relationships, not between places, but between ideas [3,5]. They are intended to represent meaningful relationships between several concepts connected by a linking word. They help to make clear to both teachers and students the small number of key ideas they must focus on for any specific learning task. The concept maps are hierarchical; that is, the more general, more inclusive concepts are at the top of the map, with progressively more specific, less inclusive concepts arranged below them. They visually emphasize both hierarchical relationships between concepts and cross-links with other associated concepts. They do not specify the exact sequence for presentation. However, they do show hierarchies of ideas that suggest psychologically valid sequence.

Concept maps can be used to determine pathways for organizing meanings and for separating significant topics from a set of topics. The concept maps can be drawn as global concept map showing the major areas to be considered in a semester. There can be a specific concept map showing the details of a specific topic of two or three weeks of class. A detailed concept map for one or two sessions of instruction is another possibility. Figure 2 shows a specific concept map for the topic of settlement analysis in geotechnical engineering.

THE VEE DIAGRAM

The "Vee" is a heuristic device invented by Gowin, [3] and it helps teachers and students to understand the structure of knowledge. At the point of the Vee are events or objects. The left side of the Vee represents the conceptual (thinking) aspects. The right side of the Vee represents the methodological (action or doing) aspects. The Vee heuristic used with explicit concept maps helps the students to see the interplay between what they already know and the new knowledge they are attempting to understand. This is useful in classroom teaching. As many teachers are aware, students make many computations and draw graphs. Many students do not think about the appropriate concept or principle to question or understand as to why they are undertaking those activities. As an example Figure 3 shows a Vee diagram prepared for the event, primary consolidation, as a part of the topic of settlement analysis. On the left side of the Vee are shown the concepts that the students must know that are relevant to the event i.e., consolidation of a saturated sample. Above the concepts, are principles and theories that are needed to understand the present material. Principles are important relationships between two or more concepts. Theories are much broader and usually involve several concepts and principles. At each level one can infer the interplay between the left and the right side of the Vee .

The focus question leads us to focus or concentrate on particular aspects of the event or object we are trying to observe or learn. The focus question in this example is "how to find the amount and rate of settlement of a structure due to primary consolidation?" We use concepts we know to observe the event and make some form of records of our observations. The kind of records that are made is guided by the focus question. The records to be made in this case are shown on the right side of the Vee diagram. These records are to be transformed into a suitable form that helps to answer the focus question. At this stage the concepts and principles we know influences the way in which we transform data. Once the transformed data is available, we apply concepts and principles we already know and deduce a 'knowledge claim', the answer to our focus question, that is the formulation of a procedure for computation of amount and rate of settlement.

The advantage with the Vee diagram is that selection of content and its sequential order in teaching can be done easily. At each step there is interplay between the left and right side of the Vee. The method for drawing the Vee diagram is explained in [3]. The authors do not claim that the concept map or the Vee diagram shown is perfect. However they are impressed with the scope of these tools and their use in classroom teaching.

CHOICE OF METHODS AND MEDIA

Once the level of outcome is decided, the next step is to select methods and media that provide the relevant learning experience to achieve the intended instructional outcome. This obviously depends on the subject matter, desired learning outcomes, available resources, and the mastery of prerequisites by learners. In the choice of instructional method and media the teacher has different varieties to choose from. To specify exactly which method or media gives best results in a given learning situation is difficult and hence calls for experience and judgement of the teacher. This is especially so in the levels three to six of Bloom's taxonomy. In the first three levels the students have to know specific nomenclature, facts, theories, etc. These can be instructed by lecture/tutorial method and assessed by conventional paper and pencil tests.

For teaching at higher levels of Bloom's taxonomy namely analysis, synthesis, and evaluation, instruction can be facilitated by teacher's role as a researcher with his or her students. This role will be very helpful and natural here. Students may be asked to carry out research for further exploration of some of the topics of study. This additional research by students can supplement the lecture in a classroom. The research by students and teaching by the teacher are thus combined synergistically to enhance learning. The varieties of learning experiences such as experimentation, numerical modeling, collection and evaluation of data, writing reports, etc. can be provided in this manner.

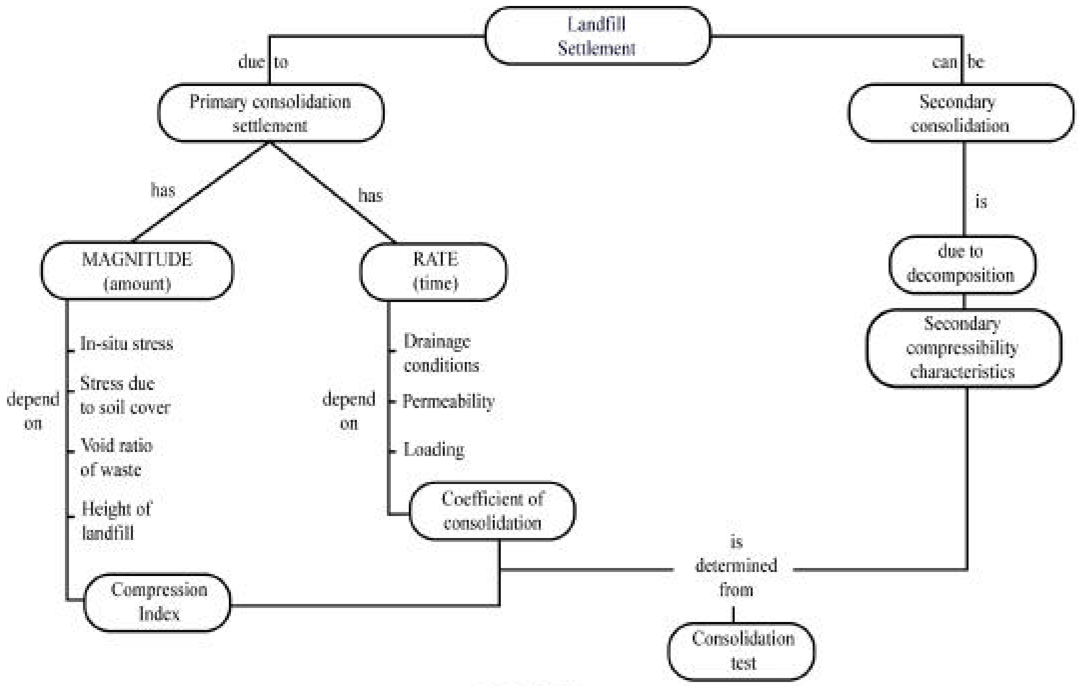

FIGURE. 2
SPECIFIC CONCEPT MAP FOR LANDFILL SETTLEMENT ANALYSIS

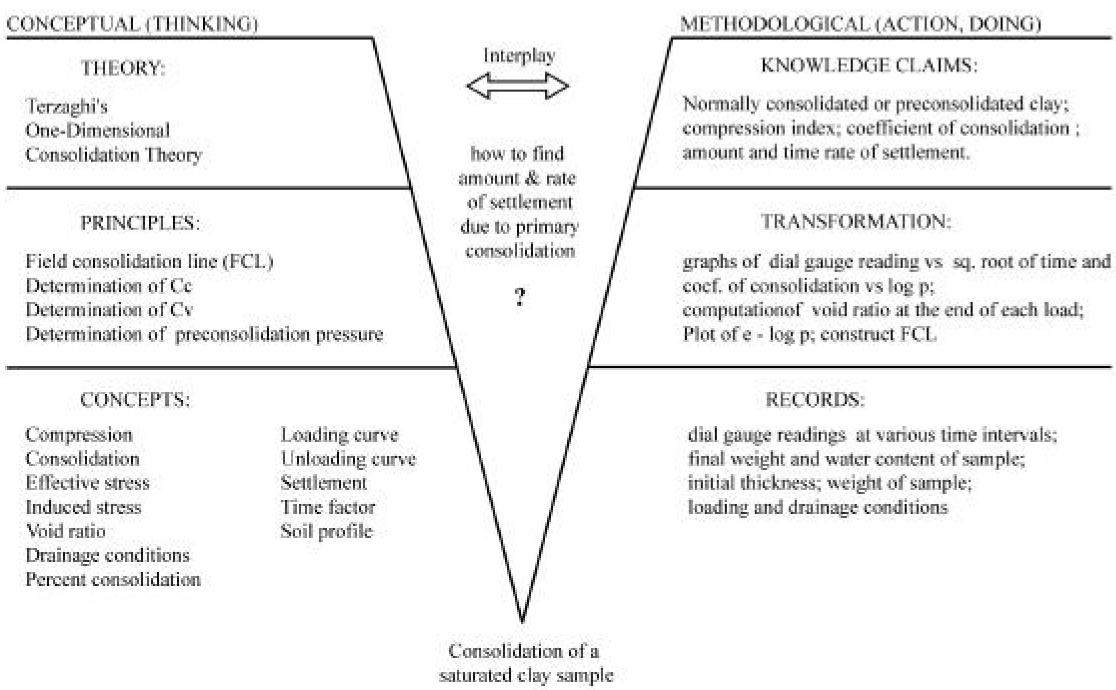

FIGURE. 3
A VEE DIAGRAM FOR PRIMARY CONSOLIDATION

RESEARCH BY STUDENTS AS A LEARNING EXPERIENCE

In any undergraduate course there are certain topics that lend themselves to be the subject of interesting research projects. In such a course several student groups can be assigned different research topics. Parametric studies, selection of best method of analysis and design procedures, statistical evaluation of experimental or numerical data etc., are useful research tools and can be taught by asking the students to do research on these aspects. The teacher provides guidance regarding reference materials, research methodology, and calibration of experimental and numerical data, analysis and presentation of results. These research projects provides students experience in research methodology. It extends and broadens their understanding of a topic better than the textbook presentation by the teacher. Thus it also provides a learning experience. Further it trains them in the use of resource materials in the library, in the analysis and evaluation of numerical or experimental data, writing of technical reports, and making technical presentation which enhances their oral communication skills. One can infer a parallel situation between classroom teaching and research methodology. Similar to learning outcomes in classroom setting, one will have measurable goals with respect to a research project. In classroom teaching his role is a teacher whereas in carrying out research he will serve as researcher and facilitator for his students. Many of the activities and techniques he uses in the classroom are used in research project, though in a different setting like a laboratory and to a different degree. The authors have tried this approach in several of their courses in geotechnical engineering, foundation engineering, and geo-environmental technology. Selected examples are provided in the following sections.

EXAMPLE 1. RATIONAL PROCEDURE FOR DESIGN OF SHALLOW FOUNDATIONS

As mentioned earlier, analysis in Bloom's taxonomy requires that students break down a topic into its components and understand the relationship between the various components. They also need to examine the assumptions made in various methods and their validity. An example of this category in geotechnical engineering is the design of shallow foundations.

The settlement and bearing capacity of shallow foundations are two distinct topics that are taught in undergraduate courses. Many methods have been proposed for the evaluation of bearing capacity. This is basically due to the shape of the failure surface assumed in the theory. Cohesionless soils usually have good bearing capacity (unless their density is very loose) and settlement controls the design of foundations. In teaching this topic, the teacher can summarize the research in this area in the classroom. Alternatively the students may be required to research for further exploration of this topic. Many methods of settlement analyses have been proposed. These different procedures are reviewed, and applied to selective case histories to evaluate the predictability of the methods. The main objective is to compare and evaluate several methods of determining the bearing capacity and settlement of shallow foundations. Then design charts are to be developed by combining rationally the predicted bearing capacity and settlement of a foundation. This example then has some overlapping with synthesis in Bloom's taxonomy.

The students are encouraged to develop computer programs or spread sheets for this purpose. This consists of three main modules. One module computes the bearing capacity by four methods, as per Balla, Hansen/ Vesic, Meyerhof, and Terzaghi [6,7,8]. The other module computes the settlement of foundations by four procedures, as per Alpan, D'Appolonia, Meyerhof, and Schmertmann. The third module is a graphics routine to develop necessary plots. The range of sizes of the footing to be designed is specified. The bearing capacity of each footing is computed by each of the four methods. Then the settlement is computed by all four methods for each footing, assuming each computed bearing capacity in turn to be the applied loading on the foundation. Thus for each footing, bearing capacity and settlement is determined by all of the methods. This data is used in the preparation of design charts by rationally combining the settlement and bearing capacity. By applying this procedure to several field cases the comparison of results from different methods with that of field values are made. The students discuss the results in class as to their variability and/or conformity in classroom and write a report.

EXAMPLE 2. STABILITY OF EARTH SLOPES

As per Blooms' taxonomy "synthesis" means bringing ideas together to form a new idea, going beyond what is known, or developing a procedure putting all relevant ideas into a coherent form. Similarly the term 'evaluation' involves all the previous levels. The students must show the ability to examine basic assumptions, analyze, compare and contrast several approaches, and bring out inconsistencies in any method or procedure. The stability of earth slopes is one of the topics taught in undergraduate geotechnical engineering. A common method that is learned by students is the ordinary method of slices. Other methods are often times omitted or cursorily explained. The examination of several methods of determining the factor of safety for a given geometry of slope or to find critical circle for a given slope is a good research topic at undergraduate level. To compare several methods of analyses and apply it to a field case, belong to the level of "evaluation" (to some extent overlaps with "synthesis") in Bloom's taxonomy.

The teacher explains the basic concepts of the forces acting on an individual slice and how they lead to statically determinate and indeterminate cases of analysis. Then the appropriate expressions for factor of safety are reviewed and procedure for computing the factor of safety is outlined. Then a numerical example (with known failure surface and with three or four slices at most) is solved by hand. Then the students are assigned to research this topic further. The use and capabilities of the several available computer programs are explained. The authors have used different computer programs, in their classrooms for instructional purposes. The capabilities and limitations of these are available in [6,9,10]. A couple of field cases are selected and students are asked to investigate the slope failure. The soil profile and soil properties are given. The center of failure circle and the radius, and factors of safety computed by various methods are to be determined. The students make a comparative analysis, discuss their results, make an oral presentation and write a report.

COMMENTS ON EVALUATION OF STUDENT LEARNING

In order to assess whether or not students have learned the material, the assessment tools like tests, quizzes, or projects are to be designed properly. The important factor is that students are to be assessed at appropriate levels of outcome. Many times some of us teach to achieve competence at a particular level of outcome but test them at a different level. It is not appropriate. If we teach students with the objective to learn at application level then it is appropriate that we test them at application level. This will then ensure that students have learned the material included in two lower levels. It is not fair to assess them at higher level like analysis or synthesis because we did not teach them to attain competence at those levels. The hierarchy of levels of outcome is to be maintained to promote learning and reduce frustration of students. Thus the importance of utmost care in the design of test items, taking into consideration the learning objectives we desired, cannot be overemphasized. For higher levels of Bloom's taxonomy, commonly used testing tools by the authors include development of design charts, design and conducting a parametric study, analysis and critique of case studies. All of these include a detailed description of properties and parameters varied, appropriate graphs generated, use of design charts or graphs developed with examples, and discussion of the results of the study.

If the method of teaching and assessment of learning adopted does not produce intended results then they are to be modified. This may include taking a fresh look at objectives, clarification of basic concepts, extra reading material, additional illustrative examples, gradual progression from one level to other, program modification if necessary. The ultimate aim must be to make the learning process easier and enjoyable. At University of New Orleans, a peer review procedure is in place to help teachers to improve their teaching if necessary, make it more effective and an enjoyable experience for the teacher.

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REFERENCES

[1] Wankat, P.C., and Oreovicz, F.S., "Teaching Engineering", McGraw-Hill Inc., New York, 1993, 370 pages.

[2] Gross, R. "Peak Learning", J.P.Tarcher Inc., Los Angeles, 1991, 280 pages.

[3] Novak, J.D., and Gowin, D.B., "Learning How to Learn", Cambridge University Press, New York, 1989, 280 pages.

[4] Cross, K.P., "Effective College Teaching", *American Society For Engineering Education – PRISM,*, October 1991, pp.27-29

[5] Wycoff, J., "Mindmapping", Berkeley Books, New York, 1991, 173 pages.

[6] Bowles, J.E., "Analytical and Computer Methods in Foundation Engineering", McGraw-Hill Inc., New York, 1974, 519 pages.

[7] Das, B.M., "Principles of Foundation Engineering", PWS Kent Publishing Company, Boston, 1999, 862 pages.

[8] Nataraj, M.S., McManis, K.L, and Bijhouwer, P., "Use of Personal Computers in Geotechnical Engineering", *Proceedings of the Ninth National Conference on Microcomputers in Civil Engineering*, Orlando, Florida, 1991, pp.74-78

[9] Nataraj, M.S., and McManis, K.L., "Computer Assisted Learning and Teaching of Geotechnical Engineering", *Proceedings of the Second Canadian Conference on Computing in Civil Engineering,* Ottawa, Canada, 1992, pp.709-719

[10] Nataraj, M.S., and McManis, K.L, "Comparison of Three Slope Stability Programs", *Proceedings of the Tenth National Conference on Microcomputers in Civil Engineering,* Orlando, Florida, 1992, pp.45-49