COACHING STUDENTS TOWARD BETTER LEARNING--A WORKSHOP APPROACH

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Introduction

In this paper, we describe an out-of-class, voluntary, weekly series of workshops that we offer to students who want help in improving their ability to learn and demonstrate learning in the engineering classroom. Weekly sessions are held, where students are given experiences in the development of a range of learning skills and problem solving skills that have been described as essential for performance on exams that test with problem solving [1-3]. The exercises engage the students in different cognitive processes, ways of thinking, and problem solving processes and demonstrate the complexity of expertise and the importance of the development of thinking skills while

Rather than the behavioral approach that would typically include topics such as time management, taking notes, motivation, and effort, the workshops follow a cognitive approach. We focus on the cognitive skills used by successful learners, basing the workshops on taxonomies of problem solving and cognition such as the Dean and Plants taxonomy of problem solving [1], Bloom's taxonomy in the cognitive domain [2], respectively, as well as other processes such as brainstorming, visualization, and organizing information. There are three objectives of the workshop series: (1) to demonstrate and disclose some of the specific, learning skills that are essential for superior performance in engineering problem solving, (2) to give students practice in acquiring the skills, and (3) to make students aware that accomplished learning requires a broader range of learning processes than just learning the solutions to homework problems.

Background Information

The workshop series was begun under the general premise that some students will benefit from a formal coaching program in learning skills, just as music students and athletes benefit from coaching in the music skills and sport skills, respectively. Through a fifteen year involvement in coaching students on an individual basis using models of learning, cognition, motivation, and individual differences, the authors have developed a series of 30-minute workshop sessions that teach students some fundamental skills that are essential for high performance on exams in a particular course. While the workshop exercises can be adapted for different courses, the authors have found it more convenient to limit participation to students in a targeted course so that applications that are common knowledge to all can be used to illustrate the principles and basic ideas.

The workshop covers process skills that instructors usually take for granted and superior students clearly possess. Just as in music and sports, which require competence in the skills of the activity, accomplished problem solvers are armed with a collection of well learned skills that facilitate learning and the demonstration of learning. Lesser accomplished learners, on the other hand, may be limited only by deficiencies in learning skills and not by limitations of intelligence as measured by cognitive measures such as IQ and the SAT exams.

The process skills that are introduced to the students who attend the workshop were developed based on relevant models from several publications on learning and problem solving. Three of the models that have served us best are the Dean and Plants taxonomy of problem solving [1] which is described in Appendix I, Bloom's Taxonomy in the cognitive domain [2] which is described in Appendix 2, and a model of puzzle solving [3] that describes how solving complex problems requires the use of insight and to be able to "go outside the box." Through careful observations of the works of students in the context of these models, exercises were developed to raise student awareness that learning is a complex composition of intellectual processes.

The General Coaching Concept Behind the Workshop Series

In order to achieve our goals of helping students improve learning through coaching, we used the following principle from coaching in a sport: ***"Whenever you see a weakness in your team's performance or in the performance of an individual, design a drill that will correct it."*** However, since thinking skills are not clearly observable to the novice, unlike the highly visible skills associated with sport, we find that we must first work on disclosing them before students can work on them. We fully realize that developing expertise in new learning skills requires repeated use over long periods of time. Thus the effectiveness of the workshops is limited to helping students develop an awareness of the broader implications of learning skills rather than to becoming skilled problem solvers.

The Specific Workshop Exercises

The exercises described in this paper may or may not be suitable for your students based on where they are in the maturity and development of their learning skills. However, the coaching principle quoted above may still be of some use to you, as might the structure of the coaching process. Five exercises are presented in detail in the following structure: *Indicators of Need, Possible Causes, Lessons to be Learned, Tasks*. The four remaining exercises are described more briefly.

<u>Exercise 1</u>: <u>Learning Things Cold</u>

This exercise is usually introduced first, because it seems to have the biggest pay-off. In engineering exams given by many instructors, time is a valuable resource. This is indicated by students reporting that the exam was too long, even though several students may have successfully complete the exam with ample time to spare. Our interviews with students have indicated to us that one of the major reasons for students running out of time is the amount of time they require to recall even the most basic propositions, even when crib sheets are allowed.

Thus we use the following workshop exercise to teach students what it means to really know the material.

Exercise 1: Knowing Things Cold	
Indicators of Need	• Students say the exam was too long when it was not. • Students say they "knew the material" but could not finish.
Possible Causes (non-trivial)	• Students did not do enough mental rehearsal to put information into short term or long term memory, thus needing extra time for recall. • They were told that they should not memorize details, and they translated this to not needing to remember anything.
Lessons to be Learned	• Accomplished athletes, accomplished musicians, and chess masters execute basic skills without thinking. Experts call on thinking only when thinking is required. • Learning is not a spectator sport, and it requires effort. • Use mental rehearsal and repetition to know "cold" what can be known "cold," saving valuable time for the difficulty thinking required to solve the problems. • When information is known well it can be linked with other information to solve complex problems. • Practice, practice, practice!
Tasks	• Ask students to make a list or draw a cognitive map of everything they know about a specific topic. • Ask students to write the step-by-step rules for executing a particular procedure.

Exercise 2: Learning a Procedure

A *procedure* is a step-by-step set of manipulations, numerical or symbolic, that lead to a result. While some students may attempt to turn every experience into a procedure to their detriment, we would venture a guess that valued procedures can be found in all engineering disciplines and science disciplines. However, our experience has shown us that there are students who have ignored learning basic procedures and must thus use valuable time on exams to re-derive them.

Exercise 2: Learning a Procedure	
Indicators of Need	• Students could not recall and execute a computational procedure. • Students tried to solve a simple procedure-based problem with time consuming general principles.
Possible Causes (non-trivial)	• Students think of knowledge and information as an only in general terms and are not aware of procedures. • Students instead try to develop all solutions from basic principles.
Lessons to be Learned	• Engineering exams often contain straight-forward problems which only call for the execution of a basic procedure.
Task	• Ask students to execute a basic procedure that should be well known. • Ask students to write the steps in a frequently used procedure.

Exercise 3: Selecting an Appropriate Strategy

Exam problems often can be solved by several different approaches, or strategies. In the problem solving taxonomy by Dean and Plants [1] (see Appendix I), the selection of a strategy is one level higher than the execution of a routine, or procedure, and two levels below the generation of a new routine. Some students see learning as the execution of routines and do not advance to the next level. Since most exams are timed, we teach students to be mindful of strategies instead of depending solely on routines or general principles.

Exercise 3: Selecting an Appropriate Strategy	
Indicators of need	• Students did not know how to approach a familiar problem. • Students chose less efficient approaches from among several applicable approaches.
Possible Causes (non-trivial)	• Students view knowledge and information as an amorphous whole and do not think in terms of strategies. • Students become satisfied when they have learned one way to solve a problem.
Lessons to be Learned	• Successful problem solvers, like successful chess players and athletes, are well armed with a collection of useful strategies.
Tasks	• Ask students to list several different ways to approach a particular problem. • Ask students to select the most efficient method to approach a particular problem.

Exercise 4: The Inverted Problem

Engineering faculty often talk about the inverted problem, where an exam problem is written in the reverse direction compared with a homework problem on the same topic. A homework problem in analysis that is re-written as a design problem is a good example. Another example is the homework problem that is re-written in such a way so that what was once the answer is now the unknown and visa versa. Such problems usually require the application of basic principles or at least a better understanding of the material.

Exercise 4: Inverted Problems	
Indicators of Need	• Students demonstrate difficulties solving problems that some faculty call "inverted," i.e., the knowns and unknowns are switched. • Students say that the exam was full of trick questions.
Possible Causes	• Students convert problem solutions to templates. • Students are not aware that learning takes place above the level of computational *routines.*
Lessons to be Learned	• Learning may involve material at different cognitive levels. • Knowns and unknowns can be exchanged in an old problem, thus giving it the appearance of a totally different problem.
Tasks	• Ask students to solve a homework problem that has been re-written it so that what was the unknown is now the given, and visa versa. • Ask student to articulate the relationship between the two problems. • Ask students to take a solved homework problem and design an inverted problem.

Exercise 5: Variations on a Problem

Through interviews with students, we have learned that some students view learning as the assimilation of known solutions to problems and that the problems assigned as homework exercises are invariant, i.e., that they are the body of knowledge to be learned. To help students make the leap from memorizing the solutions of solved problems to solving new problems, we introduce them to the concept of *Variations on a Problem*.

Exercise 5: Variations on a Problem	
Indicators of Need	• Students try to force an exam problem into looking just like a homework problem. • Students say that the exam was unfair because the problems were different than the homework problems.
Possible Causes	• Students view knowledge as solved homework problems. • Students' view of learning is at the *Routines* level (the lowest level) in the Dean and Plants taxonomy on problem solving [2] and at Bloom's second level of cognitive development [2], *Knowledge of ways and means of dealing with specifics*.
Lessons to be Learned	• Many instructor will write at least one problem that is "not just like the homework." • Knowledge extends beyond solutions to problems to basic principles. • Understanding basic principles helps solve new problems.
Tasks	• Design a set of problems that are variations of a solved homework problem. • Ask students take a solved homework problem and write several variations.

Additional Exercises

In an effort to stay within reasonable page limits, the remaining exercises in the current workshop series is summarized briefly here.

Exercise 6: Brainstorming and Going Outside the Box

Brainstorming is a well known, essential part of the creative process. Puzzles and riddles are used to let students experience the process of brainstorming and to learn that judgment should be withheld to improve the process. Puzzles and riddles help students learn to "go outside the box," an essential part of solving problems that require insight [3].

Exercise 7: Understanding Equations

Too often, some students limit their learning to the use of formulas and equations and fall short of understanding they model a physical situation. Useful exercises for this situation are short essay questions that ask students to explain and discuss a basic principle.

Exercise 8: Attaching Meanings to Symbols

Students often have a limited understanding of the use of symbols in equations and formulas. Instead of learning the meaning of each symbol, they see symbols merely as a place to substitute numbers. They need to learn that symbols carry meaning and have more uses than simply for making computations. A simple exercise that can be used is to ask students to solve a symbolic algebra problem that requires the assignment of meanings and interpretations to symbols.

Exercise 9: Precision in Learning

Students often confuse "learn the general principles" with "learn the principles generally." Some students seem to have a tolerance for ambiguity that leads to learning that is not precise. This is demonstrated by incorrect sign conventions, incorrect applications of simple principles, and lack of attention to details. Useful exercises include asking students to repeat particular principles precisely, to explain how signs are determined in a particular application, and to clearly discuss the application of a well-known procedure.

Comments on the Workshops

The effectiveness of the series of workshops on improving learning is not yet known, and an assessment process is being developed at this time. Difficulties of assessing the effectiveness are due to attendance being voluntary and the small number of participants that attend all sessions. Furthermore, effectiveness may be limited by the small amount of time that students receive coaching in the skills. Perhaps all that can be expected is that some students will benefit by learning about new ways of thinking and by being able to transform the workshop experience into a personalized process.

Concluding Remarks

This concludes our discussion of the coaching workshops that we developed to help students broaden their learning skills to improve performance on problem solving exams. The exercises are the result of the integration of careful, long-term observations of student performance with models of learning and problem solving. The underlying principle in the development of the exercises is that of coaching rather than teaching. Just as skilled performers in music and sports become accomplished through coaching, students can also become accomplished in the activity called learning. Through coaching, we try to remove a little of the "either you have it or you don't" aspect of being a good student that may exist in our current form of teaching.

References

1. Plants, H., Dean, R., Sears, J., Venable, W. (1980), A taxonomy of problem Solving activities and its implications for teaching, The Teaching of Elementary Problem Solving in Engineering and Related Fields, ASEE, pp. 21-34.

2. Stice, James (1976), A first step toward improved teaching, Engineering Education, Feb.

3. Sternberg, R.J. and Davidson, J.E. (1982), The mind of the puzzler, Psychology Today, June, pp. 37-44.

Appendices

Appendix I--The Dean and Plants Taxonomy of Problem Solving*

ROUTINES--Step by step set of operations that once begun, proceeds to a unique solution; requires no decisions once begun; based on recall of a procedure.
DIAGNOSIS--Selection of the correct routine or routines for the solution of a particular problem; sorting out appropriate routines from inappropriate routines.
STRATEGY--Choosing the best approach to solving a problem, which involves the selection of the best routine or set of routines from among appropriate routines.
INTERPRETATION--Reducing real world information to useful data for routines. Also looking at the implications of a problem solution in the real world. Includes making appropriate assumptions.
GENERATION--Development of routines which are new to the solver or putting routines together in ways new to the solver.

*Plants, Dean, Sears, Venable, "A Taxonomy of Problem Solving Activities and its Implications for Teaching," *The Teaching of Elementary Problem Solving in Engineering and Related Fields*, ASEE, 1980.

Appendix II--Bloom 's Taxonomy in the Cognitive Domain**

KNOWLEDGE--Remembering specifics of previously learned material; lowest level of learning.
KNOWLEDGE OF WAYS AND MEANS OF DEALING WITH SPECIFICS--Knowledge of conventions, classifications, criteria, methods
KNOWLEDGE OF UNIVERSALS AND ABSTRACTIONS--Knowledge of principles and generalizations, theories and structures
COMPREHENSION--The ability to grasp the meaning of material; lowest level of **understanding**.
APPLICATION--Ability to use learned material in new and concrete situations.
ANALYSIS--Ability to break down material into its component parts so that its **structure** may be understood.
SYNTHESIS--Ability to put parts together to form a new whole; creativity is stressed, with emphasis on new patterns or structures.
EVALUATION--Ability to judge the value of material for a given purpose; highest level of intellectual activity.

**Stice, James, "A First Step Toward Improved Teaching, Engineering Education, Feb. 1976.

Biographies

Dr. Charles Yokomoto holds the rank of Professor of Electrical Engineering at IUPUI. He received the BSEE, MSEE, and PhD degrees from Purdue University. His current interests are in the area of assessment of learning outcomes, coaching, learning styles, and problem solving.

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