Active Learning in the Classroom[1]

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Abstract

A model for active learning in the classroom is presented and learning activities are illustrated. Experiential learning provides the framework and cooperative learning the catalyst to engage students actively in learning.

Experiential learning is a four-stage cycle involving four fundamental learning modes (styles); their synthesis leads to higher levels of learning. The cycle can be divided into inductive and deductive learning activities. We found it helpful to view the four-stage learning cycle as a spiral in time that extends beyond a session. For example, a concept may be developed or applied in different contexts, at different times, and through different learning modes. Through experimentation and student feedback, we have developed a cooperative learning structure, a variation of think-pair-share, that is effective in the classroom.

Guidelines for developing active learning environments are drawn from the literature and our own experience. The principal incentive is: small, incremental changes in the learning environment can lead to significant gains for students. Moreover, it makes teaching more rewarding and enjoyable.

Active Learning

A well must produce its own water.
--Farsi proverb

Knowledge must be constructed by the learner; it cannot be supplied by the teacher (Bringuir, 1980). We are all responsible for our own learning; no one can learn for us.

Why do we need the term "active learning?" Doesn't learning imply active involvement? According to Conrad (1993), the need for the term "active learning" stems from the educational tradition to cover material "at the expense of intellectual and emotional engagement." Bonwell and Eison (1991) state that active learning is "anything that involves students in doing things and thinking about the things they are doing!" Learning happens especially felicitously when the learner is consciously engaged in meaningful activities that can be shared with others (Papert and Harel, 1991).

To develop an active learning environment in the classroom, one needs a framework to achieve well-defined learning objectives and guidelines for group activities. Otherwise the environment can become chaotic. We found that experiential learning (Kolb, 1984) provides the framework and cooperative learning the catalyst to engage students actively in learning.

Experiential Learning

Learning from experience is the process whereby human development occurs.
--Vygotsky in Kolb
(1984)

"Learning is described as a process whereby concepts are derived and continuously modified by experience. No two thoughts are ever the same, since experience always intervenes" (Kolb, 1984). "Knowledge… isn't a copy of reality…it's a reconstitution of reality by the concepts of the subject, who, progressively and with all kinds of mental probes, approaches the object without ever attaining it in itself" (Bringuir, 1980). Learning is a journey not a destination. The deeper the experience, the greater the potential for learning. "Any experience that does not violate expectations, is not worthy of the name experience" (Hegel in Kolb, 1984). Students who follow a lecture passively are not likely to have the kind of experience that stimulates curiosity and questioning. "Lack of experience seems to generate a lack of curiosity" (Linskie, 1977).

Experiential learning is based on the two fundamental activities of learning: grasping and transforming experience (Fig. 1). Each activity involves two fundamental modes (styles) of learning. One can grasp an experience directly through the senses (sensory, inductive mode) or indirectly in symbolic form (conceptual, deductive mode). Similarly,

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there are two distinct ways of transforming experience, by reflection or action. If we start with a concrete experience and guide students through reflection to develop a concept (abstract conceptualization), we use the inductive approach of learning. If we start with concepts and principles and apply them in the solution of problems (active experimentation), we use the deductive approach. An effective way to reach learners is to use “first induction, then deduction” (Felder and Silverman, 1988). Einstein once said: “I never discovered anything with my rational mind” (Senge, 1990). The implication is that discovery starts with the senses.

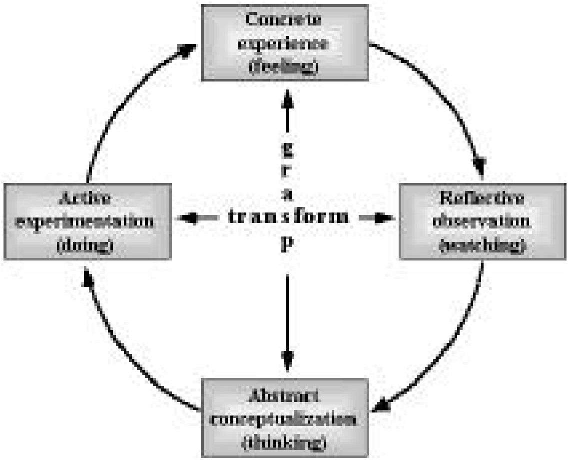


Figure 1. Experiential Learning Model (Kolb, 1984)

We represented experiential learning in the format of a double-entry notebook to promote journal writing (Fig. 2); one can record experiences on the left side, and transform them on the right side. A journal can be a special learning place: “A place to learn and to practice thinking, problem solving, and writing” (Stephen Bemiller in Fulwiler, 1987, p. 360).

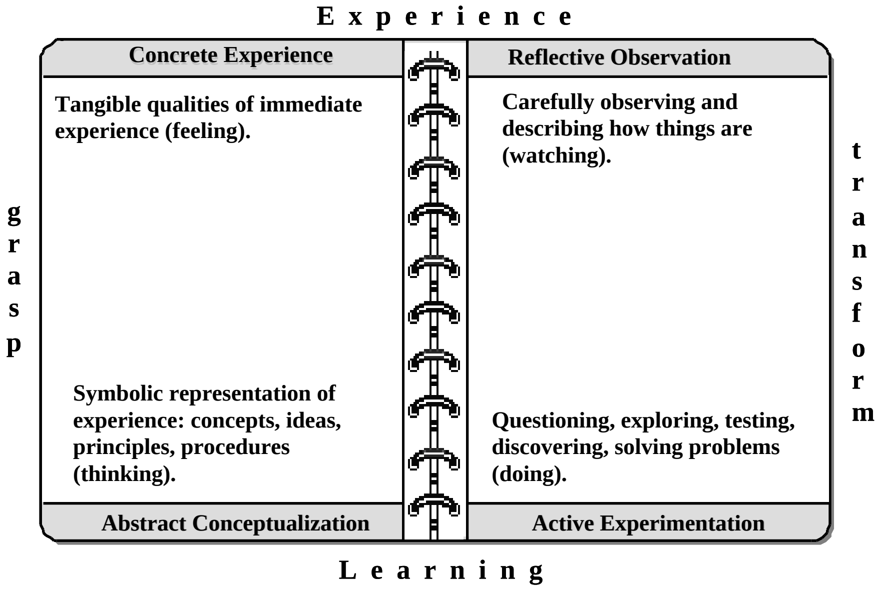


Figure 2. A journal as a learning place

Gauss. An anecdote about Carl Friedrich Gauss (1777-1855) is used to illustrate the fundamental learning modes. Gauss, one of the greatest mathematicians of all time, was a child prodigy. When he was ten years old he had a teacher who liked to keep his pupils occupied with busy work (Grossman, 1994). One day he asked his students to add the numbers from 1 to 100 (Fig. 3), a demanding experience for a ten-year old. Almost at once, Carl turned over his slate and said “there it is;” his was the only correct answer. He had transformed the addition of 100 numbers into the simple product 50 x 101 = 5050 (immediate action). Somehow Gauss had noticed that the numbers could be arranged in 50 pairs, each with the sum 101 (visual reflection in Fig. 3).

Suppose we use this example to help students develop a formula for the sum of the numbers from 1 to n. We might suggest that they work in teams and arrange the sum of the numbers from 1 to 10 into pairs; they'll obtain 5 pairs, each with the sum 11. Thus, the sum is 5 x 11 = 55. Finally, they are asked to express this process in symbolic form (abstract conceptualization). With the help of their teammates and perhaps some clues from the teacher, they'll obtain the formula in Fig. 3.

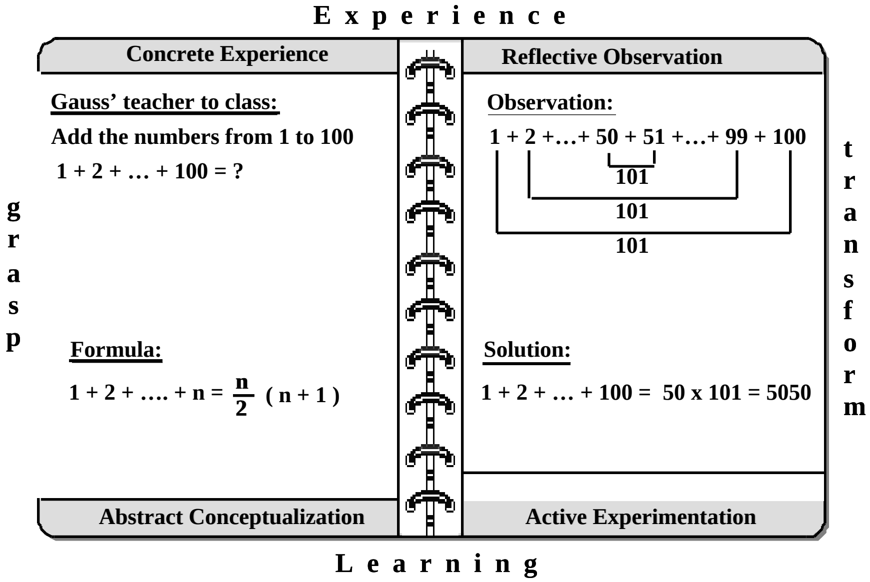


Figure 3. Gauss: transforming a sum into a product

The lesson from this exercise is that we should guide students to develop concepts and principles; they can't be given to them. This is confirmed in a study led by the U.S. Department of Education which shows that U.S. math scores lag behind because most teachers only state concepts without fully developing them: "...Students in Germany and Japan learn 10 to 20 math subjects in depth, our students are asked to cover 35 math subjects and, therefore, don't learn any of them in depth" (Sanchez and O'Harrow, 1997). When there is too much pressure to cover material, "memorization quickly becomes the most efficient way to get through the course, leaving everyone dissatisfied in its wake" (Wagener, 1991). "Coverage is the enemy of learning" (Whitehead, 1967).

Spring experiment. This illustration is taken from a session on forces in Statics. The objective is to guide students by induction to develop the concepts of a free-body diagram (FBD) and Newton's first and third laws. The students work in pairs.

1. **Concrete experience and reflection**. Each pair of students has one spring scale; their first task is to pull on the spring scale with a force of 4.5 N and describe the mechanism of the spring scale (Fig. 4).

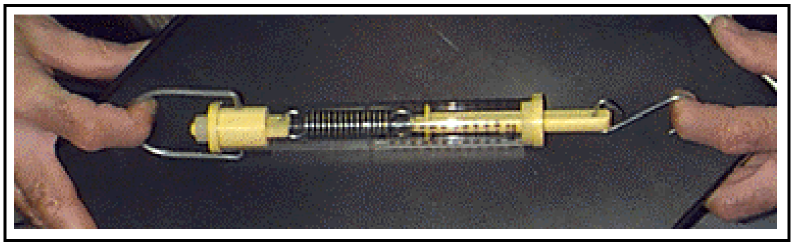


Figure 4. Spring experiment

2. **Force diagram**. The students are asked to draw a diagram that shows how the force is transferred from one finger through the spring scale to the other finger (Fig. 5). The concept of a free-body diagram is introduced through the force diagram of the isolated spring scale (Fig. 6).

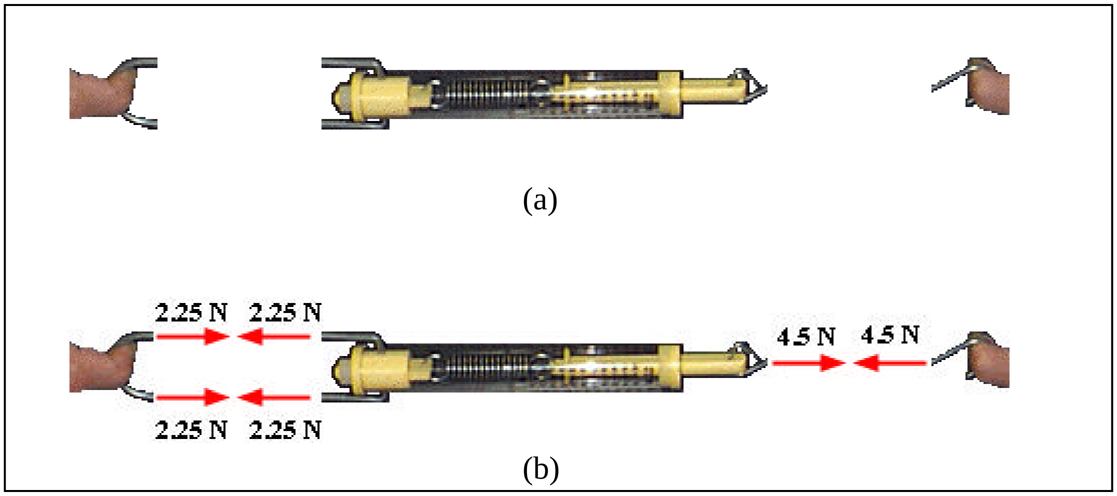
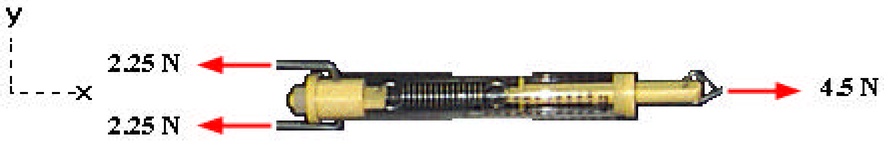


Figure 5. Construction of force diagram: (a) spring isolated from fingers; (b) force diagram

3. **Newton's first law**. On the basis of the free-body diagram of the spring scale, students discover, or depending on their background reinforce, Newton's first law (Fig. 6).

Question: What is the net force acting on the spring scale (TPS)?



(a)

Answer: The net force is zero (Newton's first law)

$$\Sigma F_x = 4.5 - 2.25 - 2.25 = 0$$

(b)

Figure 6. Newton's first law: (a) FBD; (b) equilibrium

4. **Newton's third law**. Students study the characteristics of a pair of interactive forces (Fig. 7) to infer Newton's third law.

Question: What are the properties of a pair of interacting forces (TPS)?

Answer: The interacting forces are equal in magnitude, opposite in sense, and collinear (Newton's third law).

Figure 7. Newton's third law

To summarize, experiential learning is a four-stage cycle involving four fundamental learning modes (styles); their synthesis leads to higher levels of learning (Kolb, 1984). This is supported in a study by Stice (1987), which shows that the students' retention of knowledge increases from 20% when only abstract conceptualization is involved to 90% when students are engaged in all four stages of learning. We found it helpful to view the four-stage learning cycle as a spiral in time that extends beyond a session. For example, a concept may be developed or applied in different contexts, at different times, and through different learning modes. This finding is shared by Wankat and Oreovicz (1993): "For complex information the circle is traversed several times in a spiral cycle. The spiral may extend through several courses and on into professional practice as the individual learns the material in more and more depth."

Cooperative Learning

> *...early evidence suggests that students who work in small groups, even when interacting with high-tech equipment, learn significantly more than students who work primarily alone.*
>
> --Light (1990)

Cooperative Learning is a structured learning strategy in which small groups of students work toward a common goal (Cooper et al., 1994). Benefits of cooperative learning include (Johnson et al., 1991): high-level reasoning, generation of new ideas and solutions, motivation for learning, personal responsibility, and student retention.

Moreover, attributes of an attractive engineering graduate, listed in a Boeing Corporation White Paper (Prados, 1995) include: good communication skills (written, verbal, graphic, listening); the ability to think both critically and creatively, independently and cooperatively; curiosity and desire to learn—for life; and a profound understanding of the importance of teamwork.

We experimented with various group sizes and cooperative learning structures and found that pair activities work well in class. In groups of three, for example, one student is easily left out. We also tried different cooperative structures and arrived, with the help of student feedback, at a combination of think-pair-share (**TPS**) (Lyman, 1987) and think-aloud-pair-problem-solving (**TAPPS**) (Lochhead, 1987) as our base structure. For simplicity we call the combined structure think-pair-share.

THINK-PAIR-SHARE

THINK

Think about the solution of the problem individually to organize your thoughts.

PAIR

Form pairs, a think-aloud problem solver and a listener (TAPPS), to solve the problem; reverse roles after every problem.

SHARE

Share your findings with another pair or a larger group.

Think-pair-share can also be used to answer questions or to apply the 8-2 rule: For every eight minutes the teacher is in control (e.g., giving mini lectures), students should be given at least two minutes to summarize, reflect, discuss, and hence begin to process the material (Habel, 1996).

Sessions

> *I never realized how much I can learn by helping others.*
>
> -- a Student

Sessions generally consist of three parts: (1) a warm-up problem or a puzzler to engage the students; (2) mini lectures (10-15 minutes long) interspersed with cooperative activities; (3) a minute paper (Cross, 1991), where students are asked to reflect and answer questions about the day's lesson and activities. Anonymous minute papers provide valuable insight into students' conceptions, achievements, and difficulties. This information allows one to evaluate and improve the learning environment in a continuous fashion.

Since we are sharing class time with the students, which limits the time to present content, we provide them with course packs composed of condensed lecture notes and problems with gaps. The students fill in the gaps during cooperative learning activities. The following example illustrates a class activity in Statics based on a page from the course pack.

Analysis of simple structures. Figure 8 shows the teacher version of the page; the student version does not contain the solution. A transparency of the page, with the solution parts covered by post-it notes, is projected on a screen. The students use think-pair-share to work through the various parts of the problem.

1. **Question**. Students are asked to answer the question about the magnitudes of the member forces in the two structures (Fig. 8). Physical models are available to provide hands-on experimentation (Fig. 9). The important thing at this stage is to get the students engaged and curious about the behavior of the two structures, not to answer the question correctly.
2. **Problem**. Students are asked to use the 3-step analysis procedure to compute the member forces in the truss. The solution parts, gaps into the students' version of the course pack, are covered with post-it notes on the transparencies. While they are drawing the FBD, a difficult task especially in the beginning of the course, the teacher can monitor the students' progress and provide help as needed. After the students had sufficient time to draw the FBD, the teacher removes the post-it note covering the FBD, and the diagram is discussed. This procedure is continued through steps 2 and 3 to complete the analysis. Since the teacher does not need to write the problem statement or the solution on the board, time can be devoted to group activities. The teacher may write on the board or on a transparency to facilitate discussions.

Analysis of Simple Structures

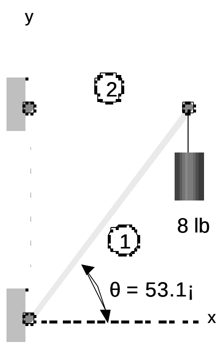


Fig. 1

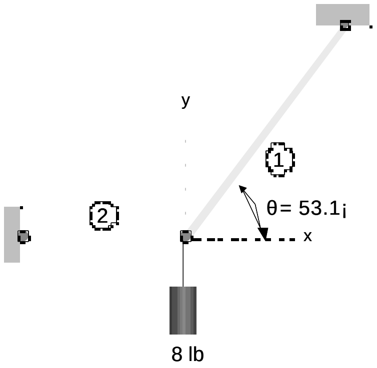


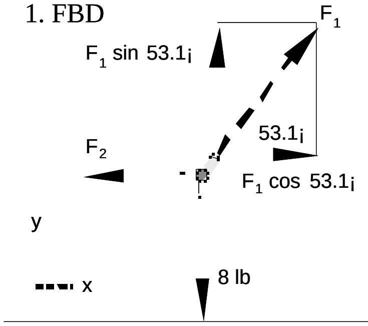
Fig. 2

Question: Do you expect the magnitudes of the member forces in the two structures to be the same or different (TPS)?

Problem: Use the 3 -step analysis procedure to compute the member forces in the truss (Fig. 2).

Solution:

1. FBD



2. Equilibrium

$$\Sigma F_y = F_1 \sin 53.1° - 8 = 0$$

$$F_1 = \frac{8}{\sin 53.1°} = 10 \text{ lb (C)}$$

$$\Sigma F_x = F_1 \cos 53.1° - F_2 = 0$$

$$F_2 = F_1 \cos 53.1° = 6 \text{ lb (T)}$$

3. Final FBD

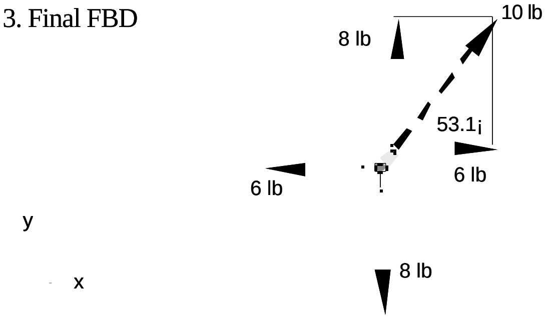


Figure 8. Course pack page: teacher's version

3. **Discussions**. It is further instructive to engage students in follow-up questions about the truss problem. For example, for what value of the angle θ is the force in member 2 zero? How do the magnitudes of the member forces change as the angle θ is reduced, to say 20°, while member 2 is kept horizontal? What

happens to the member forces as the angle θ approaches 0° while member 2 remains horizontal? Finally, the solution to the tension structure and the answer to the initial question about the magnitudes of the member forces in the two structures can be a homework assignment.

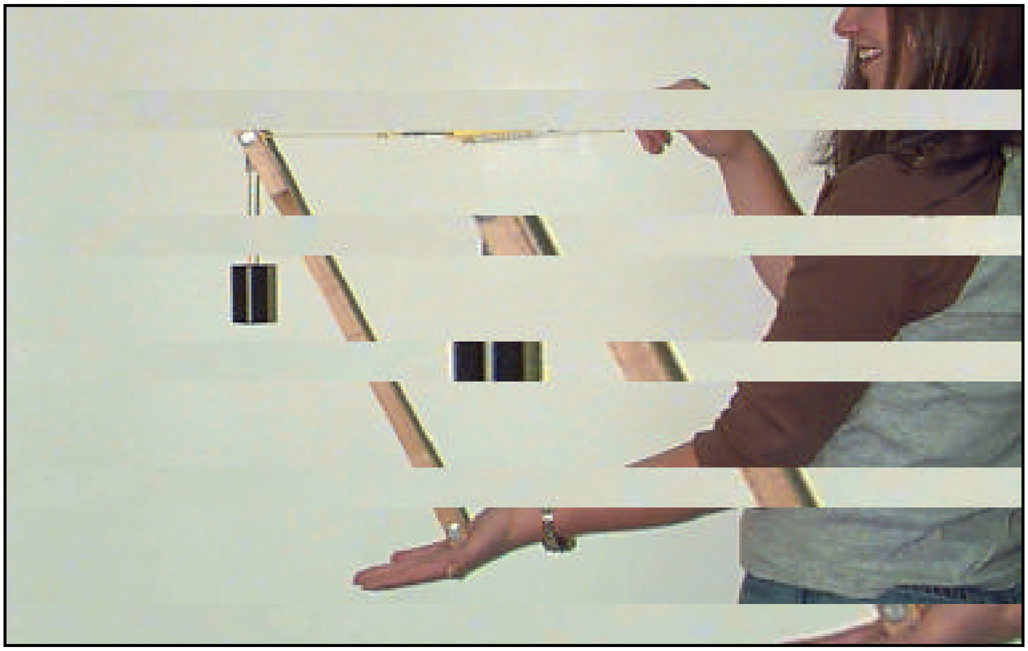


Figure 9. Hands-on experiment

This example illustrates that a course pack allows one to share class time with students and still meet course objectives. The challenge is to achieve a good balance among the various class activities. This is crucial for students who are not highly motivated or skilled learners; a rich, active learning environment can become overwhelming. This potential problem can be alleviated as follows: (1) Give students the opportunity to master one topic before moving to the next one (Terenzini and Pascarella, 1994); (2) frequently place topics in context of the course framework and objectives, the students' background, and real engineering problems; and (3) receive and provide frequent feedback. It is also important to communicate high expectations, to stress the students' responsibility for learning, and to enable them to realize the benefits of helping one another learn (AAHE, 1996).

Incentives

Small changes in the teaching format can lead to significant gains for students.

--Light (1990)

Developing an active learning environment takes time and patience; both teacher and students need to be motivated and learn to be effective. Active learning in the classroom may seem inefficient in comparison to the traditional lecture approach, but it is not if efficiency is measured in terms student learning (Barr and Tagg, 1995; Flammer, 1987; Wankat and Oreovicz, 1993). Moreover, it makes teaching more rewarding and enjoyable.

The following approach is recommended: (1) Start slowly with occasional group activities and minute papers (Cross, 1991); the minute papers facilitate formative evaluation and improvement; (2) form partnerships with colleagues who teach the same course and slowly develop course packs: one faculty member designs the content of a specific learning unit, the partners review and improve it, and students are hired to transform it into an electronic file; (3) attend teaching workshops and share new teaching and learning experiences with colleagues; form a learning community.

The course pack can also provide the basis for Internet-based teaching and learning, and for its eventual extension to an interactive multimedia program (Holzer and Andruet). If this transformation is carried out gradually, perhaps over a five-year period, it can be achieved without restricting our other missions. “An efficient teacher can do a good job teaching in the same amount of time an inefficient teacher spends doing a poor job” (Wankat and Oreovicz, 1993).

Summary

> *Team learning is vital because teams, not individuals, are the fundamental learning unit in modern organizations.*
>
> --Peter Senge (1994)

A model for active learning in the classroom is presented and learning activities are illustrated. Experiential learning provides the framework and cooperative learning the catalyst to engage students actively in learning.

Experiential learning is a four-stage cycle involving four fundamental learning modes (styles); their synthesis leads to higher levels of learning. The cycle can be divided into inductive and deductive learning activities. We found it helpful to view the four-stage learning cycle as a spiral in time that extends beyond a session. For example, a concept may be developed or applied in different contexts, at different times, and through different learning modes. Through experimentation and student feedback, we have developed a cooperative learning structure, a variation of think-pair-share, that is effective in the classroom.

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