The purpose of this section is to introduce elements of learning style theory and to show how the learning cycle can be a model for teaching.

BACKGROUND

John Dewey defined education as "the process of controlling the educational experience." This definition recognizes the great responsibility that we, as educators, have to create an environment which facilitates and enhances student learning. We must decide what, when, and how learning will occur. We believe that a large number of options are available to us as engineering educators when we make these decisions. From these options, it is our responsibility to choose the ones that best fit us as teachers, our institutional-centers of learning, and our students as seekers of enhanced knowledge and abilities.

We will first examine the learning process in order to develop a rational basis for the making of such decisions.

THEORY OF LEARNING STYLES

A common mistake made by university faculty is to assume that students learn in the same manner as the individual faculty member. In practice, this assumption often degenerates to something like "all good students learn in the same manner as I do." Consequently, students with different learning approaches are often dismissed as either lacking intelligence or as being non-cooperative.

Educational theorists have identified that people perceive (how we take things in) and process (how we make things a part of us) new information differently [1,2]. Some people prefer to perceive or grasp a new experience by feeling (sensing) their way through the experience. Others prefer to perceive by thinking and making use of symbols or conceptual models. The perceiving function can be represented as a line with the words "feeling" and "thinking" at the opposite ends of the line. The balance between perception by feeling or by thinking for an individual can be represented by a point on this line. In processing new information, some people watch and observe while others become personally and actively involved. Again, we can imagine a line with "watching" and "doing" at the opposite ends. Based on the two dimensions of perceiving (grasping) and processing (transforming), Kolb identified four different types of learners as shown in Figure 1 [1].

In quadrant 1, learners perceive in a feeling mode and process in a watching mode. Similarly, each of the other quadrants leads to
specific learner types. Kolb referred to these four types of learning as learning styles. According to Claxton and Ralston, the term "learning styles" refers to the preferred manner in which students respond to and use stimuli in the context of learning [3]. Note that the Kolb model is not the only learning style model found in the literature. However, it is the model which will be used throughout this document. All four of the Kolb learning styles are found in nearly equal proportion in the general population [1,2]. In addition, our research has shown that all four learning styles are present in each engineering class we teach.

Within the academic community, considerable interest has been generated concerning the idea of different student learning styles [4-10]. The trend is shifting away from searching for the "best" method of teaching toward the development of methods that provide instructors and students a "smorgasbord" of activities. The basic paradigm associated with the "smorgasbord" approach is that students learn in a variety of styles and that teaching effectiveness is enhanced by teaching to each learning style at least a portion of the time. Such an approach is termed a learning style format.

Kolb's model of experiential learning provides a framework for understanding learning styles [1]. In his model, Kolb defined the opposite ends of the perception axis as concrete experience (feeling) versus abstract conceptualization (thinking), and the processing axis as reflective observation (watching) versus active experimentation (doing). An extended description of each of these is found in the paragraphs which follow.

Concrete experience (CE), sensing/feeling: In concrete experience, the learner is immersed in the new experience. Feeling is emphasized over thinking or logic. The strategy is to be open, adaptable, intuitive and to maximize involvement. The stimulus from the environment needs to be sorted and selected so that feeling and valuing are dominant mind activities. Abilities in the CE area include good interpersonal relationships and sensitivity to personal values of all involved.
**Abstract conceptualization (AC) or thinking:** In abstract conceptualization, the learner attempts to logically and systematically organize information into concepts, theories, and ideas. The emphasis is on thinking as opposed to feeling or sensing. The learner is concerned with building general theories rather than intuitively understanding specific situations or areas.

**Reflective observation (RO) or watching:** In reflective observation, the learner becomes the objective observer. The strategy is to separate oneself from the particular experience and to observe the occurrence from as many different views as possible. The dominant mode is patient watching and personal reflection in order to make judgments.

**Active experimentation (AE) or doing:** In active experimentation, the learner is directly involved with the environment. The world is addressed, tested, and manipulated to obtain a response. The strategy is to find what actually works and to obtain practical results. The dominant mode is testing.

Kolb claims that the four learning styles exist as two distinct polarities of CE versus AC (perceiving) and RO versus AE (processing) as represented by the two axes previously defined in Figure 1. For example, this condition of polarity results in a mutual exclusion of involvement in the RO activities and involvement in AE activities. This is fairly obvious as learners cannot be both "removed and reflective" and "active and involved" at the same time. However, it should be pointed out that we are discussing preferred ways of perceiving and processing. Other methods of perceiving and/or processing material rather than the preferred method can also be used by individuals.

\[...\] the four learning styles are preferred ways of perceiving and processing [...]

**Determining Learning Styles**

The preferred learning style of any student can be determined by using the Kolb "Learning Style Inventory" or LSI [11]. The LSI is a forced-selection preference test that requires identification with various descriptors of the four learning abilities. The test has been administered to thousands of students to determine their preferred learning styles. Figure 2 shows a typical result of a learning style inventory where the distance along each of the four axis is proportional to the degree to which an individual prefers the perceiving and processing functions. The results are for a learner with an AC-AE preference.

While the AC-AE style of learning is preferred in Figure 2, each of the other three modes are represented as well. This will be the case for every person, i.e., that each of the four learning styles is represented. However, it will be true that one particular learning style will be dominant and hence is "preferred." Learning styles have been shown to correlate with choice of
professions, with engineering students tending to prefer the RO-AC and the AC-AE modes of learning [1].

![Learning Styles Diagram](image)

**Figure 2.** Results of a learning style inventory for a AC-AE preferred learner.

Kolb identified the four distinct learning styles as: divergers (Type 1 learners); assimilators (Type 2 learners); convergers (Type 3 learners); and accommodators (Type 4 learners) as shown in Figure 3.

Some generalized characteristics of each learning style are described below [1,2]. In addition, Figure 4 provides a summary of likes and dislikes for each of the four learning styles.

**Type 1 Learners:** These students like to integrate experience with their own personal values and feelings. They view their learning environment from many perspectives, and prefer to listen and share ideas. They must be personally involved and work constantly for harmony in their lives. They are creative and innovative. In relation to motivation, they seek to understand the value of the proposed learning and to know "why" the proposed learning would relate to themselves. They are termed divergers because they tend to be highly individualistic and seek maximum personal choice. Their favorite type of question is "Why?" as in "Why is this concept of enough value that I should learn it?"

**Figure 3.** Learning Styles.

**Type 2 Learners:** These students tend to integrate observations with existing
Figure 4. Characteristics of Different Learning Types

<table>
<thead>
<tr>
<th>Type 4</th>
<th>Type 3</th>
<th>Type 2</th>
<th>Type 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIKES</strong></td>
<td><strong>DISLIKES</strong></td>
<td><strong>LIKES</strong></td>
<td><strong>DISLIKES</strong></td>
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<tr>
<td></td>
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<td>Favorite question: <strong>WHAT</strong>?</td>
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<tr>
<td></td>
<td></td>
<td>Favorite question: <strong>HOW</strong>? (i.e. How does this work?)</td>
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knowledge. They are strong conceptualizers and use deductive problem solving. They often seek continuity between the "new" and the "old" and look to obtain knowledge from authorities. They work well with detail and data; however, if the data do not fit the model, then the data are immediately suspect. They are called assimilators because they are always seeking to assimilate new ideas and thoughts. Their favorite question is "What?" as in "What do I need to know to solve this problem?"

*Type 3 Learners*: These students integrate theory and practice, and use both abstract knowledge and common sense. They like to solve practical problems, especially under a variety of constraints. They tend to think strategically, and act pragmatically. Often they collect intellectual and hands-on skills which are saved for the time that the skill is required to solve a problem. They typically use a combination of deductive and inductive problem-solving techniques. They are called convergers because they seek for "the solution" to practical problems. Their favorite question is "How?" as in "How does this work?" or "How can I solve this problem?"

*Type 4 Learners*: These students tend to be highly active and creative. They integrate experience into application and often new experience into immediate applications. They often learn by trial-and-error and discover new knowledge without the assistance of an authority. They tend toward the use of inductive problem-solving techniques. They are highly intuitive and often generate excellent conclusions based solely on intuition. They get excited by new and challenging situations and are natural leaders and performers. They are called accommodators because they easily adapt to new situations. Their favorite question is "What if?" as in "What if we did something different to solve this problem?"

Our surveying of undergraduate engineering students has shown that there is about 10% Type 1 learners, 40% Type 2's, 30% Type 3's, and 20% Type 4's.

Information on students' learning styles can be used in the following two manners [3]:

1. by the student to improve his/her educational efforts through an understanding of the strengths and weaknesses of a particular style, and

2. by faculty to improve planning for the learning experience and to improve student-faculty interaction.

**TEACHING STYLES**

Not only do students have preferred learning styles, but faculty have preferred teaching styles which correspond to their own individual learning style. Characteristically, these teaching styles can be described in four types.

*Type 1 Teachers*: These teachers focus on the personal development of the students. They tend to develop good relations with students and to be highly motivating. Their classrooms are filled with cooperation and
discussion of values and meaning. In engineering classes, they like to engage students in discussions of life as an engineer in the profession and in society. Their teaching environment of choice involves questioning and class discussion.

Type 2 Teachers: These teachers focus primarily on the transmission of knowledge. In their classrooms, the teacher is the authority and the students learn in a hierarchical manner from the teacher. Most textbooks are written by Type 2 teachers, so these teachers often follow closely the textbook material. Their teaching environment of choice is professor-centered lectures.

Type 3 Teachers: These teachers primarily focus on promoting productivity and competence. They want to teach students the skills necessary for being a "good" engineer. They tend to be highly independent and want their students to be independent. Their teaching environment of choice is the traditional lecture format coupled with laboratories and out-of-classroom experiences.

Type 4 Teachers: Type 4 teachers encourage experiential learning. While Type 1 teachers focus upon relationships, Type 2 teachers on knowledge, and Type 3 teachers on skills, Type 4 teachers encourage self-discovery. They tend to be stimulating and dramatic, and hope to expand students' intellectual boundaries. They operate in all teaching environments and will mold the environments to meet their needs.

From our surveying of engineering faculty, about 10% are Type 1 teachers, 50% Type 2, 30% Type 3, and 10% Type 4.

From the description of teaching styles and the distribution of styles among faculty, we can see clearly one motivation behind the professor-dominated formal lecture format which is so prevalent in engineering education. It is a learning environment that is preferred by at least half of our engineering educators and one that is readily accepted (and preferred) by a large fraction of our students. It is also true that most engineering faculty members learned "how to teach" from observing their own teachers, who themselves used the professor-dominated lecture format as the teaching method of choice. Finally, lectures are an efficient way to transfer large amounts of information. Hence, lectures have become the dominant paradigm for engineering education. However, this does not imply that lectures are the ideal from an educational perspective.

LEARNING ACTIVITIES

Because students have different learning preferences, it is important that faculty provide activities for students that will allow them to feel comfortable in the learning environment. When we restrict ourselves to basically one way of presenting material,
e.g., professor-dominated formal lectures, we are not addressing the different learning styles of our students. In addition, the ability of all of our students to learn is enhanced as they are required to function in learning styles other than their preferred mode. There is a large number of activities that we can use to address the different learning styles.

Learning activities can be highly varied and can involve any number of linkages - student-teacher, student-student, student-object, student-information, and student-evaluation. Professional educators have a responsibility to control the process so that students experience all of these learning avenues. Group projects can link students to other students; out-of-class room experiences can involve many exciting and information-rich objects; and a variety of evaluations force students to look at information in different ways. Again the choices available are numerous.

A way to think about the options available in learning activities is the use of the common institutional categories of lectures, recitations, laboratories, out-of-classroom experiences, and evaluative tools. Some examples are shown in Table 1 and discussed later in the monograph.

Faculty can alter the learning environment through the use of a variety of these options. As professional educators, we need to be knowledgeable about the options, how they are accomplished, and their advantages and disadvantages. Table 1 can be viewed as a teaching "tool kit ".

THE KOLB LEARNING CYCLE AS A MODEL FOR TEACHING

It is important that each student learn how to function in all of the four quadrants (i.e., obtain answers to each of the questions, Why?, What?, How?, and What if?). These four questions represent the internal structure of the learning cycle which is a pattern for learning new concepts. A combination of the learning modes from all four learning styles produces the highest level of learning [1]. Most engineering educators have learned how to answer these questions during their graduate education while working on a doctorate in a specialized field. A major challenge in education is to help our undergraduate students learn how to address all of these questions. To do this, we need to provide various instructional activities that will address the different learning styles and move the students through the learning cycle.

. . . learning occurs by passing through the four quadrants . . .

In the learning cycle, immediate experience (CE) creates a need for learning which transfers to reflective observation (RO) of the experience which is followed by the introduction of concepts (AC) to integrate the immediate experience into what is known. After integration, testing is induced (AE) and, because this action results in new experiences, the cycle repeats (see Figure 5).
**Table 1. VARIOUS INSTRUCTIONAL ACTIVITIES**

**TYPES OF LECTURES**

- Formal lecture, thinking tone
- Formal lecture, feeling tone
- Lecture with visual aids
- Lecture with demonstrations
- Lecture with prompted responses
- Lecture with incentive quiz
- Lecture with programmed notes
- Student lectures
- Role playing
- Feedback lecture
- Interactive lecture
- Socratic lecture

**TYPES OF OUT-OF-CLASS EXPERIENCE**

- Short field trips
- Long field trips
- Internship
- Co-op with industry
- Student contest
- Large seminar
- Professional meeting
- Library search
- Teaching assistant
- Group project

**TYPES OF RECITATIONS**

- Question and answer
- Tutorial (one-on-one)
- Problem solving by instructor
- Problem solving by students
- Problem solving by groups
- Student presentations
- Seminars
- Computer-aided instruction
- Guided design

**TYPES OF PERFORMANCE EVALUATION**

- Objective test
- Subjective test
- Oral test
- Pop quiz
- Out-of-class test
- Laboratory test
- Homework problems
- Individual report
- Group project report

**TYPES OF LABORATORIES**

- Class experiment
- Group experiment
- Training
- Instructor demonstration
- TV demonstration
- Experiment and design
- Capstone design
- Computer simulation
- Games
- Independent research
- Group research
- Field work
- Think tanks
- Quality circles
Based on the work of Kolb and others, McCarthy developed the 4MAT learning system which she applied to primary and secondary education [2]. The 4MAT learning system is based on the supposition that learning is best served by passing through the four quadrants as shown in Figure 5. The cycle can be thought of as answering the various questions associated with "Why?", "What?", "How?", and "What if?".

Movement around the learning cycle can be accomplished by the proper choice of learning environment/interaction for the individual quadrants. Most choices can be intuitively placed in a particular quadrant; for example, "formal lectures, thinking tone," is clearly a quadrant 2 activity. Other choices are more difficult to place and may require actual experience. However, using Table 1, faculty may generate a teaching plan to move through the learning cycle. The next section of this monograph provides examples of activities in each quadrant, and it is designed to aid faculty members in choosing appropriate activities.

Faculty who adopt learning style theory and incorporate the learning cycle into their teaching methodology and philosophy appear to have remarkable success. Increased learning and student satisfaction coupled with increased faculty satisfaction are often noted. Stice reported potential advantages from the application of learning style theory to engineering education which included greater information retention, a very important goal for Type 2 teachers [7]. Later in the monograph, we will document some of our own and our colleagues' experiences and feelings. Learning style theory has also been applied with success in industrial research and development environments [12].

THE KOLB LEARNING CYCLE AND EDUCATIONAL GOALS

The major advantages of applying the learning cycle to engineering education include greater student satisfaction and the support of the four educational goals of improved thinking, problem-solving, communication and the development of self-motivated learners.

Student satisfaction often increases since each new concept in a course is taught through the
four learning preferences and thus reaches all four learning styles. The effective response of the students is something like "I am being personally listened to." The use of the learning cycle will improve student satisfaction for the students with learning styles not typically reached by a lecture-dominated learning environment/interaction. However, the primary reason for choosing to plan the educational experience around the learning cycle is that the learning cycle supports the educational goals mentioned above.

Persons who become excellent learners will develop good skills in all four learning styles and will travel through the learning cycle rapidly. This can be seen as the ultimate goal for helping students to become individualized self-motivated learners. This is probably the greatest advantage of the learning style theory format in that the use of the learning cycle will ultimately allow students to learn independently of the professor and the university environment.

. . . excellent learners have skills in all four learning styles . . .

This advantage cannot be overstated. Our graduates often lack the confidence to be self-learners. The source of this reality can probably be traced to the typical learning environment/interaction that involves the professor-dominated lecture format. Such a format can only encourage dependence of the learner upon both the professor and the classroom.

In addition to helping students become independent, the use of the learning cycle encourages students to use their thinking, problem-solving, and communication skills with each pass around the cycle. This is a process of repetitive practice where modeling from the professor is supplemented with nearly constant feedback. The thinking efforts are concentrated in quadrants 1 and 2; the problem-solving in quadrants 3 and 4; and the communication in quadrants 4 and 1. In this fashion, use of the learning cycle promotes the development of the higher level problem-solving skills of analysis, synthesis, and evaluation. The importance of these skills has been firmly established by Bloom [13, 14]. These skills are clearly necessary for advanced engineering education because they are important components of engineering design [15,16]. In fact, many of the inherent difficulties in teaching open-ended engineering design are probably due to such courses requiring analysis, synthesis, and evaluation skills that are not encouraged in a professor-dominated lecture format.

SUMMARY

In this section we have examined learning style theory and have defined four dominant learning styles. It was shown that each of the four styles is characterized by a favorite question namely: Why?, What?, How?, and What if?. All of the different learning preferences are present amongst the students
in our classrooms. It is therefore important to spend a portion of our time teaching to each of the learning preferences in order to meet the needs of all learners. It is also important to help our students become independent thinkers and learners by teaching them to traverse all four quadrants of the cycle. The learning cycle provides a practical model which engineering faculty may use as a basis for improved instruction of students.