CHAPTER 14

MODELS OF COGNITIVE DEVELOPMENT: PIAGET AND PERRY

We will focus on the two theories of development which have been the most influential in the education of scientists and engineers: Piaget's theories of childhood development and Perry's theory of development of college students. To some extent they are complementary as both focus on different aspects of development, and since both Piaget and Perry discuss how students learn, this material ties in with Chapter 15.

These theories are important since they speak to what we can teach students and to where we want students to be when they graduate. Both theories postulate that students cannot learn material if they have not reached a particular level of development. Attempts to teach them material which they are unable to learn leads to frustration and memorization. As engineering students become more heterogeneous, the levels of student development in classrooms will also become more heterogeneous. Thus, it is becoming increasingly important to understand the levels at which different students function.

14.1. PIAGET'S THEORY

Jean Piaget was a Swiss psychologist whose research on the development of children has profoundly affected psychological theories of development and of the teaching of children. His theory has also been widely studied for its application to the teaching of science in grade school, high school, and college. Unfortunately, Piaget's writings tend to be somewhat obscure. We will present a significantly edited version focusing on those aspects of his theory which affect engineering education. Further information is available in Flavell (1963), Gage and Berliner (1984), Goodson (1981), Inhelder and Piaget (1958), Phillips (1981), Piaget (1950, 1957), and Pavelich (1984).

14.1.1. Intellectual Development

Piaget's theory conceives of intellectual development as occurring in four distinct periods or stages. Intellectual development is continuous, but the intellectual operations in the different periods are distinctly different. Children progress through the four periods in the same order, but at very different rates. The stages do not end abruptly but tend to trail off. A child may be in two different stages in different areas.

The sensorimotor period, which is only of indirect interest to our concerns, extends from birth to about two years of age. In this period a child learns about his or her relationship to various objects. This period includes learning a variety of fundamental movements and perceptual activities. Knowledge involves the ability to manipulate objects such as holding a bottle. In the later part of this period the child starts to think about events which are not immediately present. In Piaget's terms the child is developing meaning for symbols.

The preoperational period lasts from roughly two to seven years of age. Piaget has divided this stage into the preoperational phase and the intuitive phase. In the preoperational phase children use language and try to make sense of the world but have a much less sophisticated mode of thought than adults. They need to test thoughts with reality on a daily basis and do not appear to be able to learn from generalizations made by adults. For example, to a child riding a tricycle the admonition "Slow down, you are going too fast" probably has no effect until the child falls over. This continual testing with reality helps the child to understand the meaning of "too fast." Compared to adults, the thinking of a child in the preoperational phase is very concrete and self-centered. The child's reasoning is often very crude, and he or she is unable to make very simple logical extensions. For example, the son of one of the authors was astounded when he heard that his baby sister would be a girl when she got older!

In the intuitive phase the child slowly moves away from drawing conclusions based solely on concrete experiences with objects. However, the conclusions drawn are based on rather vague impressions and perceptual judgments. At first, the conclusions are not put into words and are often erroneous (and amusing to adults). Children are perception-bound and often very rigid in their conclusions. Rational explanations have no effect on them because they are unable to think in a cause-and-effect manner. During this phase children start to respond to verbal commands and to override what they see. It becomes possible to carry on a conversation with a child. Children develop the ability to classify objects on the basis of different criteria, learn to count and use the concept of numbers (and may be fascinated by counting), and start to see relationships if they have extensive experience with the world. Unaware of the processes and categories that they are using, children are still preoperational. Introspection and metathought are still impossible.

At around age seven (or later if the environment has been limited) the child starts to enter the concrete operational stage. In this stage a person can do mental operations but only with real (concrete) objects, events, or situations. He or she can do mental experiments and can correctly classify different objects (apples and sticks, for example) by some category such as size. The child understands conservation of amounts. This can be illustrated with the results of one of Piaget's experiments (Pavelich, 1984). Two identical balls of clay are shown to a child who agrees they have the same amount of clay. While the child watches, one ball is flattened. When asked which ball has less clay, the preoperational child answers that the flattened ball has less clay. The concrete operational child is able to correctly answer this question. He or she becomes adept at addition and subtraction but can do other mathematics only by rote. In the concrete operational stage children also become less self-centered in their perceptions of the universe. Logical reasons are understood. For example, a concrete operational person can understand the need to go to bed early when it is necessary to rise early the next morning. A preoperational child, on the other hand, does not understand this logic and substitutes the psychological reason, “I want to stay up.”

Piaget thought that the concrete operational stage ended at age eleven or twelve. There is now considerable evidence that these ages are the earliest that this stage ends and that many adults remain in this stage throughout their lives. Most current estimates are that from 30 to 60 percent of adults are in the concrete operational stage (Pintrich, 1990). Thus, many college freshmen are concrete operational thinkers; however, the number in engineering is small and is probably less than 10 percent (Pavelich, 1984). For reasons which will become clear shortly, concrete operational thinkers will have difficulty in an engineering curriculum. However, these people can be fully functioning adults. Piaget’s theories at the concrete and formal operational stages measure abilities only in a very limited scientific, logical, algebraic sense. His theories do not address ethical or moral development. Thus a person may be a successful hard worker, a good, loving parent and spouse, and a good citizen, but be limited to concrete operational thought.

The final stage in Piaget’s theory is the formal operational stage, which may start as early as age eleven or twelve, but often later. A formal operational thinker can do abstract thinking and starts to enjoy abstract thought. This person becomes inventive with ideas and starts to delight in such thinking. He or she can formulate hypotheses without actually manipulating concrete objects, and when more adept can test the hypotheses mentally (Phillips, 1981). This testing of logical alternatives does not require recourse to real objects. The formal operational thinker can generalize from one kind of real object to another and to an abstract notion. In the experiment with the balls of clay, for example, the formal thinker can generalize this to sand or water and then to a general statement of conservation of matter. This person is capable of learning higher mathematics and then applying this mathematics to solve new problems. When faced with college algebra or calculus the concrete operational thinker is forced to learn the material by memorization but then is unable to use this material to solve unusual problems. The formal operational thinker is able to think ahead to plan the solution path (see Chapter 5 for a further discussion of problem solving) and do combinatorial thinking and generate many possibilities. Finally, the formal operational person is capable of metacognition, that is, thinking about thinking.

14.1.2. Application of Piaget’s Model to Engineering Education

The importance of the formal operational stage to engineering education is that engineering education requires formal operational thought. Many of the 30 to 60 percent of the adult population who have some trouble with formal operational thought appear to be in a *transitional* phase where they can correctly use formal operational thought some of the time but not all of the time. Engineering students in transition appear to be able to master engineering material (Pavelich, 1984). This probably occurs because they have learned that formal operational thought processes must be used in their engineering courses, but they have not generalized these processes to all areas of their life. This domain specificity of many students is one of the major criticisms of Piaget's theory (Pintrich, 1990).

The relatively small number of engineering students who are in the concrete operational stage will have difficulties in engineering. These students may make it through the curriculum by rote learning, partial credit, doing well in lab, repeating courses, and so forth. Concrete operational students can be identified by repeated administration of tests with novel problems on the same material (Wankat, 1983). On the first few tests students may be unable to work the problem either because of lack of knowledge or because of an inability to solve abstract problems. On the basis of a single test it is difficult to tell if lack of knowledge or poor problem-solving ability has caused the difficulties. Students who can use formal operational thinking learn from their mistakes, learn the missing knowledge, and fairly rapidly become able to solve difficult new problems. Students who are in the concrete operational stage do not appear to be able to learn from their mistakes on problems requiring formal operations. Thus, they make the same mistakes over and over. The solutions of these students do not appear to follow any logical pattern since they often just try something (anything) to see if it works and to see if they get any partial credit. These students have great difficulty in evaluating their solutions. In engineering, concrete operational students are likely to be quite frustrated and frustrating to work with.

The suggestion has been made repeatedly that freshmen-sophomore courses in engineering should be made available for nonengineering students (e.g., Bordogna, 1989). If this were done, the much higher percentage of concrete operational students in the general student population would likely cause problems in the course unless some type of screening or self-selection takes place.

14.1.3. Piaget's Theory of Learning

The presence of some concrete operational students in engineering leads us naturally to the question of how a student moves from one stage to another. This is another aspect of Piaget's theories. Piaget postulates that there are *mental structures* that determine how data and new information are perceived. If the new data make sense to the existing mental structure, then the new information is incorporated into the structure (*accommodation* in Piaget's terms). Note that the new data do not have to exactly match the existing structure to be incorporated into the structure. The process of accommodation allows for minor changes (figuratively, stretching, bending and twisting, but not breaking) in the structure to incorporate the new data. If the data are very different from the existing mental structure, it does not make any sense to incorporate them into the structure. The new information is either rejected or the information is *assimilated* or *transformed* so that it will fit into the structure. A concrete person will probably reject a concept requiring formal thought. If forced to do something with the data he or she will memorize even though the meaning is not understood. This is similar to memorizing a passage in a foreign language that one cannot speak. An example of transformation is a person's response to seeing a pink stoplight. Everyone "knows" that stoplights are red, and thus the pink stoplight will probably be registered as being red since red stoplights fit one's mental structure.

How does one develop mentally? How does one make the quantum leap from concrete to formal thinking? Mental development occurs because the organism has a natural desire to operate in a state of equilibrium. When information is received from the outside world which is too far away from the mental structure to be accommodated but makes enough sense that rejecting it is difficult, then the person is in a state of *disequilibrium.* The desire for equilibration is a very strong motivator to either change the structure or reject the data. If the new information requires formal thinking and the person is otherwise ready, then a first formal operational structure may be formed. This formal operational structure is at first specific for learning in one area and is slowly generalized (the person is in a transitional phase). The more often the person receives input which requires some formal logic, the more likely he or she is to make the jump to formal operational thought. Since this input takes place in a specific area, the transition to formal operations often occurs first in this one area. Also, a person with a less rigid personality structure and tolerance for ambiguity is probably more likely to make the transition. We emphasize that the transition to formal operations may not be easy.

Piaget developed a variety of experiments to test what stage children were in and to help them learn to make the transition to the next stage. Unfortunately, the experiments work well for testing the stage but not for moving people to the next stage. A method called the scientific *learning cycle* has been developed to help students in their mental development (Renner and Lawson, 1973; Lawson et al., 1989). In the scientific learning cycle the students are given first-hand experience, such as in a laboratory with an attempt to cause some disequilibration. The instructor then leads discussions either with individuals or in groups to introduce terms and to help accommodate the data and thus aid equilibration. Finally, students make further investigations or calculations to help the changed mental structure fit in with the other mental structures (organization). The scientific learning cycle is successful at helping people move to higher stages, but progress is very slow. Since concrete operational students may try hard but still have great difficulty in understanding abstract logic, the use of words like "obviously," "clearly," or "it is easy to show" by the professor is frustrating and demotivating to them. The scientific learning cycle is also useful for working with students who are already in the formal operational stage since these students also learn by being in a state of disequilibrium and using accommodation. The scientific learning cycle is discussed in more detail in Chapter 15.

Piaget's theory has partially withstood the test of time and partially been modified (Kurfiss, 1988). It is now generally agreed that individuals actively construct meaning. This has led to a theory called constructivism, which is discussed in more detail in Chapter 15. Piaget's general outline of how people learn and the need for disequilibrium has been validated. Disagreements with Piaget focus on the role of knowledge in learning. More recent researchers have found that both specific knowledge and general problem-solving skills are required to solve problems, while Piaget did not recognize the importance of specific knowledge.

14.2. PERRY'S THEORY OF DEVELOPMENT OF COLLEGE STUDENTS

William G. Perry, Jr., studied the development of students at Harvard University through their four years at the university. His team used open-ended interviews as the technique of measurement. Over a period of years a pattern of development could be distinguished among all the varied responses of the students. Perry then used this pattern of development to rate another group of students. This replication showed that the scheme was reproducible at least for the men at Harvard University. Since publication of the results in 1970 (Perry, 1970), interest in Perry's theory of development during the college years has grown until now his book is being called "the most influential book of the past twenty years" on how college students respond to their college education (Eble, 1988). Perry's study has been criticized since the group studied was quite homogeneous and consisted mainly of young men from privileged backgrounds. Additional studies since 1970 have essentially duplicated Perry's results and shown that his scheme has fairly general validity except that extensive modifications need to be made for the development of women (Belenky et al., 1986). See Kurfiss (1988) or Moore (1989) for references.

Although Perry's model has become quite influential in higher education in general, engineering education has lagged behind. The model appears to have been introduced in engineering education by Culver and his coworkers. Culver and Hackos (1982) presented an overview of Perry's scheme and discussed implications for engineering education. Fitch and Culver (1984) and Culver and Fitch (1988) presented data on the positions in Perry's model of engineering students, and discussed educational activities to encourage student development. Culver (1985a) described a workshop on Perry's model and discussed a developmental instructional model based on Perry's work. Culver (1985b) considered values in engineering education and specifically related them to Perry's model. Hackos (1985) discussed using writing to improve problem-solving skills and to enhance intellectual development. The next year Culver (1986) continued his series by discussing how Perry's model was useful in explaining the effects of motivation exercises. Culver (1987a) described applications of Perry's model in encouraging students to learn on their own and presented a workshop (Culver, 1987b) which was an overview of Perry's model and of applications to engineering education. Pavelich and Fitch (1988) measured engineering students' progress through Perry's positions and concluded that it is slow. Culver et al. (1990) discussed the redesign of design courses and curricula to aid the progress of students on Perry's model. [Note that in engineering education earlier efforts were made to tackle some of the problems clearly posed by Perry, but Perry's complete scheme was not used.]

It would be convenient if Perry's scheme started where Piaget's theory stops. Chronologically, the two theories do fit this way, but in other more important ways the theories are *not* a match. Perry does use Piaget's ideas of how students learn. That is, a certain amount of disequilibration is necessary for accommodation to occur. However, Perry's theory is not concerned with problem solving and the applications of logic as are the concrete and formal operational stages of Piaget's theory. Briefly stated, Perry's model is concerned first with how students move from a *dualistic* (right versus wrong) view of the universe to a more *relativistic* view, and second, how students develop commitments within this relativistic world. There is a strong learning connotation in Perry's model since students cannot understand or answer questions which are in a developmental sense too far above them.

14.2.1. Positions in Perry's Model

From his interviews and by extrapolation Perry (1970) postulated nine *positions* as shown in Figure 14-1. These positions and the movement from position to position represent the major contribution of Perry's model.

Position 1: Basic Duality. The person sees the world dualistically, right versus wrong. There are no alternatives. Authorities know all the answers. Men appear to identify with the authority figure while women do not (Belenky et al., 1986). The teacher as an authority is supposed to teach the correct answers to the students. Failure to do so means that the teacher is a bad teacher. Hard work and obedience will be rewarded. Authority is so all-knowing that all deviations from authority are lumped together with error and evil. Perry (1970) notes that this position is basically naive since there is no alternative or vantage point which allows the person to observe her- or himself.

Perry (1970) talked to freshmen after one year at Harvard. He did not talk to anyone in position 1 but inferred this position from student reports about what they had been like when they entered Harvard. Perry notes that this position's assumptions are incompatible with the culture of pluralistic universities and thus students will be unable to maintain this position if they stay at the university. Much of the confrontation with pluralism occurs in residence halls, which may be a good reason to strongly encourage freshmen to live in residence halls. Many other studies (e.g., Moffatt, 1989) have reaffirmed the importance of residence halls in the development of students. Students may start in this position because of a culturally homogeneous or narrow environment, but they will quickly lose their innocence at a university.

Confrontations with their basic dualistic position both in class and in residence halls cause disequilibration. The student tries to accommodate the new ideas of multiplicity. This can be done by moving to position 2 or, at least temporarily, by modifying position 1. The modified position 1 assumes that absolute truths exist, but that authorities may not know what these

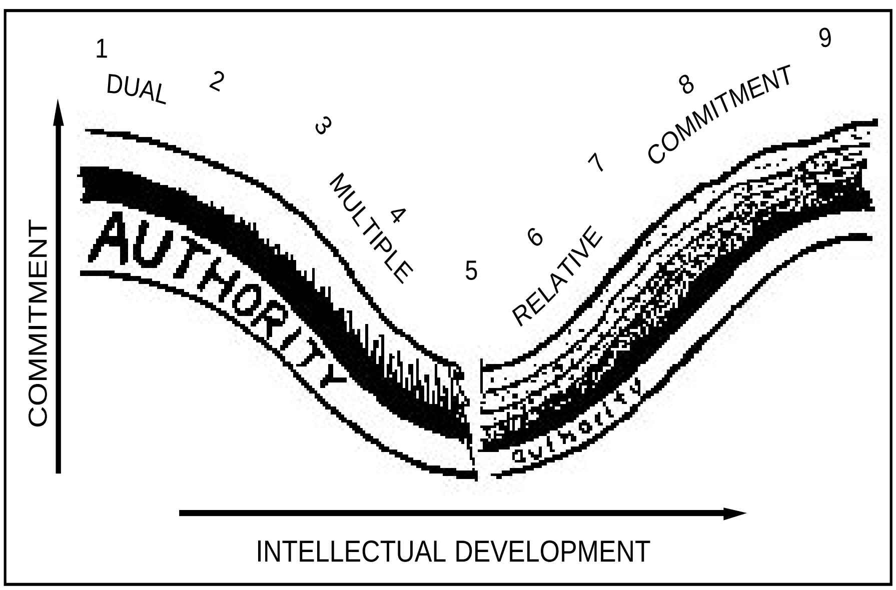

FIGURE 14-1 PERRY'S MODEL OF INTELLECTUAL DEVELOPMENT (Culver and Hackos, 1982)

truths are. Thus conflicts are explained since authority doesn't know the truth, but if one searches hard enough there is an absolute truth. This modified position itself leads to position 2 since the modified position admits that authorities can make errors. Unfortunately, there is another possible outcome to the stress induced by confronting multiplicity at the university. The student may leave.

In their study of the development of women, Belenky et al. (1986) included individuals from many social classes. By talking to women in social service agencies, they detected the presence of a position before (or below) position 1 which they called "silence." These women were from very deprived or abusive backgrounds. "Silent" women were unable to understand the words of others and were unable to articulate their own thoughts and feelings. With the steady increase in older students returning to college, some women who have once been in this position will become engineering students.

Position 1 is also the home of intolerance and bigotry. It appears to us that this is the basic position taken by some cults. Although engineering educators tend to shy away from moral arguments, there seem to be clear moral reasons to help students move out of position 1 into position 2.

Position 2: Dualism: Multiplicity Prelegitimate. In position 2 the student can perceive that multiplicity exists but still has a basic dualistic view of the world. There is a right and a wrong. Multiple views or indications that there are "gray" areas are either wrong or interpreted as authority playing games. Since it is possible for authority to be wrong, the absolutes are separate from authority. Thus, some authorities are smarter than others. This position may lead to the feeling that "I am right and authority is needlessly confused." The person may hold the view that there is one answer, but authority shows multiple answers as a game to make students learn how to find the one right answer.

An engineering student in position 2 can successfully solve problems, particularly closed-end problems, with a single right answer. These are the types of problems students in position 2 expect, and these students prefer engineering classes to humanities classes because the problems fit their dualistic mode of thought. In design classes, where problems have multiple answers, these students have difficulties, and they protest against open-ended problems. A student in position 2 wants the teacher to be the source of correct knowledge and to deliver that knowledge without confusing the issues. In this student's view a good teacher presents a logical, structured lecture and gives students chances to practice their skills. The student can then demonstrate that he or she has the right knowledge. From the student's viewpoint a fair test should be very similar to the homework.

Perry notes that students are bewildered and protest as they move from position 1 to position 2. The move from position 1 to position 2 may appear to be small; however, the student has made a major concession by allowing for some complexity and some groping into uncertainty.

In the two dualistic positions men and women use language differently. In general, men tend to talk and women listen. Since listening to authorities is the primary focus of women in the dualistic positions, Belenky et al. (1986) call these positions "received knowledge."

Position 3: Multiplicity Subordinate or Early Multiplicity. In position 3 multiplicity has become unavoidable even in hard sciences and engineering. There is still one right answer, but it may be unknown by authority. Thus the gap between authority and the one truth has been widened. The student realizes that in some areas the knowledge is "fuzzy."

This position has some built-in procedural conflicts. If authority does not yet know the answer, how can the professor evaluate the student's work? This is a considerable change from position 2 where honest hard work would presumably lead to the correct answers. Now, in position 3 honest hard work is no longer guaranteed to produce correct answers, and thus good grades seem to be based more on "good expression." The big question students ask is "What do *they* want?" The methods for evaluation become a very important issue and students want the amount of effort put into something to count. From the students' perspective a good professor clearly explains the methods used for determining the right answer even if he or she does not (temporarily) know the right answer, and the good professor presents very clearly defined criteria for evaluation.

For men education appears to play a significant role in the shift to multiplicity. From a developmental sense, one problem with engineering education is that there are few challenges at the lower levels to move the student into position 3 or 4. In class the challenges of multiplicity usually come in senior design classes and in graduate school. The lower-level classes are usually taught as if everything is known. This can lead to severe stress for students in a design course where multiple answers are expected and they are suddenly expected to function in a world with multiple answers. Students survive design courses but often do so without changing a great deal. This survival may occur because design is an isolated class which lasts only for one semester, and the legitimacy of multiplicity may not be reinforced in other classes or in the rest of the student's life. In addition, students who are academically very good can often hide from the challenges of multiplicity through competence (their design is likely to have fewer technical errors and they receive good grades). Beginning graduate students often become very frustrated as they try to determine what they are supposed to do. With less structure, fewer supports, a longer-term reward compared to seniors, and more pressure to adjust to a world of multiplicity, the graduate student's frustration is understandable. Graduate work in engineering and the physical sciences is similar to undergraduate work in the humanities in the respect that both confront the student with multiplicity and uncertainty.

For women formal education is relatively unimportant for the shift into "subjectivism" [the term used by Belenky et al. (1986) for multiplicity]. Women appeared to shift into subjectivism "after some crisis of trust in male authority in their daily lives, coupled with some confirmatory experience that they, too, could know something for sure" (Belenky et al., 1986, p. 58).

Position 4: Complex Dualism and Advanced Multiplicity. The student tries to retain a dualistic right-versus-wrong position but realizes that there are areas of legitimate uncertainty and diversity of opinion. Students react to position 4 in one of two ways. They may conform to what authority seems to want and learn the forms of independent intellectual thought. These students learn that *independent-like* thought will earn them good grades. Genuinely independent thought has not yet been achieved or even considered as an issue. Most of the students Perry studied took this route. However, learning the forms is not enough, and these students may be tempted to *escape*.

The second reaction is that the student may oppose what authority wants in areas where multiplicity is important. The student may raise this multiplicity of opinions to a pervasive viewpoint that "anyone has a right to their own opinion." This raises areas of multiplicity and uncertainty to equal status with areas of dualism. "Everyone has a right to their own opinion" is obviously a wonderful position from which to fight authority. The danger of this position is that a bland "anything goes" attitude may prevail. The student may refuse to think since he or she believes everything can be solved by intuition. Men in this position fight authority openly, while women fight authority internally as "hidden multiplists" (Belenky et al., 1986). These women may be silently alienated from college. Since engineering does not affect their interior life, engineering may appear irrelevant and they may quit engineering even though they can do the work. This position was taken by fewer students and is probably rare for engineering students.

An engineer in position 4 can solve problems cleverly and creatively. The task of solving the problems becomes a game. Unfortunately, he or she cannot see that some problems are much more important than others. This person lacks vision and may solve problems considered unimportant or even immoral by others. Many engineering graduates with both baccalaureate and advanced degrees seem to be in positions 3 and 4.

Position 5: Relativism. In position 5 a person sees everything as relative, not because authority wants it that way but because that is the way he or she sees the world. There is a revolutionary switch from position 4 to position 5. In position 5 relativism becomes the common characteristic of everything and absolutes are a special case. One must then determine if complexity is *not* necessary. In position 4 the situation was the reverse: Dualism was the general principle, and relativism was a special case useful for certain classes of problems. Perry noted that this is often an extremely quiet revolution and that students hardly notice that it has occurred. The relativistic thought process becomes habitual without being noticed. For very focused students in engineering or science, position 5 may come as a shock when they realize that everything is relative in advanced classes.

Perry saw this position as occurring in three subpositions. First, the person divides the world into a relativistic area and into a dualistic area where authority still has answers. Then, the whole world is seen as relativistic, but this position alternates with a dualistic position. Finally, the whole world is seen as relativistic.

The relativistic position can be a very powerful one. There is room for detachment and objectivity. One can think previously forbidden thoughts. This ability to stand outside the situation and think objectively may, in Perry's words, "rank with language as the distinctive triumph of the human mind." The person in the relativistic position can get beyond the statement "all opinions are equal" by using the laws of evidence to develop positions which are more likely.

Belenky et al. (1986) noted that men and women may use different logical procedures in position 5, which they called "procedural knowledge." Most men and some women use the traditional logical approach with objective analysis and argument to form opinions. This s*eparate knowledge* or *objective knowledge* (Palmer, 1983) purposefully removes the person's personal experiences and feelings from the logical analysis. Separate knowledge emphasizes doubting and argument. It is the method one would expect from thinking types on the MBTI (see Chapter 13). This corresponds to the usual engineering approach. Arguments are supposed to be between positions, but many women have difficulty separating positions from people. Some women and men use an approach called *connected knowledge* which is an empathic treatment of divergent views. Connected knowledge personalizes knowledge and attempts to understand the reasons for another's way of thinking. Belief, not doubt, that the other is right from his or her viewpoint is the key stance of connected knowledge. Both feelings and thought are important. Connected knowledge would be expected of Myers-Briggs feeling types who are in position 5. In the same way that everyone has both feeling and thinking capabilities, everyone has the potential to learn both separate and connected knowledge. Individuals who strongly prefer to use connected knowledge as a way of understanding may find the environment at an engineering college somewhat hostile—since only separate knowledge is taught. Because these individuals can make major contributions as engineers (e.g., in life cycle design or conflict resolution), it is important to accommodate them in the educational system. For women the presence of a benign and encouraging authority appears to facilitate movement into position 5.

From the student's viewpoint in position 5 a good instructor acts as a source of expertise, but does not know all the answers since many answers are unknowable. This professor helps students become adept at forming rules to develop reasonable and likely solutions or solution paths. It is important for the professor to show that good opinions are supported by reasons. The student has become much more comfortable with being evaluated in a relativistic world and realizes that the evaluation is of her or his work and not of her or him.

There are problems in position 5. The world is full of possibilities, and there does not appear to be a clear way to choose. Decisions which were made earlier are now called into doubt. The student wonders whether engineering really is the right choice. Did he or she really marry the right person? And so on. Position 5 then represents both a period of strength and possibilities and a period of doubt and loneliness. Assuming that a person is eventually going to move into position 5, it is probably better to do so early while many important career and life decisions have yet to be made. Position 5 can also appear "cold" and even sinister to others because of the focus on method and the dissociation between means and values.

Position 6: Relativism: Commitment Foreseen. The way out of the uncertainty of relativism is *commitment*. In position 6 the student can see the need for commitment but has not yet made the commitment. This need for commitment may be seen as a logical necessity (this is likely for people who are a *T* on the MBTI or may be felt (people who are an *F*). Commitment may be looked forward to with eagerness, or the person may fight commitment. People who fight commitment may stay uncomfortably in position 5, or they may escape or retreat (these are discussed later).

Many students think they have already made firm commitments. Perry uses Commitment (with a capital C) to have a special meaning. Commitment is a mature decision made after one has accepted that the world can be viewed as relativistic and has seen all the possibilities. Previous decisions have been called into doubt and looked at objectively from a detached viewpoint. The new Commitment may be the same decision made previously, but the Commitment is deeper. Commitments can be made in a variety of areas such as career, religion, marriage, politics, values, and so forth. The Commitments one makes help set the person's identity and style. At this point one makes an objective decision on how much of the past to reject and how much to retain. This shedding of parts of the past is clearly different from adolescent rebellion which tends to be mindless.

In position 6 the person can see this need for Commitment, but the Commitment has not yet been made. People who move forward into position 7 often do so in one area of their lives at a time. They remain in position 6 in other areas.

For an engineering student who has invested a great deal of time in studying engineering, going through position 5 can be very unsettling. Position 6 can be something of a relief since the student sees that it is all right to commit to engineering if objectively that is a good decision. However, a major Commitment is not to be rushed, and the person may stay in position 6 for a while.

Positions 7 through 9: Levels of Commitment. Positions 7 through 9 are all levels of Commitment starting with initial Commitment in position 7. These positions represent degrees of development and depth of Commitment and are not as clearly defined as are the other positions. The person moves from position 6 into position 7 in one area by making a Commitment of his or her own free will. For some this is risky and may be done tentatively in relatively safe areas. As the person becomes more comfortable with making Commitments, he or she makes them in areas that are not as safe, eventually finding not only that a series of finite, discrete decisions have been made, but that a way of life has been developed.

Perry sees the student in position 7 first taking responsibility for who he is or will be in some major area of his life ("I'll stay in engineering"). In position 8, stylistic issues of Commitment become important. "If I am going to be an electrical engineer, how will I do it?" "What will my specialties be?" "What degrees should I get?" And so forth. Position 9 is a postulated position of maturity where the person has developed a sense of self in both Commitments and style. Perry postulated that this is a position reached some time after graduation. Women also make a commitment but it is to a life rather than the single Commitments men often make (Belenky et al., 1986).

Belenky et al. (1986) added insight into the thought processes of the Commitment positions. The thought process uses *constructed knowledge* where procedural knowledge gained from others is integrated with personal or "inner" subjective knowledge based on personal experience and introspection. This constructed knowledge allows the individual to integrate thought and feeling and avoid the compartmentalization which Belenky et al. (1986) perceive as a shortcoming of objective knowledge. At the levels of Commitment a good instructor needs to provide freedom so that students can learn what they need to learn (e.g., Rogers, 1969). The instructor also needs to forge linkages within the class (Palmer, 1983).

Perry's model is a staged model which tends to ignore the situational specificity of behavior and knowledge. Real people in real situations have the annoying tendency to be complex. They don't fit into one stage, but depending upon the situation may be in several different stages. Despite this difficulty, Perry's model is a very useful model for conceptualizing the development of college students. A more recent model which builds on Perry's model is the reflective judgment model (Kitchener, 1986).

14.2.2. Alternatives to Growth

Perry hypothesizes that natural growth is from position 1 toward position 9. At Harvard he saw many students graduate in positions 7 and 8. However, he notes that growth is not inevitable. In engineering it is likely that many students leave in positions 3 and 4. The three alternatives to growth are *temporizing, retreat,* and *escape*. Note that these names incorporate Perry's hypothesis that movement from position 1 toward position 9 is growth and thus is desirable.

Temporizing. Growth does not occur linearly. Instead, periods of intense growth are commonly followed by pauses or plateaus. Perry defined *temporizing* as a pause in growth over a full academic year. All students go through plateau periods. Temporizing is just a rather long plateau and by itself is not bad. It may be a period in which the student gathers strength for the growth which lies ahead. In this case the student often seems aware that he or she is waiting for the correct combination of energy and will to move on. In an alternate mood of temporizing the student waits for fate to decide what will happen and may drift into escape.

Retreat. Retreat is regression to earlier positions. The most dramatic such retreat is movement back to position 3 or 2 when the complexities of relativism and multiplicity become overwhelming. (Retreat into position 1 is also possible, but in Perry's study these students presumably dropped out of Harvard.) Retreat into dualism requires an enemy. The student must be on her or his guard against the pluralistic university. Students seem to be most susceptible to retreating to dualism when they rely on authoritarian structures for emotional control. Retreat also occurs from higher levels but is not as dramatic. For example, a student may retreat from position 6 or 5 to position 4 where he or she can hide in the concept that "everyone has the right to his or her own opinion."

Escape. In escape the student avoids Commitment by exploiting the detachment afforded by positions 4 and 5. Perry's team noted two paths of escape both of which started from temporizing. In *dissociation* the student drifts into a passive delegation of responsibility to fate. She or he ends up in position 4. The alternate path is *encapsulation* which may be a favorite of engineering students. In encapsulation one avoids relativism by sheer competence in one's field. The student becomes very good at engineering but avoids any questions of deeper meaning or value. Engineers can use encapsulation to stay in position 4 or 5 for years. Escape need not be permanent, and people find different ways to resume growth.

14.2.3. Implications for Engineering Education

Perry's model has both value-free and value-laden implications for engineering education. Since the subject is less controversial, we will start with the implications which are relatively value-free. The major inescapable conclusion from Perry's model is that different students require different learning environments. This is no surprise since all models of learning come to the same conclusion. Students are not capable of understanding knowledge or questions which are too far above them as far as Perry's positions are concerned. If pushed to try to understand this material, they will become frustrated. How far above is too far? Perry does not address this issue. From our experience, questions which are one position above the student's position can, perhaps with considerable difficulty, be answered. Questions or knowledge two positions above the student's current position cause frustration. Students are capable of answering questions in positions below them although they may find these questions easy or may read too much into them. Appropriate teacher responses at each position were discussed with the descriptions of each position. How does the teacher provide an optimum learning environment for a heterogeneous class with students at a variety of levels? This is the key challenge of individualizing instruction, and there is no clear-cut answer. Some possible approaches were discussed in Chapters 5 through 10.

Most of the applications of Perry's model to engineering education involve the value judgment that growth on Perry's scale is desirable (at least up to some level) and should be fostered. Perry considered this question and decided that growth was both natural and desirable. However, his sample contained no engineering students and in many ways was quite narrow. The faculty at each school need to face the question of whether or not to encourage growth on Perry's scale. Failure to encourage growth is equivalent to a negative answer. Currently, engineering students show little progress toward higher Perry levels and may actually regress slightly during their engineering studies (Fitch and Culver, 1984; Pavelich and Fitch, 1988). Thus, if the faculty decide that growth is desirable, engineering education must be changed.

As noted previously, we feel that there are clear moral grounds for strongly encouraging students in position 1 to grow into position 2. Students and practicing engineers in positions 1 and 2 will have significant difficulty practicing engineering in our multiplistic society. Fortunately, the samples reported by Fitch and Culver (1984) and Pavelich and Fitch (1988) showed very few students who were clearly in position 2 (and none in position 1). A large number of students were in transition between positions 2 and 3, and the mean position for all engineering students was about 2.8. Students in transition between positions 2 and 3 can see and accept multiplicity in some areas, and they accept that authority does not have all the answers. This transition region appears to be the minimum region in which a student can successfully study and practice engineering. These engineers cannot see the big picture, and without further growth they are unlikely to advance significantly in their careers. Fitch and Culver (1984) also reported many students in position 3 and a few in the transition between position 3 and 4. No undergraduate engineering students in positions 4 or higher were observed. Pavelich and Fitch (1988) found that the written test used to measure students' developmental levels (Measure of Intellectual Development, the MID) was quite conservative. Interviews showed students who were at levels 4 and 5. This should be contrasted to Perry's sample of liberal arts students at Harvard where the average entering level was approximately position 4 and 75 percent were judged to be in position 7 or 8 at graduation. [Note: Perry appears to have had an unusual sample. Other studies have consistently found more students at lower levels (Kurfiss, 1988).]

The reasons for moving students to at least the transition between positions 2 and 3 are clear. Below this level they will have difficulty functioning as engineering students. Graduate students in thesis masters and Ph.D. programs will have trouble functioning below level 3 since they will not be able to answer the question "What do they want?" Research in graduate school seems to be structured to encourage the transition to position 3 if the student is not already there. Continued graduate study often moves the graduate student into position 4. Thus, engineering schools have implicitly made the decisions that undergraduates should reach at least the 2-to-3 transition and that graduate students should reach level 3 or 4 before graduation.

Is this sufficient? Probably most faculty will answer no. They want graduate students to operate at least at the level of the better students (position 4), and they want undergraduates to approach this level (say the 3-to-4 transition). In this regard Perry (1970) offers an interesting quote: “Fifty years ago [1920], our researches suggest, a college senior might achieve a world view such as that of Position 3 or Position 4 on our scheme and count himself a mature man.”

Superficially, it is easy to conclude that engineering education must change and take students past position 4. However, there are many dangers to this.

1 Taking the student to position 5 will fill the student with doubts about engineering as a profession. If a school purposely takes a student to position 5, the school must ethically help her or him to at least position 6. Some of these students will decide to make a Commitment to another profession.

2 It is difficult to take engineering students to position 5 even if we decide we want to. Engineering education at the undergraduate level reinforces positions 2 and 3, and at the graduate level does little to push students to position 5. Engineering students are very adept at escaping into competence once they reach position 3 or 4.

3 Many employers are happy with the current graduates at both undergraduate and graduate levels. This includes engineering schools as employers of Ph.D.s.

4 A consensus of engineering professors does not exist.

5 Absolute standards in physical laws are a useful mental construct despite the Heisenberg uncertainty principle. Perry’s relativism can undermine this absolute standard (Graff et al., 1991.)

6 Some professors feel that there *should* be absolute standards in engineering ethics (Graff et al., 1991). This is a different value judgment than Perry’s.

There are reasons for encouraging students to move beyond their current positions.

1 Growth appears to be natural and in this sense is “good.”

2 Growth into positions 7 through 9 appears to be necessary to function well in important positions such as vice-president, dean, president, and CEO (e.g., see Florman, 1987, p. 178). In a technological society we need more engineers in these positions.

3 “The main trouble with engineers has not been their lack of morality. It has been their failure to recognize that life is complex” (Florman, 1976, p. 27).

4 For women, movement to higher-level positions is empowering and helps them act as equals with men.

What types of activities and teaching encourage growth? Fitch and Culver (1984), Culver (1985a,b), and Culver and Fitch (1988) make the following suggestions based on the work of Lee Knefelkamp. First, since highly structured courses reinforce the lower levels, the curriculum should be restructured so that courses become progressively less structured. Second, a diversity of learning tasks is required, which means that the use of a single textbook in a course probably is not enough. Third, students need concrete learning experiences such as case studies, team projects, industrial experience, and so forth. These experiences should be designed to reinforce diversity. Fourth, a learning environment which supports risk taking needs to be developed in engineering classes and in the university as a whole. Additional suggestions can be added from the research of Belenky et al. (1986). First, the student needs assurance that she is capable, and this support is needed from the beginning. Successful programs for women in engineering always include a significant component of support. Unfortunately, many women distrust praise from male professors. “The women worried that professors who praised their minds really desired their bodies” (Belenky et al., 1986, p. 197). Second, separating evaluation from instruction is valuable for many students. It is difficult for many professors to be supportive when they know they will have to evaluate later. Evaluation and instruction can be separated by using separate competency examinations scored by outsiders or by having separate help classes taught by instructors not involved in the graded class. Third, professors need to think out loud instead of presenting prepackaged thoughts as finished solutions (see Chapter 5 for further discussion of this). Finally, it is particularly important for professors of engineering and science “to avoid the appearance of omniscience” (Belenky et al., 1986, p. 216).

One learning environment designed to encourage intellectual growth is the *practice-theory-practice* model developed by Lee Knefelkamp which has been applied in engineering education by Culver (1985a, 1986, 1987a). In this model a concrete experience (practice) is used to introduce the concept. Then theory is developed to explain the experience. Finally, further practice is used to reinforce the theory and to provide an extension to other material. This type of cycle appears to be particularly important for women who found concepts useful in understanding their experience but balked at an abstract approach devoid of experience (Belenky et al., 1986). To be effective for producing intellectual development, the experiences and theory must be understandable at the stage of development of the student, but the experience must also challenge the student. Activities appropriate for graduate students are probably inappropriate for freshmen. Learning cycles which encourage intellectual growth are discussed in detail in Chapter 15.

Perry found that dormitory living was very important for moving students out of the lower levels. He also found that liberal arts courses were very valuable in helping students grow. Can liberal arts courses help engineering students grow on Perry’s scale? The answer appears to be of the “yes, but” variety. Florman (1987) is strongly in favor of liberal arts for engineers, yet he notes (p. 173), “One need not be a broadly educated scholar in order to be a topnotch engineer.” Liberal arts courses can be useful, but some restructuring is probably needed. Certain courses such as beginning language courses and beginning economics courses have little effect. In other liberal arts courses engineers need to be mixed in with students from other areas. Putting all engineers into the same class defeats much of the purpose of achieving diversity. Since engineering students often see liberal arts courses as unimportant, the engineering *faculty* has to work hard to change this opinion. And since the students do not take a critical mass of liberal arts courses, ideas of multiplicity and relativism need to be reinforced in engineering classes. The liberal arts courses should be selected to challenge the student successfully no matter what his or her level. Dissonance, which is necessary for change, can be generated by writing or discussion but not by multiple-choice tests. Thus, courses must have significant writing or discussion.

One additional implication of Perry's model is somewhat disturbing. Mature students may find beginning engineering and science courses intellectually unchallenging and perhaps even stultifying. These students may find liberal arts or the social sciences more intellectually fulfilling and drop engineering. Evidence for this is contained in the study of Tobias (1990) exploring why some students drop science and engineering. A paradoxical result of this is that with current course levels it may be advantageous to delay intellectual growth until students have completed the lower-level courses. Obviously, there are many views on how much engineering education should do to move students on Perry's scale, but there is absolutely no correct view.

14.3. CHAPTER COMMENTS

Piaget's theories have had a major impact on the teaching of science, but little impact in engineering. One possible reason for this difference is that engineers generally teach only engineers, whereas scientists teach everyone in the university. Thus, engineering classes have a small percentage of students who are in the concrete operational stage. Since there are few of them and most of them do not survive in engineering, it has been easy for engineering professors to ignore them.

Teaching Perry's model to graduate students can be an interesting experience for an engineering professor. We have encountered strong resistance to Perry's value judgment that growth on his model is positive. This resistance came from strongly religious graduate students. The most palatable presentation of Perry's model for these students clearly separated the observed behavior (the positions) from the value judgment. In addition, these students preferred to consider relativism as a way in which people *can* look at the world instead of Perry's formulation that this *is* the way the world is.

There is a strong tendency to demand equal rights and opportunities for women without looking at the real differences between men and women which were discovered in the research by Belenky et al. (1986). In our opinion equal opportunity does not imply an education that is exactly the same for men and women. Since many current educational practices are more tuned to the ways men learn and develop, women have less opportunity to benefit. Ideally, an equal opportunity education would involve many educational opportunities which are helpful for students with very different developmental needs and methods of knowing. Belenky et al. (1986) noted that there are different methods of knowing than those identified by Perry (1970). The different paths appear to be the result of socialization, not hardwired gender differences. Once we admit to more than one approach to knowledge, it is logical while studying multiplicity to expect multiple paths caused by different socialization procedures in different societies. What other paths might there be? Palmer (1983) discusses a spiritual path. Another path is through dreams. The Senoi tribe in Malaysia clearly uses dreams as a path to knowledge (Garfield, 1974). Although it is difficult to conceive of teaching engineering in Western society through dreams, they have often played a role in the solution of technical problems. Other paths to knowing exist and have been explored by anthropologists.

14.4. SUMMARY AND OBJECTIVES

After reading this chapter, you should be able to:

• Describe Piaget's theory to another engineering professor and discuss its implications for engineering education.

• Describe Perry's theory to another engineering professor and discuss the specific value judgments in this theory. Do you agree or disagree with these values? Outline how Perry's theory as modified by your value judgments impacts engineering education.

• Discuss how the development of men and women may differ. Outline the consequences of this in engineering education.

HOMEWORK

1 Several students come to you to complain bitterly that Prof. Whatastar gives tests that are very different from the reading and homework assignments; he also requires solving problems the students have never seen before.
  a Use Piaget's model and Perry's model to explain what is going on.
  b What can the students do to prepare better for Prof. Whatastar's exams?

2 Explore the differences and similarities between a good sophomore engineering course and a good graduate-level engineering course. Bolster your discussion with evidence from the theories discussed in this chapter.

3 Students who earn B.A. degrees and then return to take engineering courses often do not do well. Although there may be a variety of reasons for this phenomenon, discuss possible reasons based on Piaget's and Perry's theories.

4 Should you share with students their level on Perry's scheme? Discuss the pros and cons of sharing this information.

5 Individuals in the concrete operational stage often become very frustrated by science and engineering courses in college. What course of action would you take? Explain why. Do you believe universities should try to help concrete operational students grow into the formal operational stage?

6 Should engineering education be reorganized to produce larger gains on Perry's scale? Note: Do all three parts.
  a Assume the answer is yes and argue in favor of changing the system.
  b For part a, discuss what changes you would recommend.
  c Assume the answer is no and argue against changing the system.

7 Classify yourself on Perry's model or on the modified model for women.

8 It is often noted that Piaget was really an epistemologist and not a psychologist. Do you agree? Does it really matter?

9 Do the third objective in Section 14.4.

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