The First Step of Being an Effective Engineering Educator: Know Your Students' Learning Styles

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***Abstract*:** People have different learning styles that are reflected in different academic strengths, weaknesses, skills, and interests. Given the almost unlimited variety of job descriptions within engineering, it is safe to say that students with every possible learning style have the potential to succeed as engineers. However, they may not be equally likely to succeed in engineering school, since they respond differently to different instructional approaches and the predominant mode of instruction favours some learning styles over others. Understanding learning style differences is thus an important step in designing balanced instruction that is effective for all students. The *Index of Learning Styles* which is a self-scoring instrument that assesses preferences on the Sensing/Intuiting, Visual/Verbal, Active/Reflective, and Sequential/Global dimensions developed by Felder and Silverman was administered to all first year students taking engineering programmes at Universiti Teknologi Malaysia. Students' preferences are categorized into strong, moderate and fairly balanced. The paper also suggests method of instructions that can benefit students of all types in lectures, seminars and labs.

1.0 Introduction

Students learn in many ways by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing and drawing analogies and building mathematical models. Teaching methods also vary. Some lecturers lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding. How much a student learns in a class is governed in part by that student's native ability and prior preparation but also by the compatibility of his or her learning style and the instructor's teaching style.

Serious mismatches may occur between the learning styles of students in a class and the teaching style of the instructor [1] with unfortunate potential consequences. The students tend to be bored and inattentive in class, do poorly on tests, get discouraged about the course, and may conclude that they are no good at the subject of the course and give up [1][2]. Lecturers, confronted by low test grades, unresponsive or hostile classes, poor attendance, and dropouts, may become overly critical of their students (making things even worse) or begin to question their own competence as teachers.

In this paper, we will explore the following questions:

(a) Which aspects of learning style are particularly significant in engineering education?
(b) Which learning styles are preferred by most students?
(c) What can be done to reach students whose learning styles are not addressed by standard methods of engineering education?

2.0 Dimensions of Learning

In the following sections, we describe five dichotomous learning style dimensions derived from work of Felder et al. [1][2], indicating the ways in which the educational needs of students with strong preferences for certain poles of the dimensions are not met by traditional approaches. The proposed learning style dimensions may be defined in terms of the answers to the following five questions:

1. What type of information does the student preferentially perceive: *sensory* - sights, sounds, physical sensations, or *intuitive* - memories, ideas, insights?
2. Through which modality is sensory information most effectively perceived: *visual* - pictures, diagrams, graphs, demonstrations, or *verbal* - written and spoken words and formulas?
3. With which organization of information is the student most comfortable: *inductive* – facts and observations are given, underlying principles are inferred or *deductive* - principles are given, consequences and applications are deduced?
4. How does the student prefer to process information: *actively* - through engagement in physical activity or discussion, or *reflectively* - through introspection?
5. How does the student progress toward understanding: *sequentially* - *in* a logical progression of small incremental steps, or *globally* - *in* large jumps, holistically?

2.1 Sensing and Intuitive Learners

In his theory of psychological types, Jung [3] introduced *sensation* and *intuition* as the two ways in which people tend to perceive the world. Sensing involves observing, gathering data through the senses; intuition involves indirect perception by way of the subconscious - accessing memory, speculating, imagining. Everyone uses both faculties constantly, but most people tend to favour one over the other.

Sensors like facts, data, and experimentation; intuitors prefer principles and theories. Sensors like solving problems by standard methods and dislike "surprises"; intuitors like innovation and dislike repetition. Sensors are patient with detail but do not like complications; intuitors are bored by detail and welcome complications. Sensors are good at memorizing facts; intuitors are good at grasping new concepts. Sensors are careful but may be slow; intuitors are quick but may be careless. These characteristics are tendencies of the two types, not invariable behavior patterns: any individual - even a strong sensor or intuitor - may manifest signs of either type on any given occasion.

Most engineering courses other than laboratories emphasize concepts rather than facts and use primarily lectures and readings (words, symbols) to transmit information, and so favour intuitive learners.

2.2 Visual and Verbal Learners

The ways people receive information may be divided into three categories, sometimes referred to as modalities: *visual* - sights, pictures, diagrams, symbols; *auditory* - sounds, words; *kinesthetic* - taste, touch, and smell. An extensive body of research has established that most people learn most effectively with one of the three modalities and tend to miss or ignore information presented in either of the other two [1][4]. There are thus visual, auditory, and kinesthetic learners.

Visual learners remember best what they see: pictures, diagrams, flow charts, time lines, films, demonstrations. If something is simply said to them they will probably forget it. Auditory learners remember much of what they hear and more of what they hear and then say. They get a lot out of discussion, prefer verbal explanation to visual demonstration, and learn effectively by explaining things to others.

Most people of college age and older are visual [1] while most college teaching is verbal i.e. the information presented is predominantly auditory (lecturing) or a visual representation of auditory information (words and mathematical symbols written in texts and handouts, on transparencies, or on a chalkboard).

2.3 Inductive and deductive Learners

Induction is a reasoning progression that proceeds from particulars (observations, measurements, data) to generalities (governing rules, laws, theories). *Deduction* proceeds in the opposite direction. In induction one infers principles; in deduction one deduces consequences. *Induction is the natural human learning style.* Babies do not come into life with a set of general principles but rather observe the world around them and draw inferences: "If I throw my bottle and scream loudly, someone eventually shows up." Most of what we learn on our own (as opposed to in class) originates in a real situation or problem that needs to be addressed and solved, not in a general principle; deduction may be part of the solution process but it is never the entire process

On the other hand, *deduction is the natural human teaching style,* at least for technical subjects at the university level. Stating the governing principles and working down to the applications is an efficient and elegant way to organize and present material *that is already understood.* Consequently, most engineering curricula are laid out along deductive lines, beginning with "fundamentals" for second year and arriving at design and operations by the final year. A similar progression is normally used to present material within individual subjects: principles first, applications later.

2.4 Active and Reflective Learners

The complex mental processes by which perceived information is converted into knowledge can be conveniently grouped into two categories: *active experimentation* and *reflective observation* [5]. Active processing involves doing something in the external world with the information - discussing it or explaining it or testing it in some way - and reflective processing involves examining and manipulating the information introspectively.

An *active learner* is someone with more of a natural tendency toward active experimentation than toward reflective observation, and conversely for a *reflective learner.* Active learners learn well in situations that enable them to do something physical and reflective learners learn well in situations that provide them with opportunities to think about the information being presented. The more opportunities students have to both participate and reflect in class, the better they will learn new material and the longer they are likely to retain it [5][6].

Engineering classes in which all students are relegated to passive roles, listening to and observing the lecturer and taking notes, do little to promote learning for either active or reflective learners. Engineering classes should therefore include a variety of active learning experiences, such as discussion, problem solving, and group activities, and reflective experiences, such as brief writing exercises and question formulation exercises.

Small-group exercises can be extremely effective for both active and reflective learners [7]. Pose a question or problem and have students come up with answers working in groups of four, with one group member acting as recorder. Such exercises engage all the students, not just the small minority who typically participate in class, and are a rich source of responses and material for subsequent discussion. The exercises also relieve the monotony of continuous lectures. In our experience, as little as five minutes of group work in a 50-minute period can be enough to maintain the students' attention for the entire class.

2.5 Sequential and Global Learners

Sequential learners absorb information and acquire understanding of material in small connected chunks, and *global learners* take in information in seemingly unconnected fragments and achieve understanding in large holistic leaps. Before global learners can master the details of a subject they need to understand how the material being presented relates to their prior knowledge and experience, a perspective that relatively few instructors routinely provide.

Consequently, strongly global learners may appear slow and do poorly on homework and tests until they grasp the total picture, but once they have it they can often see connections that escape sequential learners. On the other hand, sequential learners can function with incomplete understanding of course material, but they may lack a grasp of the broad context of a body of knowledge and its interrelationships with other subjects and disciplines.

3.0 Determining a Student's Learning Style

The *Index of Learning Styles* (Felder & Soloman, 1999)[8] was an instrument used to assess preferences on the four dimensions of the learning style model. Dr. Felder and Barbara A. Soloman, also of North Carolina State University, developed the questionnaire in order to determine the magnitudes of students' learning styles preferences.

Based on the answers to 44 questions, the students will be able to determine where they fall on the learning scale. Once they know their learning style, and the strength of that style, students will understand how they learn best.

Felder believed that while induction and deduction are indeed different learning preferences and different teaching approaches, the "best" method of teaching – at least below the graduate school level – is induction, whether it is called problem-based learning, discovery learning, inquiry learning, or some variation on those themes. On the other hand, the traditional university teaching method is deduction, starting with "fundamentals" and proceeding to applications.

The problem with inductive presentation is that it isn't concise and prescriptive; one has to take a thorny problem or a collection of observations or data and try to make sense of it and hence Felder has omitted this dimension from the model in the questionnaire.

3.1 Experimental Group

The subjects of the study, henceforth designated the experimental group, are first year engineering students who enrolled in all the engineering programmes in the session 2004/05 semester I. The survey was carried out at the beginning of the semester and the number of respondents for each faculty is given in Table 1.

Table 1. Experimental Group

Faculty	No of respondents
Civil Engineering, **FKA**	232
Electrical Engineering, **FKE**	333
Mechanical Engineering, **FKM**	283
Chemical and Natural Resources Engineering, **FKKKSA**	272

3.2 Results

Figures 1, 2, 3 and 4 show the results of the four dimensions of learning style for the entire engineering faculty at UTM. All the experimental groups show the same trend for all the dimensions.

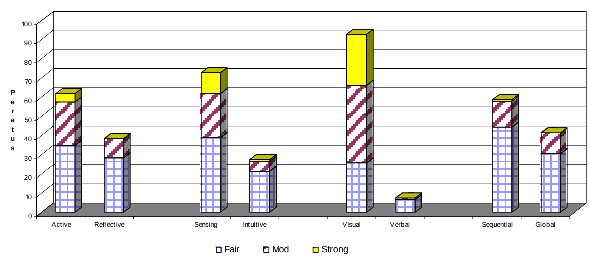

Figure 1. Results for Civil Engineering

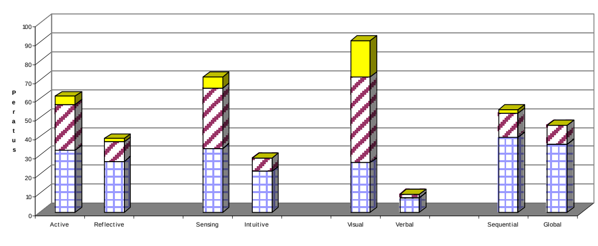

Figure 2. Results for Electrical Engineering

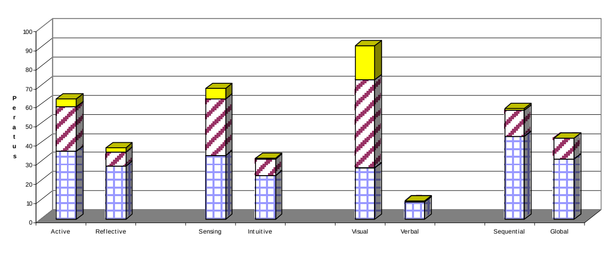

Figure 3. Results for Mechanical Engineering

For active and reflective learning styles, majority of the respondents show fairly balanced or moderate preference on active learning. The same trend can be seen for sensing and intuition but there are high percentages on moderate and strong preferences on visual over verbal for all the groups. Nearly equal number of respondents has the same preference on either sequential or global learning style.

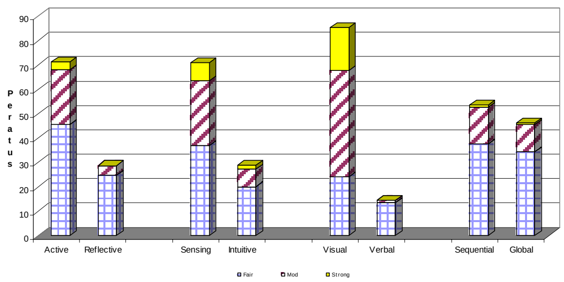

Figure 4. Results for Chemical and Natural Resources Engineering

Data in Table 2 shows that 63.09%, 59.41%, 62.96% and 66.30% of Civil, Electrical, Mechanical and Chemical engineering students respectively have fairly balanced preference of active and reflective learning. This phenomenon indicates that lecturers should alternate lectures with occasional pauses for thought (reflective) and brief discussion or problem-solving activities (active), and should present material that emphasizes both practical problem solving (active) and fundamental understanding (reflective). An exceptionally effective technique for reaching active learners is to have students organize themselves at their seats in groups of three or four and periodically come up with collective answers to questions posed by the instructor [1][9][10][11][12].

For the sensing and intuitive learning style, the percentages of those who moderately prefer intuitive approach are 23.18%, 31.64%, 29.73% and 38.1% for civil, electrical, mechanical and chemical engineering students respectively as shown in Table 3. This made up about one-third of the student population but nearly 55% of them have fairly balanced preference. Consequently, an effective engineering educator should reach both types, rather than directing him/herself primarily to intuitors. The material presented should be a blend of concrete information (facts, data, and observable phenomena) and abstract concepts (principles, theories, mathematical models) [1][9].

About 43% of the total students have moderate preference for visual learning as shown in Table 4. Some engineering lecturers would have to modify what they usually do in order to present information auditorily: lectures accomplish this task. What must generally be added to accommodate all students is visual material - pictures, diagrams, and sketches. Process flow charts, network diagrams, and logic or information flow charts should be used to illustrate complex processes or algorithms; mathematical functions should be illustrated by graphs; and films or live demonstrations of working processes should be presented whenever possible[1][9].

Finally, for the sequential and global learning style, it was found that about 75% of the total students have fairly balanced preference of both approaches as depicted in Table 5. What is the best method of teaching the global learners? Everything required to meet the needs of sequential learners is already being done from first grade through the university: curricula are sequential, course syllabi are sequential, textbooks are sequential, and most lecturers teach sequentially. To reach the global learners in a class, the lecturer should provide the big picture or goal of a lesson before presenting the steps, doing as much as possible to establish the context and relevance of the subject matter and to relate it to the students' experience.

Applications and "what ifs" should be liberally furnished. The students should be given the freedom to devise their own methods of solving problems rather than being forced to adopt the professor's strategy, and they should be exposed periodically to advanced concepts before these concepts would normally be introduced. A particularly valuable way for instructors to serve the global learners in their classes, as well as the sequential learners, is to assign creativity exercises i.e. problems that involve generating alternative solutions and bringing in material from other courses or disciplines [1][9][10][11][12].

4.0 Teaching to All Types

Knowing that students have a variety of learning styles is useful, but knowing how to accommodate those styles in a classroom setting is harder. The mismatches between the prevailing teaching style in most engineering courses and the learning styles of most of the students have several serious consequences, such as loss of interest by students, lower grades for some students and increased drop-out rates. One means of avoiding these consequences is for lecturers to modify their teaching practices to accommodate the learning styles of all students in their courses.

The prospect of trying to address all the different learning styles simultaneously in a single class might seem forbidding to most instructors; the point, however, is not to determine each student's learning style and then teach to it exclusively but simply to address each side of each learning style dimension at least some of the time. Some general techniques [1][9][10][11][12][13] to assist engineering educators in presenting their materials in a way that appeals to a range of learning styles can be adopted are as follows:

• **Teach theoretical material by first presenting phenomena and problems that relate to the theory *(sensing, global)*.** For example, don't jump directly into free-body diagrams and force balances on the first day of a statics course. First describe problems associated with the design of buildings and bridges and artificial limbs, and perhaps give the students some of those problems and see how far they can go before they get all the tools for solving them.

• **Balance conceptual information *(intuitive)* with concrete information *(sensing)*.** Intuitors favour conceptual information – theories, mathematical models, and material that emphasizes fundamental understanding. Sensors prefer concrete information such as descriptions of physical phenomena, results from real and simulated experiments, demonstrations, and problem-solving algorithms. For example, when covering concepts of vapour-liquid equilibria, explain Raoult's and Henry's Law calculations and nonideal solution behaviour, but also explain how these concepts relate to barometric pressure and the manufacture of carbonated beverages. Give the relations between torque, moments, and angular motion – but first get students to exert pressure on a door at different perpendicular distances from the hinges and then have them try to interpret the results.

• **Make extensive use of sketches, plots, schematics, vector diagrams, computer graphics, and physical demonstrations *(visual)* in addition to oral and written explanations and derivations *(verbal)* in lectures and readings.** For example, show flow charts of the reaction and transport processes that occur in particle accelerators, test tubes, and biological cells before presenting the relevant theories, and sketch or demonstrate the experiments used to validate the theories.

• **To illustrate an abstract concept or problem-solving algorithm, use at least one numerical example *(sensing)* to supplement the usual algebraic example *(intuitive)*.** For example, when presenting Euler's method for numerical integration, instead of simply giving the formulas for successive steps, use the algorithm to integrate a simple function like $y = x^2$ and work out the first few steps on the chalkboard with a hand calculator.

• **Use physical analogies and demonstrations to illustrate the magnitudes of calculated quantities *(sensing, global)*.** For example, tell your students to think of 100 microns as about the thickness of a sheet of paper, and to think of a mole as a very large dozen molecules. Have them pick up a 100ml bottle of water and a 100ml bottle of mercury before talking about density.

• **Provide class time for students to think about the material being presented *(reflective)* and for active student participation *(active)*.** Occasionally pause during a lecture to allow time for thinking and formulating questions. Assign "one-minute papers" near the end of a lecture period, having students write on index cards the lecture's most important point and the single most pressing unanswered question. Assign brief group problem-solving exercises in class that require students to work in groups of three or four.

• **Encourage or mandate cooperation on homework *(every style category)*.** Hundreds of research studies show that students who participate in cooperative learning experiences tend to earn better grades, display more enthusiasm for their chosen field, and improve their chances for graduation in that field relative to their counterparts in more traditional class settings.

• **Demonstrate the logical flow of individual course topics *(sequential)***, but also point out connections between the current material and other relevant material in the same course, in other courses in the same discipline, in other disciplines, and in everyday experience *(global)*.

5. 0 Conclusion

The following points illustrate some of the concerns engineering educators should have about learning styles and teaching:

- Students have different mode of learning style preference.
- Most lecturers teach as they were taught.
- Changing one's teaching style may involve changing one's paradigm of teaching and learning at higher institutions.
- Changing one's teaching style may limit the lecturer's ability to impart all the information that is necessary.

These statements are both valid and complex. At the very least, lecturers must recognize that there are differences in the ways that students learn. If lecturers cannot justify changes in their own teaching styles, they should help their students understand how some learning styles can be adapted to their own teaching styles. This is where the difference between scholarly teaching and the scholarship of learning becomes apparent.

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Table 2. Active and Reflective Learning Style

Faculty		**Percentage**		
		Fair	**Mod**	**Strong**
FKA	Active	34.76	22.75	4.29
	Reflective	28.33	9.87	0.0
FKE	Active	32.54	24.48	4.18
	Reflective	26.87	10.15	1.79
FKM	Active	35.35	23.23	4.38
	Reflective	27.61	7.41	2.02
FKKKSA	Active	37.36	25.32	5.15
	Reflective	28.94	8.58	0.43

Table 3. Sensing and Intuitive Learning Style

Faculty		**Percentage**		
		Fair	**Mod**	**Strong**
FKA	Sensing	38.63	23.18	10.73
	Intuitive	21.46	5.15	0.86
FKE	Sensing	33.73	31.64	5.97
	Intuitive	21.49	7.16	0
FKM	Sensing	33.22	29.37	5.59
	Intuitive	22.73	8.39	0.7
FKKKSA	Sensing	28.94	38.1	11.72
	Intuitive	16.48	2.93	1.47

Table 4. Visual and Verbal Learning Style

Faculty		**Percentage**		
		Fair	Mod	Strong
FKA	Visual	25.86	40.09	26.72
	Verbal	6.47	0.86	0
FKE	Visual	26.05	45.21	19.16
	Verbal	7.49	2.1	0
FKM	Visual	26.6	46.1	18.09
	Verbal	8.87	0.35	0
FKKKSA	Visual	31.25	38.6	17.65
	Verbal	11.4	1.47	0

Table5. Sequential and Global Learning Style

Faculty		**Percentage**		
		Fair	Mod	Strong
FKA	Sequential	44.21	13.73	0.86
	Global	30.47	10.73	0
FKE	Sequential	39.64	12.61	1.8
	Global	36.04	9.91	0
FKM	Sequential	43.01	13.99	0.7
	Global	31.12	11.19	0
FKKKSA	Sequential	46.52	14.65	0.37
	Global	30.4	8.06	0