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An innovative 4-MAT-based system for geo, solid and fluid mechanics education with geo-mechanics applications

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ABSTRACT: There are now many 4-MAT-based teaching and learning systems that have been reported in the literature. However, no evidence has been detected that one exists for engineering mechanics (hereafter abbreviated as mechanics). The purpose of the present article extends beyond filling students with mechanics subjects in a conventional way that, from the authors' experience, makes such subjects too hard to understand. The goal of the new approach, as suggested in the present article, is to train students to think, learn and exercise competent judgement using the 4MAT formation in an innovative way. The authors applied the suggested new approach to mechanics units, including geo-engineering units, for a number of years at Monash University. In the article, the authors explain such an approach to mechanics teaching by showing the detailed approach for geo-mechanics teaching. As discussed in the article, the authors find that such a comprehensive approach has proved to bring students' potentials to their fullest, regardless of their style of learning within the eight brain sectors.

INTRODUCTION

Learning styles vary from student to student and from subject to subject [1-5]. For example, some students learn better by dealing with printed or written materials (expressed in or using words or language, especially as opposed to pictorial representation type of learners), while others learn better by conducting the use of tests and trials in order to make discoveries (feeling type of learners). Furthermore, students have different learning styles, abilities, capacities, strengths and preferences in the ways they absorb information. Consequently, various types of learners include the following:

- Facts, data and algorithms learners;
- Theories and mathematical models learners;
- Visual forms of information learners;
- Written and spoken explanations learners;
- Experimental learners;
- Active and interactive learners;
- Reflective-individual learners.

Engineering educators need to tailor the above towards teaching various engineering subjects with sensitivity [6]. The above-mentioned principles are coupled with previous successful research in this engineering education area [7]. This has motivated the authors to tailor a special teaching approach to teach engineering mechanics, hereafter abbreviated as mechanics, (ie geo-mechanics, solid-mechanics and fluid-mechanics) subjects by integrating reading, hearing, seeing, speaking, as well as trying and realising.

In the present article, the authors demonstrate such an approach to teaching mechanics by showing the detailed approach for geo-mechanics teaching. This is a departure from orienting the teaching of mechanics towards introverts, intuitors, thinkers and judgers only.

HANDS-ON EXPERIENCE

Innovative 4-MAT hands-on experience is the key to effective learning, especially in the engineering and science disciplines [8-12]. The purpose of the present article extends beyond filling students with conventional teaching of mechanics, knowing that mechanics is the common denominator of geo-mechanics, solid mechanics and fluid mechanics, as shown in Figure 1.

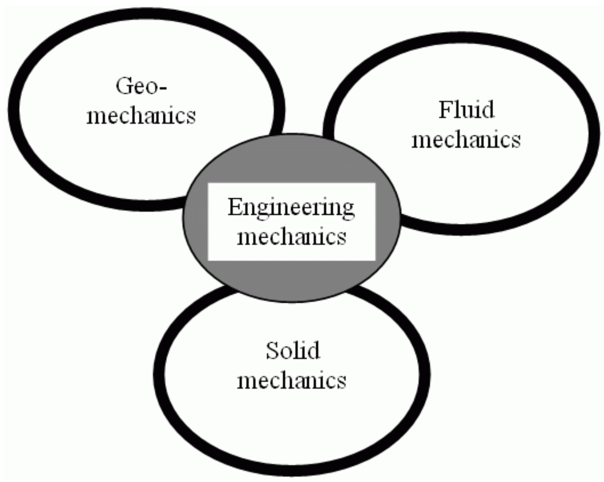

Figure 1: The elements of engineering mechanics.

Consequently, the teaching and learning strategy for any branch of mechanics, as shown in Figure 1, would be the same in relation to the Myers-Briggs Type Indicator (MBTI) [13].

However, the strategy of the present article covers more types of students than the classical preferences (ie extraverts or introverts; sensors or intuitors; thinkers or feelers; and judgers or perceivers).

GOAL AND EMPHASIS

The goal is to train students to think, learn and exercise competent judgement in multiple situations using the 4MAT formation. There are now many teaching and learning applications to 4-MAT that have been reported in the literature [1-6]. However, no evidence has been detected that a 4-MAT system has ever been introduced to enhance the mechanics learning process. This summarises the need for the present article. Consequently, the authors present a new avenue in 4-MAT applications in engineering education. The emphasis in the present article is on geo-mechanics applications as a showcase on how to apply 4-MAT principles in mechanics teaching and learning by looking carefully into a first level (second year) unit, namely *Introduction to Geo-engineering*.

STRATEGY

The article incorporates the following three pillars in teaching 4-MAT-based geo-mechanics:

- *Theory*: This is intended to demonstrate to students knowledge of the theory and extend it to uncover new relationships, which will help students, later in their career, to address unconventional issues using fundamental principles;
- *Problem solving*: This requires students to apply fundamental principles and concepts to a wide variety of problems. This will test students' understanding and use of the fundamental principles. For most problems, there is no unique method or procedure for finding solutions (creativity);
- *Practical*: This is intended to create either real situations or almost real situations for students to use not only the specific topics, but other related topics encountered in earlier studies. This will help students to feel how the materials studied earlier can be applied in practice.

APPLICATION

Introduction to Geo-engineering is a second year engineering unit at Monash University. The unit is used in this article to show the 4MAT innovative teaching and learning within the teaching of mechanics area. The aim and objective of the unit is to give students exposure to the fundamental concepts of soil mechanics, rock mechanics, as well as foundation engineering. Upon completion, students should understand basic engineering geology, rock formations and weathering processes, understand various types of soils and rocks and their properties, in addition to understanding the analysis and design of the shallow and deep foundations for simplified loading and ground conditions.

UNIT INNOVATIVE 4-MAT ANATOMY

This anatomy has been applied to the mechanics stream of units within the Bachelor of Civil and Environmental Engineering course at Monash University, Australia. In order to explain this innovative approach, the authors have selected ENG2206: *Introduction to Geo-engineering* as an example unit. This unit deals with all aspects of geo-engineering at an elementary level, as well as basic engineering geology, formation and weathering processes, sedimentary, igneous and metamorphic rocks, the geotechnical spectrum – soil, rock, weathering, deposition cycle, basic soil and rock properties, void ratio, water content, etc, and the two phase model.

In this particular unit, all materials are assumed to be granular and frictional. The unit includes the analysis and design of slopes, shallow and deep foundations, retaining walls and pavements; effective stresses only are used. Visualisation is developed through the mapping and modelling exercise. The unit's clear emphasis is on sustainable design.

The unit has five assignments/tasks, which specifically cover the aims and objectives of the unit in addition to training students to think, learn and exercise competent judgement using the 4MAT formation in an innovative method. The assignment/tasks of the unit also explore and exploit all avenues (sectors) of the 4MAT system with attention to both individual and group tasks. The tasks are as follows:

- *Task 1*: A small research project on an individual basis;
- *Task 2*: A desk study of geological maps, familiarity of soil/rock samples on a group basis;
- *Task 3*: Individual: emphasis on phase relationship/soil strength and effective stress on an individual basis;
- *Task 4*: Group: hands-on laboratory experiments and report writing of soils properties on a group basis;
- *Task 5*: Foundations design – shallow and deep geo-engineering on an individual basis.

Table 1 shows the individual assignments/tasks allocated percentage of potential brain activities of each sector of the brain for quadrants 1-4. Table 2 shows the individual assignments/tasks allocated percentage of potential brain activities of each sector of the brain for quadrants 5-8.

Table 1: Individual assignments/tasks allocated percentage of potential brain activities for brain quadrants 1-4.

	GEO-ENGINEERING ASSIGNMENT ATTRIBUTES CODE			
	λ_1	λ_2	λ_3	λ_4
4MAT Quadrant Number	1	1	2	2
4MAT Mode	Right	Left	Right	Left
4MAT Attributes	Connect	Examine	Image	Define
Individual Assignments/Tasks Percentage of Brian Activity	Task1 (30%)	Task1 (30%)	Task1 (15%)	Task1 (10%)
			Task 3 (40%)	Task 3 (40%)
	Task 5 (5%)	Task 5 (5%)	Task 5 (10%)	Task 5 (10%)
Group Assignments/Tasks				
4MAT Cycle of Learning	Imaginative Learners		Analytical Learners	
4MAT Lecturer's Role	Discussion (Lecturer / Students Interacting)		Information (Lecturer Acting)	

The percentage distributions, shown in Tables 1 and 2, are based on a thorough design and analysis of the tasks' components. The authors recognise that it is virtually impossible to fill all brain segments with activities that are of equal percentage. However, such a distribution is a balanced approach between meeting unit objectives and addressing all the brain sectors. Furthermore, the suggested balanced approach to brain sector activities, without compromising the unit objectives, is shown in Tables 1 and 2, which takes into account the *4MAT four quadrants and their two modes per quadrant, namely left and right.*

Table 2: Individual assignments/tasks allocated percentage of potential brain activities for brain quadrants 5-8.

	INTERNET LAB EXPERIMENTS ATTRIBUTES CODE			
	λ_5	λ_6	λ_7	λ_8
4MAT Quadrant Number	3	3	4	4
4MAT Mode	Left	Right	Left	Right
4MAT Attributes	Try	Extend	Refine	Integrate
Individual Assignment s/Tasks Percentage of Brian Activity	Task 1 (15%)			
	Task 3 (10%)	Task 3 (10%)		
	Task 5 (15%)	Task 5 (15%)	Task 5 (20%)	Task 5 (20%)
Group Assignment s/Tasks Percentage of Brian Activity	Task 2 (10%)	Task 2 (10%)	Task 2 (40%)	Task 2 (40%)
			Task 4 (50%)	Task 4 (50%)
4MAT Cycle of Learning	Common Sense Learners		Dynamic Learners	
4MAT Lecturer's Role	Coaching (Students Reacting)		Self-Discovery (Students More Active)	

The key objective of the *quadrant one, right mode (type one learners)* is triggered by students' involvements in the generation of ideas related to the concepts of the integration of engineering mechanics. The key objective of the *quadrant one, left mode (type one learners)* is to examine the engineering mechanics concept and its pyramids of geo-mechanics (soil and rock mechanics) and fluid mechanics components. The key objective of the *quadrant two, right mode (type two learners)* is to connect what students already know at this stage to what students ought to be taught in a traditional geo-engineering course with an emphasis on engineering judgement, engineering modelling and simulation, and modelling aspects. The key objective of the *quadrant two, left mode (type two learners)* is triggered by defining the unit's theories in a traditional lecture and checking students' understanding. The key objective of the *quadrant three, left mode (type three learners* is to set exercises based on the reinforcement and manipulation of geo-engineering problems. The key objective of the *quadrant three, right mode (type three learners)* calls for additional assignments and site visits to be designed to extend students and encourage them to tackle advanced ideas. The key objective of the *quadrant four, left mode (type four learners)* is to evaluate assignments' usefulness and industrial applications. The key objective of the *quadrant four, right mode (type four learners)* is triggered by transforming the gained knowledge into an integrated understanding with total quality assurance of skills.

4-MAT DISSEMINATING PRINCIPLES

All learners are taught in various ways, although all learners were at their best at different places in the learning cycle. Each of the four learning styles was taught with both right- and left-mode 4MAT methods. The development and integration of all four styles of learning and the development and integration of both right- and left-mode processing skills have been accommodated in the five tasks shown in Tables 1 and 2, along with their percentage of brain quadrant potential use. These are as follows:

- Quadrant One, Right Mode (Type One learners, ie λ_1) incorporates elements of tasks 1 and 5;
- Quadrant One, Left Mode (Type One learners, ie λ_2) incorporates elements of tasks 1 and 5;
- Quadrant Two, Right Mode (Type Two learners, ie λ_3) incorporates elements of tasks 1, 3 and 5;
- Quadrant Two, Left Mode (Type Two learners, ie λ_4) incorporates elements of tasks 1, 3 and 5;
- Quadrant Three, Left Mode (Type Three learners, ie λ_5 incorporates elements of tasks 1, 2, 3 and 5;
- Quadrant Three, Right Mode (Type Three learners, ie λ_6) incorporates elements of tasks 2, 3 and 5;
- Quadrant Four, Left Mode (Type Four learners, ie λ_7) incorporates elements of tasks 2, 4 and 5;
- Quadrant Four, Right Mode (Type Four learners, ie λ_8) incorporates elements of tasks 2, 4 and 5.

The details of each task are presented next, along with its attributes.

λ_i ATTRIBUTES

Each λ_i has a specific educational function as detailed below:

- λ_1: Connect students directly to the subject, begin with a level that is familiar to students and builds on what they already know by developing and demonstrating research skills;
- λ_2: Explore with students the needs to develop a broad introductory understanding of the geo-engineering field, summarise and review similarities and differences in basic concepts of excavations for basements, cut-and-cover tunnels, pumping stations, underground storage areas; clarify the reasons for the learning the various types of geotechnical structures and guide students' thinking to landfills for domestic or industrial waste and pollutants;
- λ_3: Connect what students already know at this stage to what students ought to be taught in a traditional lecture with an emphasis on engineering judgement and engineering modelling. In this regard, students should understand the basic attributes of geo-technical problems, such as slope stability, bearing capacity of the foundation and excavations. Emphasis should be on the connection between the geo-engineering concept and its relationship to students' professional activities, like soils-phase relationships, and soil stresses and strength. This is achieved in a way that relates what students already know to what the literature survey has found;
- λ_4: Define geo-engineering theories in a traditional lecture and check students' understanding. Emphasis should be on the most significant aspects of geo-engineering technology in relation to sample inspection and identification. Students' attention should be drawn to the

following important technical aspects of soils and rocks characteristics: colour, grain size, foliation, hardness and strength;

- λ_5: Set exercises based on reinforcement and manipulation of experimental work in relation to error estimation and the use of norms derived from error estimates to obtain realistic geo-engineering analysis applicable to *real world* situations. This includes hands-on activities, eg asking students not to wet the soil sample too much, but just moisten a little between their fingers, so students can then more easily feel the relative smoothness/stickiness, which should help them to distinguish between silt and clay. Clay has finer particles than silt, and should feel smoother and stickier when moist. The set geo-mechanics based laboratory experiments provide avenues for students to practice new learning skills; the laboratory experiments are driven by high expectations of the quality assurance of skills;
- λ_6: Additional experiments are set to extend students, encourage toying with soil data collections, computations, presentation and interpretation of results, pertinent graphs of important attributes, such as strength characteristics. Extractions of various capabilities and limitations of experimental work imbedded in the set exercises. Tutorials, exercises and laboratory experiments are set up in such a way so that students have to find information not readily available or not available at all in their textbooks; such as the textbooks by Das and Waltham [14-15]. Additional tutorials, exercises and laboratory experiments are set up in a way so as to provide opportunities for students to design their own open-ended skills developments in geo-engineering;
- λ_7: Evaluate the usefulness of industrial applications and adopt state of the art field technology. Students must reach the ability to analyse, design and optimise shallow footings and deep foundations. Students must maintain high expectations for the detection and refinements of seepage patterns (flow-net). Students must explore their own mistakes as mechanisms for learning enhancements. Students must be able to evaluate their own cumulative geo-engineering experience. This will test students' understanding and use of fundamental principles, keeping in mind that for geo-technical problems, there is no unique method or procedure for a solution;
- λ_8: Transform the gained knowledge into an integrated understanding with total quality assurance of skills and highlight new advances in geo-engineering, in relation to field experimentation, mathematical modelling and simulation. Allow students to practice various geo-mechanics failure patterns. Make student learning shared by the relevant industries for comprehensive feedback and flexible adaptation of design philosophy, thereby extending students' eagerness to integrate learning into their future professional work.

CONCLUDING REMARKS

The feedback from the current and past students indicates that the adapted methodology has proven to be extremely valuable in achieving the unit's aims utilising 4MAT-improved techniques. The percentage distributions of the unit tasks for various brain activities, as presented in this article, have proven to be efficient in meeting various unit objectives, ie local optimum in N-dimensional Euclidean design space. However, further research in this area is recommended in order to find the ideal situation, keeping in mind that integrating different learning approaches into an undergraduate mechanics classes without compromising objectives is a big challenge for teaching such a difficult subject area.

In conclusion, all mechanics educators should ensure that their courses present information that looks after various ranges of learning styles.

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