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Mastery Learning for Undergraduates in Engineering

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Mastery Learning for the Undergraduates in Engineering

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Abstract

The paper gives examples on the importance of mastery learning, that is learning a profession to its perfection and even extending it to excellence, in engineering education and in engineering training, such as the CO-OPs, especially during the undergraduate years. In order to achieve it, only academic counselling is not enough; it needs a more intimate *'mentoring'* for both incoming Freshmen and outgoing Senior undergraduates. During the present crisis of COVID-19 and in the post-COVID-19 scenario thereafter in engineering education, when online instructions are rapidly replacing in-presence lectures at the undergraduate level, mastery learning is even more important in order to avoid professional limitations, and in the long run of lifelong learning, professional obsolescence.

Key words: concentration, COVID-19, online instructions and lab experiments, academic counselling vs. mentoring.

Introduction

In one of the Indian epics, *Mahabharata* [1], the master archer*, Drona,* was teaching his pupils how to shoot an arrow. Drona asked a student: What do you see on the tree? The student: A bird, Sir. Drona: Concentrate on the bird. The student: Yes, Sir. Drona: Now, what do you see? Student: The eye of the bird, Sir. Drona: Now shoot your arrow!

This is one example of mastery learning. Perfection demands concentration. There are similar examples in *Ramayana*, [2] the other Indian epic. King *Rama* trained his army under *Hanuman* to mastery learning for fighting against *Ravana* and for releasing his wife *Sita* from imprisonment. Thus, mastery learning means a very good knowledge, almost to its perfection, on a subject matter. Some go beyond perfection*: Excellence*!

The oriental and the occidental teaching philosophies on mastery learning are very different, often diametrically and dramatically opposite. I still remember in Canada, one of my professors used to write on the board in his very first class, the word FUNDAMENTAL, in capital letters! Then he would say: You must have *fun* in my class. Then he would wink his eyes with a smile, and suddenly rub off from the board the first FUN part of the word, and burst into laughter, almost shouting hysterically, "Unless you have FUN, the rest is Damn Mental!"

Unless you are enjoying there is no mastery learning. The Buddha preached totally opposite: You must go through suffering for reaching self-realization: *Nirvana*! Not only the Buddha of India but also

Confucius and Lao Tse of China taught that one had to go through some pain in order to achieve the ultimate pleasure of knowledge: *Wisdom,* through Mastery Learning!

Thus, we have two different schools of thought for mastery learning: through pleasure and through pain. In the globalized education of today when the West is approaching the East very fast, or *vice versa*, perhaps a *pleasing pain* in the starting point, and a *painful pleasure* at the end are the two keys for the culmination of mastery learning.

In modern times, both in mathematics and physics, mastery learning is emphasized. Ramanujan, the famous Indian mathematician, and his British professor, Thomas Hardy, pioneered Number Theory by hard work and through mastery learning. Ramanujan, due to his perfection in numerical calculations (in the early 1900s without a computer!), was called by many other famous mathematicians of his time as *magician of numbers.* In Theoretical Physics, Niels Bohr and his distinguished disciples, like Schrödinger, Heisenberg, Pauli, Gamow, etc. and many others were perfectionists, in other words, master learners [3]. Their Physics group at Gottingen was a center for mastery learning, and many Nobel Laureates stem from that group. As Einstein once confirmed: *God does not play dice with the universe.*

Mastery Learning by Induction and Deduction

In philosophy there are two different approaches through inductive logic and deductive logic. Similarly, in mastery learning, we use the learning process by induction or intuition and by deduction. The infants learn their native language through induction from the speaking and hearing environment around them, whereas the adults learn their second, third or the nth language by deduction. The kids speak first their native tongue long before opening the grammar and composition books. The birds sing without seeing the musical notes, the grammar of music! Another example is swimming. The Amerindians in the Amazon learn swimming just by jumping into the river. They do not need swimming instructions at a YMCA pool. The village kids in India do the same in the Ganges!

Going back to the example of *Mahabharata,* the young disciples of Drona were becoming master archers by induction, intuition and concentration, just the way the infants start dabbling their native tongue. On the other hand, in *Bhagavad-Gita* [4], which is just a small part of Mahabharata*, Krishna* was teaching *Arjuna* by deduction, using logical, step-by-step arguments and examples throughout its eighteen chapters, in a very similar fashion the adults learn a second language from books and recorded tapes. Both the examples, how to shoot an arrow and how to speak a language, demand mastery learning. Depending on the age group of the learners and the environment around them, the methods vary from induction to deduction.

Mastery Learning in Engineering

In Europe, engineering first started in the military academy in France, and one of its first Engineering schools was established, not in Sorbonne of Paris but in Grenoble. In Grenoble, mainly Civil Engineering and Mechanical Engineering were taught and practiced under strict military discipline. This means hard work, not just fun!

In Hinduism there is a god for every aspect of life. So, there is also a god for Engineering**,** *Biswakarma*, the Master Engineer! Even in today's modern India there is a day fixed and reserved in the year for celebrating *Biswakarma Puja*; and as India is progressing and pioneering in Information Technology (IT)

during the last few decades, worshipping (*Puja* in Sanskrit) of Biswakarma is getting increasingly important!

Today, as technology moves from North to South, admission in the Engineering schools of the Americas, especially in the countries like USA, Canada, Mexico, Brazil, Argentina, Chile, etc. is getting very competitive. You do not get into a Graduate program unless you have an A average in your Undergraduate transcripts. Again, Mastery Learning!

Mastery Learning in the Undergraduate Engineering Programs

Mastery learning essentially needs a very close and strong communication between the teacher and the students, between the mentor and the mentees, between the preceptor and the disciples, between the Guru/ *Acharya* and the *sishyas* [5,6]. This is a difficult task in today's online instruction. We, the teachers and the students, are facing many challenging circumstances, especially during these totally locked down months since March 2020, due to the worldwide proliferation of this new and unknown virus COVID-19. We, the teachers, need face-to-face two-way communication with our students just for information transfer, not to speak of mastery learning. In Bloom's taxonomy pyramid, culmination of *knowledge* comes one step above *information* transfer. *Wisdom* is again one step above knowledge. When we talk about mastery learning, we are in the realm of *wisdom transfer* between the mentor and the mentee [7].

In Indian classical music, there is a term called 'Gharana'*; Ghar* means home. The student is advised to live in the home of the music teacher for an intimate mentorship, and thus for acquiring mastery in music. For the same reason, all the eight (8) Indian Institutes of Technology (IITs) are strictly residential, not only for the engineering students but also for their instructors and the research faculty members as well. The students live in their dormitories, and their professors have their houses within the IIT campuses. The faculty members live with their families close to the students for creating a stronger bond with the students in the wider sense of an extended family relationship between the mentors and their mentees. This facilitates mastery learning. Even in Europe today, in Germany, for example, many professional schools prefer on-campus residence. I remember in 1962 in Reutlingen, near Stuttgart, a baker had his young apprentice living in his family! Closest proximity between the master and the disciples helps mastery learning! In apprenticeship, such as in this case of baking a bread, online instructions are not enough. The same example holds good for the engineering workshops and laboratories where the personal touch is very important. Like in engineering, in architecture and in the arts, such as painting, poetry and music, mastery learning exceeds over the level of perfection to excellence.

Owing to my Oriental upbringing up to the first four undergraduate years in engineering, I do believe that mastery learning needs hard work, concentration and some sacrifice, some suffering [8,9]. It is not all just for fun! In most of the engineering schools in the Americas, especially in USA and Canada, we have an academic counselor in each department who takes care of the course requirements, minimum credit hours and the other routine check-ups for each undergraduate student. This is necessary but not sufficient for a student who has just left the high school and is entering into a totally new and novel world of *academic freedom*! The student needs the "touch of a helping hand" of a senior professor who can instill enough confidence and security in the heart of a newcomer. Without this helping hand there is no mastery learning [10].

The same is true when the student in the final year, finishing capstone courses, and needs professional orientation from an experienced faculty member regarding the onset of a lifelong career path in future. This is not only on the technical gadgets but also a focus on the difference between the academia and the industries in relation with time management, safety factors and cost analyses. A command and hence a control on each of these areas can only be achieved through mastery learning.

The science fictions of yesterday *are* science today! Thus, from the ancient oriental histories and mythologies we can learn how some of the confusions of a professional career can be cleared up through mastery learning. In the Indian epic, Mahabharata, a famous scene is the onset of a battle, the *battle of Kurukshetra*, and one of the great Generals put down his weapons, extremely confused about starting a war against his own fellows, friends and family members just for a petty landownership! This General is *Arjuna*, the famous fighter! The entire Bhagavad-Gita [4] in its 18 chapters is devoted on the conversation between *Arjuna*, the mentee and *Krishna*, his mentor, regarding the duty of Arjuna as a warrior as against his love and compassion for his clans. Krishna finally convinced him*: Duty first!* This is an ideal example that such a mentorship can only be executed at a mastery learning level. Arjuna is the master archer and Krishna, his mentor and friend, is the master of *wisdom*!

Many engineers, both in the academe and in industries, underestimate the need for mastery learning at the undergraduate level in engineering. But this is not a right approach. A plant needs the maximum attention, the perfect care when its seeds are just embedded in the soil and germinating, and not when it is already flourishing as a full-grown tree with its branches, leaves and fruits. In Mechanical Engineering, for example, the basics, that means essentially the seeds for the plant to survive and grow, are the knowledge in Materials, Mechanics and Thermodynamics. An Undergraduate in Mechanical Engineering must possess mastery learning in these three basic courses. Then, and only then, this knowledge can be applied in many other allied and advanced fields [11].

Mastery Learning in the Post- COVID-19 Period

Since March 2020, our education is in turmoil for the transition from in-presence to online instructions. While distance education, especially in the professional schools, has many benefits, the pressure of learning about teaching online came very suddenly. In the beginning, in March 2020 it was a nightmare both for the students and their instructors. Many of us are still struggling!

For not having a face-to-face contact with the students, the click-n-drag practice on a computer screen has increased over the past semesters. Even in the exams, for the true/false and multiple-choice questions, the probability of hitting a right answer (even without knowing it!) is high. Essay type questions that demand *critical thinking* for a conceptually detailed answer are lacking during this period for not having in-presence lectures. Pre-recorded lectures are monologues, not dialogues, for both synchronized and asynchronized classes. This leaves a wide gap between the instructor and the students. A very distinguished and respected Engineering Faculty member at Texas A&M recently commented pensively, “Alas, I can’t see into the eyes of my students in my class anymore!”

The Juniors and the Seniors in the Undergraduate courses will face serious problems in their professional preparation for not having this face-to-face contact with their instructors and mentors. In this age of smartphones and face-books direct human communication is increasingly lacking in every sphere of our daily existence. On top of it, this COVID-19 emergency has put new barriers of communication by

enforcing 'educational distancing'. Educational distancing is not just '*physical distancing'*! It includes *'social distancing'* as well on a live college campus. Students in Engineering, those graduating this year or in the next year, will not have the same preparation as those who graduated a few semesters earlier. For example, the laboratory experiments online do not have the same feelings of "touch and test" as those in an in-presence lab. Besides, the personal safety precautions taken in a real lab experiment or in a workshop practice do not exist in the environment of a virtual simulation. Liquid aluminum at 400F never spills accidentally on the laptop screen in a "virtual" experiment on metal casting![11]. We need to consider the limitations of such *'virtual labs'* in the light of mastery learning.

Post-COVID-19 scenario in higher education is uncertain. In many universities online teaching will continue, if not intensify, simply because the university administration has invested a significant amount of money in it during the emergency period of 2020 – 2021. In Puerto Rico, for example, where the undergraduate engineering programs are for five years, (because of the bilingual and more importantly the multicultural nature of education in this island), online and hybrid instructions will continue at least till the Fall semester of 2021. The administrative authorities want to drag it as long as they can, simply because they want to "justify" their investment in distance learning, and mainly to keep the fund-givers from the US Federal government happy!

Dr. Rafael Reif, the current President of MIT, expressed in a speech a few years ago that distance learning would be the future of higher education [12]. The students would be able to work and go to school without sacrificing either. They would not need to move from place to place for job-related relocation every now and then, which is very difficult for the students with families. Hence, distance education is easier and cheaper for the students. Whether it will be better for the students, and for their instructors, is a post-COVID-19 question! Can online instructions vis-à-vis in-presence lectures offer mastery learning for perfection and excellence in undergraduate engineering education?

For example, long video lectures in online classes make people stressed up and anxious. According to Jeremy Bailenson[13], founding director of the Visual Interaction Lab at Stanford University, the proliferation of video calls during the pandemic has made 'listeners become speakers'. Bailenman commented that "Before COVID-19, there had been very few studies of how hours of video calls might affect mental health." He mentioned about several stressors in long video conferences. Some other experts [14] in online virtual classes suggest that the optimal time for one single video recorded for a classroom environment or for a lab is between 7 and 10 minutes. Beyond that time the student studying from a video, not just watching a game, loses concentration. As it is stressed in the beginning of this article, concentration is the first stepping-stone for mastery learning. In this respect, online classes cannot compete with the direct and open one-to-one communication of an in-presence lecture or lab.

Closing Remarks

In the American countries Mastery Learning is preached but not much practiced. The grades of evaluation in exams, from high school to Graduate school, are very much inflated. In Puerto Rico, for example, the passing grade is 70%, and almost everybody passes! The list of Honor Role is long. While this tendency improves a sense of false self-esteem, the engineering students face confusion when they start to work in industries. All 'A's in courses and no practical training through CO-OP or any other industrial internship create this confusion on professional competence, and in the extreme case can lead to professional obsolescence.

India was a British colony till 1947, and some of the British norms and standards for higher education still exist in the engineering schools in India. The passing grade is 50% (and not everybody passes!); the "Letter Grade" is 80%. The word 'Letter" stems out of the British "Matriculation" system where the school Principal literally writes a letter of congratulation to those students who receive 80% or more in a course. The Honor Role is usually a short list of 10 or 12 students in a class of about 100 students. Admission in an Undergraduate Engineering program is based on tough competition, and very often a student needs to wait a year or two to get into it.

Thus, Mastery Learning is practiced while students are honed through a tough, four-year Undergraduate degree program. The exams are based on "critical thinking", and multiple choice and True/False type questions are unheard of. This is one of the reasons why the Asian students perform very well in the Graduate schools in America.

Finally, mastery learning is of utmost importance for a successful professional career in Engineering, Medicine and Law. While in Medical and Law schools, an Undergraduate degree in an allied field is an essential prerequisite for admission, in Engineering an Undergraduate degree is a terminal academic preparation for most of the professionals. Only about 10 to 15 percent of the Bachelor's degree holders go for Graduate studies in Engineering. Some go for an Executive MBA paid by their companies.

Hence, mastery learning is even more important at the Undergraduate level in Engineering. It is the last chance for academic preparation before entering in the professional workforce. Needless to emphasize that such a preparation is unique when guided by a mentor who treats the student as a disciple and as a friend.

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