The Paradigm-Based Idea Generating Process (ParaBIGPro) – A Creativity Tool Related to Kuhn's Concept of Paradigms

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ABSTRACT

In starting to write the "Structure of Scientific Revolutions," Thomas Kuhn had to define the paradigm of a profession to resolve a problem he perceived between natural and social scientists. In the centennial of chemical engineering in 1988, a report from the National Council in the U.S. delineated the paradigm of the chemical engineering profession based on Kuhn's definition. I used it to develop a method of generating ideas, which jived with a unique technique I used during my first job. It took me more than three decades to complete the process due to the influence of the phrase "paradigm shift," which interfered with imparting my concept to others. I called the process "probing paradigms." I initially used it in formulating strategies and developing innovations in teaching chemical engineering. Having received favorable student feedback, I extended the application to teaching, research, and extension service in environmental, biochemical, energy, and design engineering. It was only in 2009 that I finally devised the necessary framework. We probe paradigms and systematically map them in our minds. Connecting ideas in our brain (a powerful neural network computer) results in other ideas (some new) from which to select. The method consists of (1) analysis of paradigms, (2) systematic organization of ideas, (3) mapping of these ideas in one's mind, and (4) connecting ideas to form new ideas. I give some examples as well as the application in its current condition.

Keywords: paradigms, probing, shift, idea generation, innovation, creativity

1 INTRODUCTION

The Covid 19 Pandemic has ushered in a new normal in our way of life. At the same time, the advent of Industry 4.0 with the advances in computers, artificial intelligence, and deep learning is changing the landscape in business, industry, education, and governance, among others. Climate change, terrorism, and global conflicts add to the burden. Big problems require great solutions that we must plan. Suddenly, everyone must react, with the learning curve shortened. We need creative and innovative ideas. It seemed somehow that I had been preparing for this for the last 50 years. I have been conducting a project since 1971, which offers some solutions to the problems mentioned above by serendipity. In my first job, the success I had in research allowed me to daydream an ambitious objective: create a new technique in creativity. The 50-year project took a life of its own.

2 BACKGROUND OF THE ACTIVITY

My professional career spanned from 1970 until my retirement in 2012. I had no plans to teach after graduating from college. During my job-hunting days, a congenital heart defect surfaced during the routine physical examination. The doctors, who were not cardiologists, recommended rejecting my employment application. This action limited my job choices. The condition affected my career objectives and lifestyle. In my first job, I was a confidential technical assistant to the head of a military research installation. My job was a do-all as they came sans training and proper facilities. I took with nonchalance the assignment to work on explosives. I knew I had to prepare. Thoroughly I did, but I had scary moments along the way. While being quite a limited field, the area of explosives is heavy on chemistry, physics, and safety considerations. Typical in a government agency in our country, delays in appropriating funds for procuring materials and equipment were common. The facilities were inadequate. Training on research and handling explosives was not available locally. Therefore, I had to improvise in preparing my setup and my formulations. The next assignment was more specific: reverse engineer a pyrotechnic cartridge for artificial rain stimulation. How could an ill-equipped facility cope with such a job? As a chemical engineer, I knew the first step was to find its chemical analysis. This stage proved daunting because interfering elements had been purposely incorporated into the formulation, preventing the components' detection. The recourse was to perform a thorough literature review.

I read numerous journal articles, books, magazines, and abstracts. Within the confines of the specific topic, I could view ideas in another context. They seemed mapped within the area of the subject matter. While the information given by each reference was usually limited, the overall total could provide more actual data. We could interpolate the information gaps. Thus, I could deduce the formulation of the cartridge and produce a prototype using improvised equipment. Against all odds, I was successful. Emerging with confidence, I felt so creative and innovative. I reviewed everything I did right, reserving the knowledge obtained for the future. Converting the said technique to a new method of creativity has always been in my mind. I then took a Master of Science Course in chemical engineering at the University of the Philippines (UP). I continued my research on artificial rain stimulation, which eventually became the topic of my M.S. thesis. All along, I was being creative. When an opportunity to teach at UP became available, I applied and became an instructor in 1974. The job perfectly suited me with performing research as one of the duties. I used the technique I learned earlier and conducted much research. I felt the urge to impart my knowledge on creativity in teaching, but I still needed the proper framework and basis. Since then, it has become an obsession for me.

In 1988, the National Research Council of the USA issued a Report on the Frontiers of Chemical Engineering. This report included a description of the paradigm of chemical engineering. (Commission, 1988) At about the same time, Proctor and Gamble, Philippines, invited me to a "Seven Habits of Highly Effective People" seminar by Stephen Covey. In this seminar, Covey brought home his point by using paradigms. The said two events stimulated me to think about some applications of the concept of paradigms in chemical engineering.

3 CONCEPT OF PARADIGMS

3.1 What is a Paradigm?

The term paradigm comes from "paradeigma," a Greek word derived from "paradeiknynai" which means "to show side by side." In Aristotle's time, "paradeigma" was an example of an argument in rhetoric. In modern European languages, limited usage prevailed, primarily concerning grammar. In the German language, philosophers used it as a metaphor. This practice did not take off in English until Thomas Kuhn used it in his essay, The Structure of Scientific Revolutions. Here, Kuhn argued that without revolution or "paradigm shift," science would not progress. He started drafting the essay by defining the "paradigm of a profession" as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners." However, he used the word paradigm in twenty-one distinct ways in the essay. (Mastermann) He did not further elaborate on the paradigm of a profession. As a result, the word paradigm has many connotations today, and the phrase "paradigm shift" has been in the mainstream. Few professions have described and elaborated their paradigms, with chemical engineering as one of them. As mentioned earlier, I based my activity on generating ideas in chemical engineering. The examples follow along that line.

3.2 Determining Paradigms

Each profession has its paradigm—a set of knowledge that defines or guides a profession. The paradigm of chemical engineering refers to the characteristic set of problems and systematic methods for obtaining solutions.

The logical way to determine the paradigm of a profession is to trace and examine its history. We must critically note the developments, especially new ideas, themes, theses, and arguments. That leads to new directions or points of view not seen before. We should carefully find paradigm shifts, if any exist. Professional organizations are another source of information. The practices of an organization's members and the proceedings of conferences can provide us with valuable insights. Parallel to the practice of the profession is the development of the curriculum. These two aspects interact and usually settle down to adapting the same paradigm. However, some academic activities may have different objectives or goals from those in the industry. Usually, obtaining feedback from each other occurs. Textbooks, reference books, trade books, equipment catalogs, newsletters, and patent literature, among others, all reflect data for paradigm determination. Stories, anecdotes, speeches, memoirs, biographies, recollections, etc., are valuable sources, too. Current events and the prevailing conditions of the world certainly affect the paradigm of a profession. Using other relevant parameters, one can determine the paradigms of other areas that are more specific.

3.3 Probing Paradigms

Like reading history, just noting the paradigm of a profession could be more gainful. We should analyze, investigate and "probe the paradigm." This situation means a complete understanding of every aspect of the paradigm – like "feeling" its "guts." Some equivalent terms are finding insights, viewing perspectives, and observing points of view, outlook, stand, position, attitudes, and many others. The synonyms of the word probe, such as contemplate, muse, ponder, brood, mull over, meditate, investigate, study, examine thoroughly, go deep into, and feel around, certainly add more complexity to the term. Since paradigms are patterns or models, we can consider paradigms as maps of knowledge. After the probing, many new thoughts and ideas come out of our minds that we might have missed. It could be because more prominent ones in our minds covered them up. The combination of two or more ideas may reveal another point of view.

Thomas Kuhn (1970) probed the paradigm of the history of science, which he presented as "The Structure of Scientific Revolutions." The result was the introduction of the concept of "paradigm shift," which he believed was necessary for science to advance. Henry Small argued that paradigm shifts might only sometimes be present. The presence of a shift represents an extreme, and the opposite is the total absence. We will observe a spectrum of shifts between these two extremes.

I have employed the method of probing paradigms in my teaching, research, and extension service activities. I have formulated teaching strategies and innovations, developed inventions, and introduced new fields based on probing paradigms. I became more creative and innovative.

Having analyzed the paradigm of chemical engineering, I thought about initiating new strategies in my other areas of interest, such as education, biotechnology, environment, energy, and design engineering. In 1995, I started revising my textbook, "Introductory Concepts in Chemical Engineering." Based on the analysis of the paradigm of chemical engineering, I restructured the textbook using a sequence of topics quite different from other textbooks at that time. I introduced more straightforward techniques of solutions.

In 1998, I attended a seminar on Technology Intelligence (T.I.), which was about how to find the desired information from various sources. This fact reminded me of how I solved a problem in my first job: a form of T.I. Tinkering with the idea, I drew a graphic of an area bounding some small areas representing the known information. The rest of the area harbors unknown data. I interpreted the graphic as a paradigm consisting of several components. However, this conjecture needs support from the literature; I had to wait.

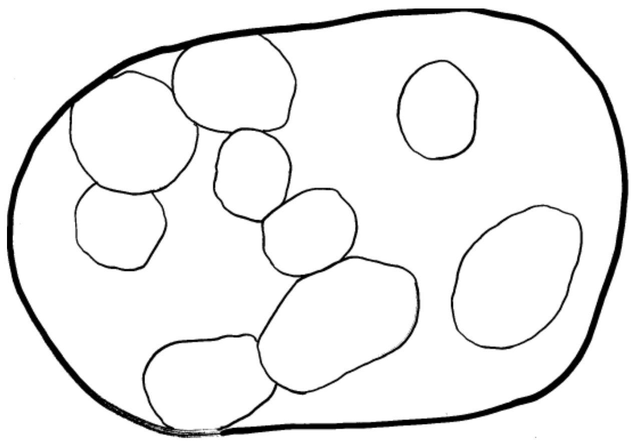

Figure 1. Graphic representing the information from a literature review. The large area represents the scope of the topic. The small areas are information from different references.

In the meantime, I started developing my technique based on the experience I gained from 1989 to 1998 on probing paradigms. A person must know how to probe the paradigm of a profession (usually the first one) for practice. The following are the steps:

1. Review your college education
2. Trace and examine the history of the profession
3. Critically note the developments
4. Find shifts in paradigms
5. Examine the practices in the profession
6. Follow the development of curriculum; books used
7. Find reviews, stories, anecdotes, etc.

In my 1998 professorial chair lecture, I presented my first paper on probing the paradigm of chemical engineering, "The Wijose Strategy on Chemical Engineering Education: A Teaching Strategy Based on an Analysis of the Paradigm of Chemical Engineering." By using the technique, I was able to develop some teaching innovations. In 1999, I delivered a lecture on chemical and environmental engineering paradigms at the National Convention of the Philippine Institute of Chemical Engineers. Well received, this talk was the first of my series of presentations on probing paradigms. Over the next six years, this was the subject of my chair lectures. However, the technique still lacked a conceptual framework. This situation prevented me from fully disseminating the method.

4 ESTABLISHING THE CONCEPTUAL FRAMEWORK OF THE METHOD

Having obtained positive results from the activity of probing paradigms, I next concentrated on finding a suitable conceptual framework. I read several papers and books on creativity and innovation. According to Plsek (1997), we should understand the theory behind creativity and innovation to be creative on demand because of three reasons: (1) research has shown that common myths that block creative thinking are not true, (2) knowing the theory allows us to realize what we want to accomplish when we use a particular technique, and (3) proceeding without a sound theory is not productive. The essential elements of a theory of creativity have surfaced over the past several decades (Gardner, 1985). The details of thinking and the mechanics of the mind point to the following: (1) Creative thinking is not a regular part of our normal thought processes, and (2) our mental actions can purposefully lead to creative thoughts (Plsek, 1997). The mechanics of the mind has four major components: perception, memory, judgment, and higher-order thinking. Around us is the reality of the world, which we receive through our five senses. We make sense of them through our mental subsystems of perception and memory. We decide what to do about them through the mental subsystem of judgment/choice. From here, we can then change the reality we perceive. A higher-order thinking subsystem controls these actions. We collect and evaluate the data and information we receive, and they become components of our beliefs and paradigms. We usually use paradigms in our minds as filters for the information we receive. The following topics have influenced the formulation of my conceptual basis.

4.1 The Connectionist Model and Spreading Activation Theories

In cognitive science, modern theory intimates the wide distribution and intricate interconnection of memories in the brain, which the connectionist model and the spreading activation theory acknowledge. A concept in memory corresponds to a particular pattern of activity among billions of interconnected brain cells called neurons. A network of neurons represents many mental concepts. The activation in one part of the network indicates the start of thinking. The thinking then spreads progressively by electrical and chemical means.

Cognitive psychologists employ the Connectionist Model Theory. Interconnected networks of units that are simple and uniform can represent mental episodes. Depending on the model, the units and the structural connections can vary. The neurons are the units, with the synapses as the neural network connections. Cognitive scientists use the Spreading Activation Theory. According to this theory, the activation of a unit spreads to all the other units connected to it. It is always a feature of neural network models. Regarding idea generation, the spread of the idea can continue to link to other ideas.

4.2 Mechanism of the Mind

According to De Bono (1969), the mind is like a place consisting of valleys and low points that fill with separate run-off streams. Water flow corresponds to the flow of thought, while the valleys represent perception channeled to the stream. We can picture creative thinking as linking valleys, not usually linked. New streams can carve, or two existing streams can connect, representing a new idea.

4.3 Visualization of Paradigms

What I had been waiting for occurred when Henry Small (2003) published a paper on visualizing and mapping scientific paradigms. He made a map based on citations of different authors and researchers on new ideas on nuclear physics. This arrangement indicated that maps could represent paradigms. As a doctoral candidate in the history of science in 1972, Kuhn's view of science influenced Small. He wondered whether mapping a field is related to the concept of paradigms and empirically validated Kuhn's theory. He concluded that this was impossible because of Kuhn's vagueness about the idea of paradigms, which remained at the philosophical level. What a coincidence, as it was in 1972 that I viewed the literature review as a map.

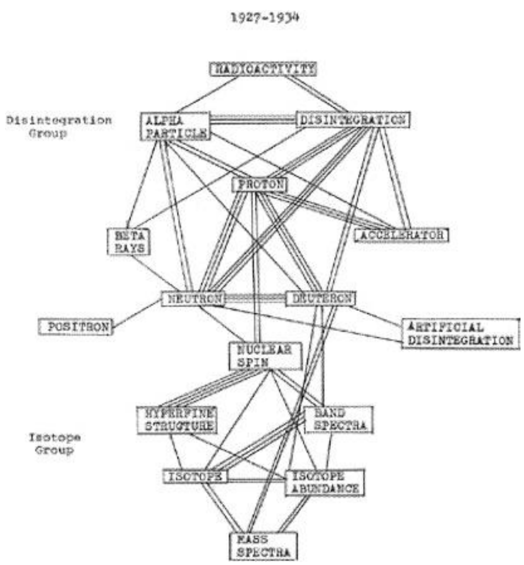

Fig. 2. Map showing keywords in nuclear physics papers from 1927–1934 linked by co-usage.

Small's knowledge map has a limitation because some citations can take place over several years. The progress of the mapping is relatively slow in this case. A new method is to collect clickstream data from scholarly journals that maps scientists' online behavior. One would collect, normalize, and convert the online usage data into a map, giving the relationships among different fields of knowledge. We can thus visualize trends in scientific research. (Bollen et al., 2009) This map presents the professions and disciplines as components of the paradigm of knowledge. Figure 2 validates my graphical representation of the paradigm of a profession.

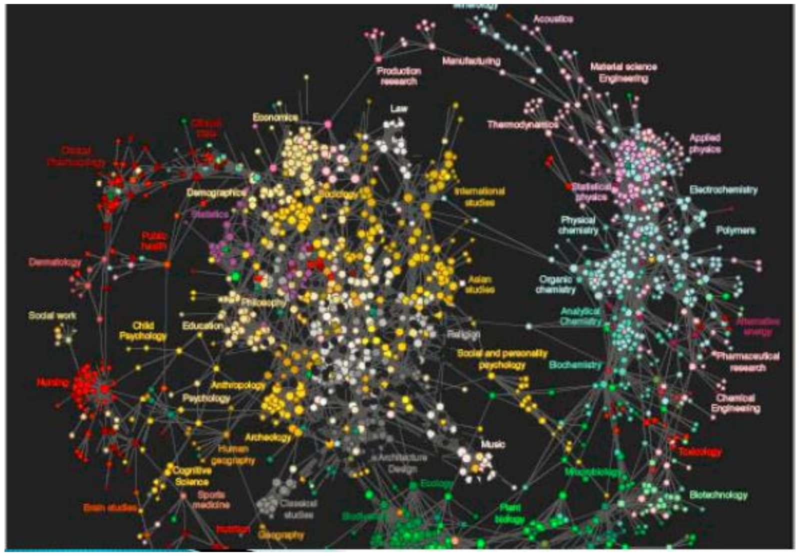

Figure 2. Map of science or the science paradigm with professions and disciplines as components. (Bollen et al., 2009)

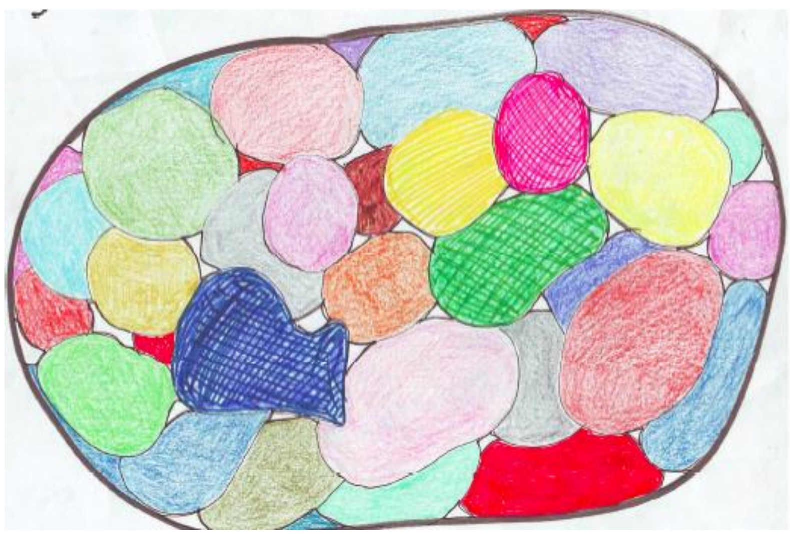

Figure 3. Paradigm represented by an area consisting of component paradigms (small areas)

4.4 The Human Brain as a Neural network

The brain is a powerful massive parallel computer with about eighty-six billion neurons. A single synapse connects to about 10,000 other units. It is a biological neural network that scientists aim to duplicate. We input tremendous amounts of data to the brain, which processes information slower than manufactured computers.

4.5 Stephen Thaler

Stephen Thaler is a scientist who built a synthetic brain capable of human-level discovery and invention. He created a creativity machine with a neural network that could perform activities like what humans can do. When he inputted the English language rules, the device made 1.5 million novel words. It composed classical music when inputted with the knowledge of classical music. It also invented products and processes. He based the machine's performance on discovering that a neural network invents (or hallucinates) when he purposely destroyed some neurons. (Thaler, 1996, 1997). Thaler's work jibes with my research, so I do not have to perform experiments with a neural network computer.

4.6 Integrating the information

The items above are the information that supports the conceptual basis of my technique. When we probe paradigms, all the data and information are systematically organized and mapped directly by our brains. After some period (about six months to two years), we voluntarily or involuntarily connect two ideas in our minds to come out with innovative ideas. We can do this either while we are awake or asleep. The brain is a powerful neural network computer that we expect to produce many ideas. The technique helps formulate strategies and new methods. After a while, ideas for invention and innovation naturally flow out. Thus, I developed a method based on paradigms, which I discuss below.

5 THE PARADIGM-BASED IDEA GENERATION PROCESS (PARABIGPRO)

5.1 How the technique works

The method consists of the following: (1) analysis of paradigms, (2) systematic organization of ideas, (3) mapping of these ideas in one's mind, and (4) connecting ideas to form new ideas.
We store these ideas in various parts of the brain. Referring to the Spreading Activation and Connectionist Theories from cognitive science, connecting two ideas may result in a new one that could become an innovation. Ideas can connect actively (awake or in the beta state) or passively (asleep or in the alpha state). While awake, we can use mind maps or concept maps to organize ideas or use the computer to organize them consciously. Passively, we can lead our mind into the alpha state with recorded information fed using an earphone. We can also explain the process by considering that our brain is a neural network computer consisting of two layers: the conscious and the subconscious minds. When we feed the information to the brain, the neural network computer learns and processes the data and produces outputs in terms of new ideas. Unconsciously, we input them again. By becoming aware, we evaluate and choose the good ones.

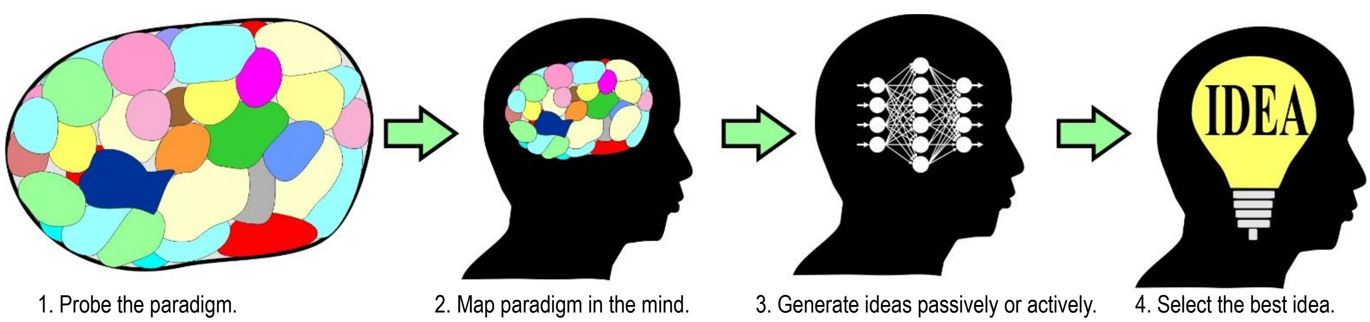

Figure 4. A graphic of how Para-BIGPro works.

The following are the steps we must follow:

1. Decide on the topic, area, subject matter, etc.
2. Determine the paradigm
3. Probe the paradigm
4. Map ideas in the mind

5. Connect ideas to produce new ideas
6. Harvest the ideas
7. Evaluate and select ideas
8. Refine the selected idea

For example, we can apply the above steps to a particular project on the biological treatment of wastewater. The relevant disciplines and representative knowledge involved are environmental engineering, chemical engineering, biochemical engineering, biotechnology, microbiology, biochemistry, chemistry, waste management, etc. To support these areas of study, some sources of information are the review of related literature, patents, and state-of-the-art knowledge. The probing depends on the researcher or team members involved in the case of a team project.

5.2 The paradigm of a profession (or the field of interest) concerning the paradigms of related areas of study

From 1989 to 1998, I initially probed the paradigm of my profession, chemical engineering. We can apply chemical engineering principles in the fields (or areas) of environment, energy, biotechnology, coconut processing, and design engineering, among others. As my research concerned these areas of study, I also probed their paradigms. The result was a constant influx of mostly original topics. By the end of this period, I felt an increased sense of creativity, which I could not fathom. This time, I can readily explain the mechanism. Refer to Fig. 5.

Figure 5.

6 SOME EXAMPLE APPLICATIONS

6.1 Formulating Teaching Strategies

In the first application of the technique, I found it effective to formulate, explain, and emphasize ideas or strategies in various aspects of improving chemical engineering education. In one approach, a student is given the fundamentals of the paradigm in a structured manner that promotes a reinforced understanding. The chemical engineering paradigm is "flexible" because of the profession's numerous changes. A realization of this fact will boost the students' confidence (Jose, 1998). The application of the strategy resulted in the development of a textbook, "Introductory Concepts in Chemical Engineering."

The first chemical engineering course's primary topic is mass and energy balance calculations. Implicitly, problems are solved using algebra and arithmetic (or only algebra in some cases). All chemical engineering students have taken up arithmetic and algebra subjects in high school and their first year in college. In arithmetic and algebra, they have solved verbal problems with mixing, compounding, separation, etc. The students were not aware that those problems were mass balance problems. The proposed strategy is to view or regard mass and energy balance calculations (MEBC) problems under steady-state situations as verbal problems in algebra or arithmetic. I applied the system in a textbook that I wrote. I structured the course to give only a few new relationships in each chapter. Thus, overloading the students does not happen. With all the relationships given (towards the end of the book), students would have gained confidence in solving MEBC problems.

During the initial class meeting, we tell students that they have solved mass balance problems before in their arithmetic and algebra classes. They will recall familiar situations by giving typical verbal problems in arithmetic and algebra. This setup usually builds up the confidence of the students. We then introduce the relationships necessary to solve those problems. The first is the mass balance equation: sum of mass inputs = sum of mass outputs, a simple relationship expressed as an algebraic equation. We emphasize that the technique used in solving mass balance problems is the same as in solving more complicated MEBC in other chemical engineering subjects or actual practice.

Mass and energy balance problems require certain relationships for their solution. Using arithmetic, we use the operations of addition, subtraction, multiplication, and division to solve the problem using certain relationships. We assign letters (e.g., x, y, and z) to the unknowns in algebra. n unknowns need n equations. Using the relationships, we set up the system of equations. A limitation of using algebra is that a manual solution is complicated if the number of unknowns or equations exceeds three. Therefore, the number of unknowns should be no more than three. This setup is possible by using the arithmetic method together with algebra.

6.2 Environmental Research

Human activities cause many environmental problems that require a multidisciplinary approach. Engineers recognize their role in solving issues directly concerning their field. Still, they must also realize that some ecological problems need expertise from other disciplines, such as social science, economics, natural science, and among others. This area is environmental engineering, better understood by identifying and probing its paradigm. The method of probing the paradigm of environmental engineering is based on its history, later practices, and present status. Since all engineering disciplines engage in environmental concerns, the paradigms of their respective fields reflect on the interpretation of the environmental engineering paradigm. Awareness of the paradigm can aid practitioners in having a better understanding of the overall policies, procedures, objectives, plans, and strategies.

Engineers from different disciplines can help in the solution of the problems such as in the management of solid wastes, municipal water and wastewater treatment, agricultural, groundwater, and soil pollution, environmental management, air pollution control, industrial pollution reduction, waste minimization, clean technologies, and environmental impact assessment, among others.

Knowing a clear paradigm of environmental engineering will enable us to formulate teaching strategies that will result in more accessible learning. We can plan research works better using the same techniques.

The objective of related research is to provide an effective biological wastewater treatment system for industries and residential areas through the local government units (LGUs) in the Philippines. This research requires knowledge of many disciplines, such as those mentioned above. We can optimize the use of technology by process intensification, whereby the resulting process rate increases when we combine appropriate new and old principles. For example, we could design attached growth systems to treat wastewater to produce an effluent with acceptable quality that passes regulatory standards. The cost of the usual microbial support materials is prohibitive. By immobilizing the microorganisms on support materials, the rate and effectiveness of the biological reaction become enhanced. The system is more robust, stable, and not prone to shock loading and process failure. System maintenance is less than that required by an equivalent activated sludge system. This research utilizes waste materials (plastics and biomass) as microbial support. The system consists of an anaerobic baffled filter reactor and an aerobic attached film reactor, evaluated in bench, pilot-plant, and commercial scales. The system startup and operation in both continuous and semi-batch modes are tested. The system has been successfully implemented on a commercial scale. I attribute the success of this research to the technique of probing paradigms.

6.3 Introducing a New Area of Study

In 2001, my professorial chair lecture was "Mass and Energy Balance of the Human Body." I came up with this idea by connecting the paradigm of chemical engineering with my health experiences. It was merely a direct application of chemical engineering principles to another area of study and an illustration of a result of probing paradigms. I revisited the topic in 2010. With additional probing and extending the issues, I realized that the subject is a new study area.

Professionally, health and wellness are usually the concern of health and medical practitioners. However, the analogy and similarity between biological and engineering systems are striking that engineers become interested in studying potential applications. The human body is more complicated than many engineering systems. Applying engineering principles to the human body can logically improve its performance. Five important principles (mass balance, energy balance, momentum balance, charge balance, and moment balance) apply to the human body. About two (2) dozen auxiliary principles (fundamentals usually studied in physics and chemistry) supplement the important principles. I have discussed some practical applications in my lectures; however, direct applications of some principles may be complex and have some limitations. Genetic makeup, environmental factors, and lifestyle practices affect the body's performance. A more realistic alternative is to apply the principle of preventive maintenance of engineering systems to the human body. This application will result in a well-functioning and healthy body.

We possess an intricate machine (the body) and a powerful computer (the brain), but we do not get an "owner's manual" on how to operate them. The government should provide an essential manual that every person can follow. Of course, every person has free will and consciousness, which makes the human body superior to engineering systems.

I am now drafting a book about health and wellness with many innovative ideas because of probing paradigms.

6.4 Inventions

Inventions come as a bonus to the technique. After practicing the routine, innovative ideas will naturally come, which we can eventually develop as full-blown inventions. The result depends on the type of background the practitioner has. A professional with a sound footing in his field will experience increased creativity and innovation after some practice with the technique. The sophistication of the invention directly correlates with the knowledge and information one possesses.

7 CONCLUSION

We often take for granted the knowledge and information we obtain formally or informally. If we meticulously organize the information in our minds, then the paradigm in our minds strengthens. We can use that paradigm to filter the information that we receive. This situation can assist our brain as a neural network computer to function more efficiently. These were always part of my activities. After five decades of work, a concrete result that concerns creativity and innovation has evolved. In the era of the new normal, the pandemic, and Industry 4.0, we need creativity and innovation. ParaBIGPro is one of the methods we can employ.

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