Steps to pluripotent learning: provocative teaching

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Submitted 13 July 2011; accepted in final form 31 July 2011

Rangachari PK. Steps to pluripotent learning: provocative teaching. Adv Physiol Educ 35: 323–329, 2011; doi:10.1152/advan.00065.2011.—Education involves interactions between students and teachers in a societal framework. Teachers can best serve their students and society by making students flexible enough to thrive under uncertain conditions. They should, in a sense, nourish, nurture, provoke, and stimulate pluripotent “educatoblasts.”

active learning; evaluation; student-centered learning

CONSERVER LA SANTÉ ET GUERIR LES MALADIES (to preserve health and fight disease), the opening words of Claude Bernard’s classic work, sets his agenda for a proper scientific approach to medicine. He goes on to remark “pour embrasser le problème médical dans son entier, la médecine expérimentale doit comprendre trois parties fondamentales: la physiologie, la pathologie et la thérapeutique” (1). This can be loosely paraphrased to say that experimental medicine must be composed of three fundamental components: physiology, pathology, and therapeutics. I have often told my students that pharmacology is fairly simple, provided they have had a good grasp of physiology.

I am deeply grateful that your society chose a card-carrying pharmacologist for this signal honor. It is an enormous privilege to be asked to give the Claude Bernard Distinguished Lecture. When I look at the roster of the many who have given this lecture in the past, I feel both honored and humbled to find myself in a distinguished company of teachers, many of whom have authored standard textbooks and had enormous influence on the teaching of physiology on a global scale. There is an added pleasure since I have got to know several of them (Penny Hansen, Dee Silverthorn, Joel Michael, and Harold Modell) through diverse meetings of the American Physiological Society. I would like to mention, in particular, the late Howard Barrows, who received this award in 1995. I got to know Howard only in the last few years and found him to be a critical, thoughtful, and humble teacher who genuinely fostered student-centred learning. I would like to dedicate this lecture to his memory. I am really grateful to Mary Anne Rokitka and Penny Hansen for their efforts on my behalf.

Although we know Bernard mostly for his research work, he took teaching very seriously. His lectures at the College de France were markedly different from the ones that students received at the university. Whereas the conventional lectures were plain speeches to the audience, Bernard’s presentations were more active. He always showed new results, included demonstrations, and used the lecture hall as an extension of the laboratory. He sought to cover practically all aspects of physiology and emphasized experimental approaches. In his first lecture on December 14th, 1847, he discussed the results that William Beaumont had obtained using the accidental gastric fistula produced in Alexis St. Martin (37). Bernard was not alone. Henle, Ludwig, and, above all, Purkyne were not only outstanding researchers but excellent teachers who propounded what we would now call “active learning” (29). The perceived dichotomy between research and teaching is a much later construct.

Although we take teachers and teaching for granted, it is instructive to consider a comment made by Margaret Mead several decades ago (16). She noted that “a human being’s most human characteristic is not the ability to learn, which human beings share with many other species, but the ability to teach and store what others have developed and taught them. Learning, which is based on human dependency, is relatively simple.” In simpler, self-contained, relatively homogeneous cultures, dependent learning was sufficient to ensure that the young could absorb all that their elders knew. These were closed systems that simply replicated the past. In more complex systems, open to outside influences, this could not always be ensured, so complex teaching systems arose. Mead had commented earlier (17) that there was “a shift from the need for an individual to learn something which everyone agrees he would wish to know, to the will of some individual to teach something which it is not agreed that anyone has any desire to know. Such a shift in emphasis could only come with the breakdown of self-contained and self-regulated cultural homogeneity.” Even even in complex teachable systems, eminent teachers from diverse cultures and different ages (Ibn Sina, Petalozzi, Tagore, Montessori, Dewey, Freinet, and Freire, to name just a few) have recognized the value in making students autonomous and self-directed learners. Yet in our fact-ridden world, teachers are reluctant to shift the locus of control entirely to their students. A sensible balance needs to be struck to preserve student-centred learning in a standards-based world (3).

Mead’s comments highlight the three essential components of any educational enterprise: the student, the teacher, and the society or cultural context in which these interactions occur. The expectations that each of these parties bring to the enterprise can differ, and the lack of concordance may give rise to considerable tensions.

All educational endeavors are intrinsically optimistic since they attempt to alter the status quo, preferably for the better. Students, either through their own volition or the urging of others (parents or society), enroll in educational programs to improve their lot. Universities are no exception. Hope springs eternal in convocation addresses either by recipients of honorary degrees or valedictorians. Yet amidst all that exuberance and optimism lies the uneasy feeling that the future is an uncertain one. Universities can best serve their students, and through them society, by equipping them to face uncertain but
exciting futures. How can this be done and what role should teachers play?

Teachers must see their students much like stem cells that can survive and flourish in any environment. We should, in a sense, nourish, nurture, provoke, and stimulate pluripotent “educatoblasts.” This looks like a very tall order, and it certainly is. How can we set about this? Perhaps by trying hard to be more flexible, less doctrinaire, unstranded, and, dare I say it, undisciplined? We should be agent provocateurs. In a delightful, witty, and provocative essay, McWilliam (15) makes much the same arguments. She says that the shift from the sage on the stage model to guide on the side, although necessary, is no longer effective. Facilitation may well be an excuse for inaction. She challenges teachers to be meddlers in the middle and asks them to work along with their students. This is easier said than done, and, in the sections to follow, I will try and expand on that theme by drawing mostly on my experiences in teaching undergraduate students in diverse programs. I apologize in advance for what looks like excessive self-citations.

Chickering and Garmson (2) listed seven principles that define good practice in undergraduate education. Teachers should 1) encourage contact between students and faculty members, 2) develop reciprocity and cooperation among students, 3) foster active learning, 4) give prompt feedback, 5) emphasize time on task, 6) communicate high expectations, and 7) respect diverse talents and ways of learning.

Putting Principles Into Practice

Teachers who want to put the above principles into practice should ask themselves four questions before embarking on any teaching assignment: 1) what am I going to teach (objectives)? 2) How should I teach (delivery)? 3) How will I judge whether my students have learned anything (evaluation of course)? and 4) How would I know that I have done my job well (evaluation of course)? A teacher who sets out to encourage their students to become pluripotent learners should consider each of these elements.

Objectives. Most departments and teachers spend considerable time and effort specifying the objectives of a course, since what needs to be learned sets the stage for all that follows. There are three broad categories that should be considered: knowledge, skills, and attitudes. The knowledge component of a course clearly varies from course to course. A course in engineering physics would obviously have different expectations of students than a course in nursing. It is, however, reasonable to expect that in any science-based course, students should know the relevant facts, concepts, techniques, procedures, assumptions, and sources of error. Given the volume of information available, the tendency to overload the curricular content is an ever-present danger. This temptation must be resisted, since there is really no point in submerging a student with information that can be barely recalled. Elsewhere I have argued for a “nonembarrassing” approach (24), which leads to the production of a list of items/concepts that would be so basic and general that a lack of appreciation or awareness would be an embarrassment to the program. There is a tacit dimension to knowing, as Polanyi (22) pointed out, which involves the procedures, values, and tricks of the trade that are rarely codified or published. Yet, from the perspective of experimental sciences, these need to be considered.

A greater emphasis on generic skills may be more relevant in preparing students for uncertain futures; particularly useful would be skills associated with the gathering and processing of information. Experience with computers may not necessarily translate into information literacy. In fact, students may feel that “two clicks of the mouse” may substitute for the three rubs on a magical lamp to get them what they want (6), and it may be worth giving students some exposure to useful techniques (32). Students should also be able to communicate effectively both orally and in writing and share information. Other generic skills that have been discussed at length include abilities to share information as well as abilities to assess their own performance. Evaluating these is not easy.

In most of my courses, I have considered objectives in a slightly different fashion, based on an approach proposed by Eisner (7). He argued that educational goals have two components: an instructional component and an expressive component. The first (generally termed “course content”) can be readily defined. This states explicitly what facts, items of information, concepts, and skills that a student will acquire or needs to acquire when they take a specific course. These can be stated explicitly, and appropriate evaluation procedures can be set in place. Expressive goals, on the other hand, provide students an opportunity to explore issues that are of particular relevance to them. To use Eisner’s words, they describe “...an educational encounter–identifies a situation, a problem, a task in which they ought to engage; but does not specify WHAT–they ought to learn...[and] provides both the teacher and the student with an invitation to explore, defer, or focus on issues that are of peculiar interest or import to the enquirer...An expressive objective is evocative rather than prescriptive.

In contrast to instructional objectives or outcomes, assessing expressive objectives is very difficult. However, in terms of preparing the student for an uncertain, unpredictable future, an emphasis on expressive outcomes is vital.

Delivery. Active learning works, as shown by data drawn from a variety of disciplines (learning sciences, cognitive psychology, and educational psychology) (18, 23). Unfortunately, the precise format by which such learning can be fostered has become mired in acrimonious acronyms. The educational literature is rife with discussions about the relative merits of “PBL,” “POGIL,” “e-PBL,” etc. One is tempted to invoke Freud’s notion of the narcissism of small differences! All these approaches have something in common: they are student centred to varying extents, encourage students to seek, synthesize, and integrate information from a variety of sources, and assess performance in diverse ways. Active learning can be fostered in a variety of setting ranging from small to large groups and in face-to-face settings as well as online. The appropriate approach is restricted only by the availability of resources, the willingness of the teachers, and the collective imagination of those entrusted with the task of achieving these ends! These are all really variations on a theme enunciated by Dewey (5) under the rubric of inquiry. In his view, the process of inquiry was the “directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole.” Essentially, a student
begins with incomplete information and gathers the required information to help him or her progress to a point where they can state with confidence that they have learned something. Dewey used the exquisite phrase “warranted assertibility” to capture the incompleteness of the process. All the active learning strategies that are discussed in the burgeoning educational literature are really variations. The important element is the student must recognize the tentative nature of their conclusions but be able to back these up with evidence and demonstrate to their teachers that they can gauge the extent of their knowledge or ignorance. This, in turn, puts the onus on the teachers to evaluate performances adequately.

**Evaluation.** Evaluation is the thorniest problem of all. The two words “assessment” and “evaluation” are often used interchangeably, although they have slightly different connotations. Assessment is the process by which one gathers evidence to determine the worth of an item, whereas evaluation is defining the worth of that entity. For my purposes, I will simply use the term “evaluation” since we are finally interested in making some sort of judgment. It is important to remember that evaluation is never neutral or easy. In their excellent manual for teachers, Fenwick and Parsons (19) note that “evaluation is shot through with issues of power, responsibility, sensitivity, and even personal taste.” Even so-called “objective” tests have their own agendas, usually in the selection of questions. The term “objective” itself is a very odd one when placed in its proper historical context. Dear (4) has traced the shift in meaning of that word from its original sense of referring to objects to our current notion of disinterestedness. As he puts it, all its virtues are negative; “truth is beside the point.”

Evaluation entails a view of society. It is vitally important to recognize that success or failure is contextual. A student’s transcript gives some information about his or her performance in diverse courses. However, it is a relatively “thin” description, to use a term borrowed from the anthropological literature (10). What we need is a “thick” description. When looking at a sea of transcripts, we should ask why a particular student did well in such and such a course and poorly in others. I often take on students with rather patchy transcripts, if I can get a sense that the student did well on challenging courses that interested them. Unfortunately, it is rather time consuming to do such detailed analyses so we often resort to more convenient measures. Convenience is a perfectly good reason to take action as long as we do not camouflage it with profundity! Teachers, students, and society often differ about the meaning and purpose of evaluation. Teachers focus on whether or not their students have learned anything from their courses. Students, on the other hand, are concerned about the impact the evaluation has on their progress. To them, fairness is a major issue, and they would prefer to be justly rewarded for effort they have put in (34). Society is more concerned as to whether they can trust the procedures that have been put in place to recognize true merit in the students who take particular courses or programs of study.

In the sections to follow, I give my personal approach to the evaluation problem. I would like to confess at the outset that I am always uneasy about this element of the educational process. I try to follow three cardinal principles. First, students must learn from the procedures. Ideally, any examination must be followed by a detailed discussion in the classroom where the answers are discussed in the class. This is often impossible to do, since summative assessments are usually done at the end of a term, and, by the time the exams have been graded, the students have left. Second, all procedures used must be consistent with the goals of the course or program. This seems self-evident, but it is often not practiced. One of the purported goals of inquiry-based or problem-based learning is to provide students with the skills to seek, synthesize, and integrate information from multiple sources, and yet many problem-based learning courses examine their students with variations of multiple-choice questions, which seems decidedly irrational. Finally, students must be given multiple options. This is crucial, since not only do students have different learning styles, but they have differing strengths and weaknesses at assessments. It is unfair to impose one system of evaluation on all. Ideally, I would like to have the students select their particular option from a menu of options so they have some choice. When this is possible, it works very well, since it carries self-directed learning into the domain of assessment (28), but usually multiple constraints proscribe this approach in most courses.

As noted earlier, all courses of study should have both instructional and expressive outcomes. In most of my courses, I try to balance the assessment of both instructional and expressive outcomes. The former can be stated quite explicitly in behavioral terms, and a vast array of assessment procedures is available (9, 13). The choice of these is really based on class sizes and resources. The value of assessing instructional outcomes cannot be dismissed, but an excessive focus on competencies may short change students in the long term (11, 35). Expressive outcomes are more problematic.

**Beyond Competencies: Fostering Flair**

If we are serious about preparing students for uncertain futures, we must put in place assessments that move beyond merely gauging competencies. We should foster imagination, creativity, and flair. In many of my courses, I try to include assessments that challenge students in different ways and transgress disciplinary boundaries. Although these look disparate, there are common elements and can be considered evaluation isoforms, to use the standard language of my discipline. I describe several of these below.

The legacy tripartite problem-solving exercise. Several years ago, I developed a process-oriented exercise [the tripartite problem-solving exercise (TRIPSE)] that was modeled on the normal practice of science (25). Students are given a situation with limited information and are asked to frame a set of possible explanations (part 1). They then select either the best explanation or all explanations and suggest avenues for further exploration (part 2). In part 3, students are provided more information and are asked to reassess their original explanations/tests. The exercise was originally designed for smaller classes of 15–20 students but was later revamped to suit larger classes (20). For a freshman course in cell biology, we refashioned the TRIPSE to foster student engagement and creativity. In the first part of the course, a series of standard lectures gave students a framework to look at cellular signaling mechanisms. Several molecules (histamine, acetylcholine, and norepinephrine, in particular) were studied in detail. Students were familiar with the elements of a TRIPSE, having taken a few. Here, we threw the ball into their court and challenged
them to design “novel” problems that could be used by us for future classes. In this way, they were leaving a legacy to the program.

The instructions were fairly simple. Students were told to 1) write challenging problems based on published material; 2) state four plausible hypotheses and, for each hypothesis, indicate the appropriate experimental tests; and 3) provide annotated references. Interim feedback was given. Groups were assessed on clarity, creativity, plausibility of hypotheses, relevance of the experiments proposed, and corroborated for statements made. The students rose to the challenge and demonstrated creativity and even a touch of whimsy. They were often quite irreverent, using the instructors as characters in the problems they wrote. They relished the opportunities given, and, from our perspective, we had a sizeable bank of problems to use in the future (31).

The UNSIN Project. The UNSIN Project formed part of the same undergraduate biology course as mentioned above. Students had been provided a framework and detailed information about a limited set of molecules. In this project, we challenged them to transfer their learning to a novel domain. They were asked to explore the molecular underpinnings of sins. Students were divided into groups, and each group was given the task of devising a molecular approach to tackling ONE of the following sins: gluttony, lust, wrath, and sloth. They were expected to read the primary literature and come up with a coherent plan. I met with each group at specified time slots to provide comments on their progress. At each session, one student was selected at random to ensure that the groups had worked well together. This project worked very well, and students explored various molecules (ranging from dopamine, serotonin, ghrelin, leptin, cGRP, norepinephrine, etc.). A group of students presented a poster on this project at Experimental Biology 2011 (19).

Improv exercises. These were developed for a course that attempted to meld toxicology and creative writing. Students were expected to learn the essentials of toxicology and demonstrate their learning in different ways. These included writing book and movie reviews as well as stories, poems, and plays. In addition, I designed two timed “exams” labeled as “CRIME” and “GRIME.” The creative-writing improv exercise (CRIME) was an individual exercise, whereas the group improv exercise (GRIME) required group effort. Students were given the license to explore any poison(s) they chose and be prepared to write a creative piece within a specified time limit. To start them off, they were provided triggers. Their tasks were to incorporate all the disparate elements into a believable story and ensure that the “facts” were correct. Students provided an appendix to explain how their facts were properly incorporated. The triggers used were varied. Sometimes I just gave them a list of items that needed to be incorporated (e.g., a young person, an old woman and a cat, a wild raucous party in a penthouse suite, an elegant woman dressed in a shocking shade of pink having a hysterical fit, a partially open elevator stuck on the 29th floor of a high-rise building, and a body slumped in a corner). At other times, I gave them a few sentences that needed to be incorporated somewhere in their story.

Students responded very well to these exams. They themselves were quite surprised as to how creative they could be under somewhat stressful conditions. One group was able to compose a mini-musical within that time frame and even played bits of their music on a nearby piano. Rigor was maintained by ensuring that the “facts” were properly incorporated into their tales. Transgressing disciplinary boundaries was quite exhilarating for them. Details have been published earlier (30).

Conversations. Conversations provide students an opportunity to explore complex issues, since they can present several sides of an argument. One of the best of these is the celebrated dialogues that Galileo used to discuss the two world systems of Ptolemy and Copernicus. This approach is quite flexible and can be readily adapted to a variety of courses. In an inquiry course that explored different facets of teaching and learning, students were given a list of eminent educators and asked to frame a conversation among several of them using contemporary themes. The students responded well. The topics chosen ranged from standardized testing, student-centred learning, the role of religion in education, intellectual-based segregation, and Africentric schools. The last topic was particularly interesting. This was an approach being considered by the Province of Ontario, and students framed this as a conversation among Paulo Freire, Celestin Freinet, Pope Benedict, and Booker T. Washington. Appropriately, they set the conversation in the home of the premier of the province (Dalton McGuinty), who had graduated from McMaster University with a degree in Biology. When I wrote to him, he said that he would be delighted to read their report, but his busy political life did not give him an opportunity to comment on the report. Later, I taught a similar course online at the University of Keele with senior Pharmacy students. Their conversations focused on issues relevant to Britain.

As mentioned above, this approach is quite flexible. Students in a course that dealt with historical development of medical technologies explored a variety of topics ranging from human papillomavirus vaccines, cochlear implants, the ethics of transplantation, and the framing of hand-washing campaigns, among other topics. In another course that dealt with taste perception, a student wrote a fine and amusing conversation among chefs and patrons at a new restaurant. Below is the abstract for his conversation:

In the year 2100, personalized medicine is old news. Advances in taste research and genome sequencing technology have ushered in an era of “tastomics” leading to the personalization of taste. The world’s first ever personalized restaurant, “Chez Toi,” has been created. The Andersen family is Chez Toi’s very first customers.

He neatly integrated the molecular biology of taste receptors and molecular gastronomy in an amusing piece.

Students were given considerable license to frame these conversations. However, they had to submit a list of annotated references to document their sources. The three elements used to assess these reports were content, clarity, and corroborated. The above exercises give a flavor of the approaches I have used to provoke students to go beyond disciplinary boundaries and be creative.

Earlier I mentioned the seven principles of good teaching practice. In looking back on my own teaching career, I feel that overall I have done reasonably well on most of them, although I have been relatively casual about deadlines and probably not as good on giving prompt feedback.
Deadlines, particularly in the context of learning, make me uncomfortable. I express my position quite clearly in my course outlines:

I am very ambivalent about deadlines and make my position transparent so there are NO misunderstandings. On the one hand, I believe that rigid deadlines hinder true learning. If one wants to be a lifelong learner, the only true deadline is set by HER who knows best. I have no clear instructions from that source. The real problem is that students do not delay handing in items BECAUSE they want to learn better but because they focus on different issues. By not penalizing late submissions, teachers do injustice to those who follow them. In addition to the Registrar’s office, the calendar constrain us. So for this course I am going to shift some of that responsibility onto you.

Do students take advantage of this leniency? Some do. Interestingly, in the one course where I gave students complete license to set their own deadlines and hand in material at the times that suited them, the response was excellent (28). I wish I could be more doctrinaire. Some of my colleagues have criticized me since I am not preparing students well enough for a world that has clear and non-negotiable deadlines.

Feedback is another thorny issue, and I have never really resolved it well. The term itself is used widely in the educational literature, and although everyone accepts that it is important to provide students comments so that they can improve, how exactly this should be done, how often, and in what form remain difficult to standardize. Even more perplexing is what exactly this means to the student who is the recipient of such comments (21, 34). In my courses, I try to monitor student performances and provide comments at periodic intervals. On all written reports, I provide detailed and individualized comments. Even when I teach large classes (150–200 students), I read the answers to all exams and wherever possible write comments. Unfortunately, major projects and submissions occur toward the end of a course, and although I give detailed comments, it often seems to me that students are more concerned with their overall mark (grade). My behavior was not that much different with respect to comments on grant proposals. When funding was denied and I knew that I had to make vast improvements in the next submission, I took the comments far more seriously!

Another difficult issue to deal with relates to self-assessment. There is little doubt that this is crucial toward developing self-directed learners. Fenwick and Parsons (9) note that “self-assessment returns the ownership of knowledge and the accountability for working and learning, back to the learner where it belongs.” Clearly providing them the skills to monitor their own performance is vital, but how exactly this is to be done, and how frequently, is contentious. Eva and Regehr (8) pointed out that the term itself is used inconsistently. In standard, small-group problem-based learning tutorials, time is usually set apart for peer and self-assessment. This works well if carefully monitored, but, more often than not, lip service is paid to this component. Although it is easy to list criteria and set guidelines, consistency in practice is very difficult, especially so in large classes. One very useful approach has been to make students keep a log of their own learning. In one course, I made it mandatory. Students were asked to keep personal logs that I examined on a weekly basis. I posted logs of my own performance for them to see. The response was quite mixed (27). I have made it an optional component of several courses. Some students do this very well and relish the opportunity; others do not. I confess that I have never been entirely satisfied with all my attempts at getting students to assess their performances. Whether self-directed learning can stand up to external assessment is an issue worth considering (14).

Much of the emphasis on assessments has been on assessment OF learning. Thus, teachers want to assure themselves (and society) that their students have acquired the needed knowledge, skills, and attitudes that courses are designed to foster. It is equally important to consider assessment FOR learning. There is little doubt that assessments do drive learning. If we are to encourage and foster learning beyond the narrow confines of the class room and prepare students for the future, we have to set in place assessments that make them want to learn and encourage learning. The term “consequential validity” (34) has been used in this context, but, like many other terms in the educational world, it is open to diverse interpretations. In my courses, I designed evaluation procedures to serve two purposes. The first was to have multiple evaluation procedures to give students an opportunity to demonstrate their strengths and not be penalized by a single approach. The other was to provide them a rich learning experience so that they could appreciate the complexities involved in the practice of science.

Student comments at the end of a course provide some useful information about their learning experiences but do not touch on long-term consequences. Recently, I had an opportunity to discuss these issues with two former students. In 1994, the three of us wrote a paper contrasting our views on evaluation procedures used in a problem-based learning course in pharmacology (33). Sixteen years later, we revisited that paper. By then, both the students had become established professionals. One was an academic gastroenterologist and the other had continued working in industry. The revisit enabled them to discuss the long-term consequences of each of the procedures that had been put in place (36). We specifically discussed tutorial evaluations, problem-solving exercises, etc. Both of them felt that the processes had helped them in the long term. This was really gratifying to know as the teacher to see that I had really done little harm and may have helped them in their professional goals!

Thus far, I have been espousing the cause of a flexible, nondoctrinaire approach to teaching and learning. Much of these opinions have been shaped by my own educational journey. I was lucky that I grew up in India, a statement that may raise concerns about my sanity but is true. I was born in Tiruchirapalli (Trichy or Trichinopoly), a midsized town in southern India, during the middle of the Second World War. Postwar India faced many challenges, and my youth was spent in a newly emergent country that could not quite shake off colonial shackles. My father, who had joined the Royal Indian Air Force during the war, continued to serve in the forces, and so we moved around quite a bit; the inevitable disruptions gave me a flexibility that proved useful in later years.

I grew up surrounded by books. By the time I was four I could read and write both Tamil, my native language, as well as English. One of my great-grandfathers, a celebrated criminal lawyer, had been knighted by the British, and my childhood was spent in a delightful polyglot muddle where multiple mythologies jostled in my mind. Hindu, Norse, and Greek gods...
(Rama, Krishna, Thor, and Jupiter) wrestled with more modern ones (Hopalong Cassidy, Gene Autry, Tom Mix, and Audie Murphy) brought along by a flood of comic books and films at the local cinema. There were no summer camps, no obligatory sports clubs, no orchestrated social activities; only a delightful sense of freedom. I doubt if I would have survived a North American childhood without serious counseling. At the age of 10, I found myself wandering parks rather than attending classes, since we had no truant officers cross-checking our whereabouts. My parents were quite distraught, but fortunately that delinquent phase passed, and I quickly morphed into a bookish nerd just as I reached high school.

Raising the Indian tricolor flag did not eliminate a lingering affection for the British system of education, and I found myself shuttling from one missionary school to another, since there was a mistaken belief that such schools instilled “discipline.” They did, particularly the Irish Christian Brothers, who caned us with gay abandon. Sore palms and sore bums did not curtail us though. It was an all-boys school, and we remained a wild raucous bunch. I was quite fascinated with the taxonomy of sins and learned to steer carefully between the Scylla of Hindu shame and Charybdis of Catholic guilt. The good brothers gave me a deep love for history and English literature. However, they taught science and mathematics very badly. We even learned Euclid by rote! Curiously, my interest in science came through my interest in history. While studying English history of the 17th century, I realized that science was not as dull as my teachers made it to be, but it had been “constructed,” to use a current term. Much of my science learning occurred outside the classroom. A lot of this stimulus came from a classmate, Mohan Chari, who later distinguished himself as an organic chemist, first in Germany and then in the United States. He got me excited about astronomy and physics, and we became ardent rock hounds as well. Oddly, I usually got better marks than Mohan did in school, though he was far more gifted.

When I was in my final year at high school, the Russians launched Sputnik, and we were all agog with the exciting frontiers that were being conquered. The marvelous library attached to the United States Information Service (USIS) in New Delhi was a blessing. The Eisenhower administration had promulgated the Atoms for Peace initiative, and so the library had an excellent collection of material on a variety of subjects. I devoured books and journals on a variety of subjects ranging from mineralogy, anthropology, and astronomy to nuclear physics. In addition, the Voice of America radio programs had excellent discussions on scientific matters. I remember very well listening to a fascinating talk late at night by Seymour Kety on neurotransmitters in the brain. George Gamow’s books were extremely popular, and many of us were entranced by the exciting world of science, so different from the dullness purveyed in the classroom. Several years later, I heard Gamow talk at Delhi University and found him even more enchanting as a raconteur. Niels Bohr, on the other hand, was barely audible. When I read Salman Rushdie’s Midnight Children, the events he described were eerily familiar, since I lived through them, but my reactions to them were obviously far different from those of his protagonists. Perhaps I lacked his artistic temperament or I just found science far too exciting and real to take refuge in matters fantastic.

When I came to North America, I was surprised at the enormous effort that students made to “prepare” themselves for medical school. I just drifted in. I had really no interest in practicing medicine, and my entry into a medical school was the result of a series of mishaps that derailed my attempts to enter an honours program in chemistry. This forced me to do a premedical program at Delhi University, where I realized that the chemistry that was truly exciting was biochemistry. However, the only opportunity to follow that path was to enter a medical school, which I did in 1961. I was fortunate in entering a research-intensive medical school (All-India Institute of Medical Sciences) where the basic scientists were world class. Luckily there were no interviews for admission then, with selection being based entirely on written exams. I may not have done well in any interview since I would have had to confess that I honestly had no interest in saving the world or helping anybody and it was pure, unbridled curiosity that was driving me on! Both my professors of physiology had enviable reputations. B. K. Anand had played a significant role in defining the role of the limbic system in feeding and satiety, whereas A. S. Paintal had discovered gastric stretch receptors and was widely regarded as a leading sensory physiologist. G. P. Talwar, the Head of Biochemistry, had studied with Jacques Monod at the Institut Pasteur and brought to the classroom the excitement of doing fundamental research. N. K. Bhide, an eccentric pharmacologist, made his classes interactive and used his lectures as sounding boards for discussion. We also had excellent demonstrators who helped us in the laboratories. One of them, Usha Nayar, became quite active with International Union of Physiological Sciences activities later on. After those giddy, exhilarating experiences in the basic sciences, the clinical years were deadly dull, and it was inevitable that I gladly left the bedside for the bench. I was recruited as a demonstrator in pharmacology—a job that made me responsible for running the laboratory courses for third- and fourth-year medical students. That was quite enjoyable while it lasted. Internal political problems drove me away to the University of Alberta in Edmonton, Alberta, Canada, where I completed my PhD in pharmacology and then began a series of wanderings to diverse laboratories in the United States as well as France. When I got a faculty position at McMaster University, it was due largely to my having external funding, since I had done little teaching over a 16-year period. In an earlier commentary, I described my introduction to problem-based learning, which produced a major transition in my professional life (26).

As a student, I was fortunate to have had many excellent teachers. Drs. D. M. Paton and E. E. Daniel, my PhD supervisors at the University of Alberta, were rigorous and demanding. Richard Durbin, with whom I spent 2 delightful years at the Cardiovascular Research Institute in San Francisco, CA, had started out as a particle physicist before shifting to physiology. He was an unusual and divergent thinker who was splendid in the laboratory setting. It was however, Paintal, whom I mentioned above, who was electrifying. A twitchy, sparrow-like figure, he would dart around the room, making cryptic comments that kept us guessing for days. His classes would run for an hour or a few minutes depending entirely on his mood. He would throw out questions at random and make off the cuff remarks that got us searching long and hard for what he meant. He would sometimes end his classes abruptly, drag us to his laboratory, and show us oscilloscope traces and
recordings from vagal afferents. I learned more physics in his classes than I ever did in 2 yr of a premed program, since that emerged in the context of real-life problems, not as mere answers to cookbook exams. He would talk toss off words and names—Keith Lucas, Erlanger and Gasser, Katz, Miledi, Adrian, and others. Physiology was a living discipline, not arid facts in textbooks. Paintal was never dull; he broke all the rules, never began with a set of items he would cover, had no clear outlines, no objectives were ever set out in behavioral terms, nor were there any standardized exams! What he did leave behind was something far more precious and long lasting, a palpable sense of excitement and wonder. Stimulating confusion proved more effective than depressing clarity! He was a master provocateur who, in a sense, was practicing problem-based learning before that term became fashionable, since he triggered in me, at least, the impetus to seek, search, and track down information, often from the most obscure sources. Half a century later, I still have vivid memories of his terms, nor were there any standardized exams! What he did bared me in that same way.

I want to end with a fairly long quote from Margaret Mead in an essay published the year I was born (16):

It is most uncertain whether the educational intervention made by those who emphasized teaching or the educational invention made by those who emphasized learning will survive. But the more rapidly we can erase from our society those discrepancies in position and privilege which tend to perpetuate and strengthen the power and manipulative aspects of education, the more hope we may have that the other invention—the use of education for unknown ends which shall exalt man above his present stature—may survive.

If teachers functioned not as passive repositories of stored knowledge but agent provocateurs who stimulate, encourage, and cajole students to select from the past and imaginatively tailor their needs to an uncertain future, then all will be well. True grit WILL make pearls.

ACKNOWLEDGMENTS

The privileges of living in a safe country cannot be taken for granted. I owe a deep debt to the Canadian taxpayers, who invest in public universities such as McMaster University, my haven for several decades. My exuberant students make teaching worthwhile. Dr. Del Harnish, the Assistant Dean of my program, has been extraordinarily tolerant and given me license to transgress disciplinary boundaries with impunity.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

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