Shifting the Emphasis from Cognition to Non-Cognitive Values in Science Education: A Case for the Inclusion of Critical Pedagogy in the Science Curriculum

Grace Sirju-Charran

Department of Life Sciences, University of the West Indies, St. Augustine, Trinidad

grace.sirju-charran@sta.uwi.edu

A comparison of the different teaching and assessment strategies for a science course, (Molecular Biology) and a course about science (Gender and Science), revealed that while content and class size may pose challenges to the use of certain pedagogical tools, the use of critical pedagogy which promotes democracy, dialogue and constructivism might be the most important factor in inculcating non-cognitive values. While the traditional content of science courses does not lend itself easily to the methods of critical pedagogy, new developments in science e.g. biotechnology; genetic engineering; nanotechnology as well as the critiques of the impact that many of the earlier scientific discoveries have had on society and the environment require a new social contract with science and society which necessitates the inclusion of an ethical analysis. Therefore, courses on bioethics and science and society that lend themselves to critical pedagogy should be included in the biology curriculum in order to develop those values and attitudes valued by employers and that are desirable for the "distinctive" university graduate.

Keywords: Critical pedagogy, Cognition, Non-cognitive values, Critical thinking

Introduction

> *"...We educators must reconstruct the university so that we can produce a liberally educated population rather than gadabouts or narrow specialists".*

This statement was articulated by Robert Maynard Hutchins (1899-1977) and cited by Howard Gardner (1995) in his publication, *"Leading minds, an anatomy of leadership"*. Hutchins was one of the eleven individuals deemed to be leaders in the field of education as analysed by Gardner. Before reaching the age of thirty, Hutchins was appointed president of the University of Chicago and he became well known as an innovator of ideas in American education during the Second World War. He was critical of the existing undergraduate programme with its emphasis on academic specialization, training for a career and football, stating that:

> "…we in the American higher education have lost our way. We have followed many false gods- sports, vocationalism, and cafeteria-style electives...that could lead to passing successes but that ultimately will yield a **vacuous** existence". *(my emphasis) Howard Gardner (1995)*.

The goal of his educational philosophy, was to create "the optimal education for undergraduates" which sought to 'nurture the mind' with an emphasis on the "...arts of reading, writing, thinking, speaking and mathematics". His proposal to achieve this was to introduce yearlong, inter-disciplinary courses based on the readings of classical texts including those of Aristotle and Aquinas. He argued that through study of this metaphysics, "students would come to understand the nature of the various disciplines and the relationships to one another". Further, he recommended the use of ***dialogic discussion*** *as* a pedagogical tool in order to ***"embody in one's living***, the key ideas and processes exemplified in these books" (my emphasis).

In spite of the distinguished alumni produced during Hutchins' programme e.g. Carl Sagan, and several Nobel laureates like Harry Markowitz, it was discontinued in 1952, one year after his departure from Chicago. Sixty years later, science and science education have evolved in precisely the opposite direction proposed by Hutchins, with an over-emphasis on empirical science, specialized courses in single disciplines and preparation of students for careers. Each of the scientific disciplines has become extremely reductionist, exemplified in biology, by the emphasis and controlling power that is being attributed to the DNA molecule and its individual bases (cytosine, guanine, thymine and adenine). Little attention is given to the power of the complexity of the interactions among the numerous other cell components and the organism as a whole. Undue emphasis is given to cognition, exemplified by the current higher percentage allocated to written examinations, the importance given to the second hand information given in textbooks and the necessity for students to memorize 'facts'.

While science graduates generally have good cognitive abilities grounded in one or two narrow disciplines, feedback from their employers' indicate a deficiency in non-cognitive qualities. Now that information is readily available with the click of a 'mouse' on Google, Facebook and Twitter, the past emphasis on cognition has receded in the background bringing to the forefront the non-cognitive qualities alluded to by Hutchins. It is not surprising therefore that science educators are being forced to examine their approach to teaching science, giving due consideration to the ideas espoused in Hutchins' philosophy of higher education. Emphasis must now be given to teaching principles and concepts rather than facts; to satisfying intellectual needs rather than training to get a degree as a passport for a job with a higher salary.

Non- Cognitive Learning Outcomes

If the goal of education is to produce critical thinkers with enhanced qualities that may be non-cognitive (such as ethics and values), a study of the great classics as a yearlong interdisciplinary course is not without its merit. However, it is hardly a viable option in today's educational scenario. The classics and yearlong programmes have for the most part, disappeared from the undergraduate curriculum and the semester system, not unlike Eliot's elective system (Carpenter, 1951) which he introduced during his tenure as President of Harvard, is very much entrenched in most institutions of higher education. Nevertheless, shades of Hutchin's philosophy of nurturance of the "life of the mind" as the target for learning outcomes is in the forefront of contemporary discussions on higher education. These are espoused in quality assurance issues, which speak to the attainment of non-cognitive qualities (e.g. team work, innovation, life-long learning, creativity, values, and ethics).

While the difficulty in measuring these qualities is acknowledged (Kyllonen, 2005), graduates who possess them are ranked more highly by their employers since they perform better in the work place than those who may have higher cognitive abilities but lack these qualities. Applicants seeking admission to medicine and related programmes are now being assessed for these non-cognitive qualities viz. self-esteem, persistence, discipline, and ethical values through the requirement to include with their application, a personal statement which is assessed for these qualities, since grades are generally the results from assessment instruments which measure cognitive qualities.

Institutions have adopted several approaches to address the deficiency of non-cognitive qualities in their graduates. Those with a four-year degree programme have dedicated the first year to a set of common courses e.g. history, philosophy, and communication studies with appropriate pedagogy in order to develop these non-cognitive life skills, preparing the student for life-long learning and responsible citizenship. The University of the West Indies (UWI), having retained a three-year degree programme and adopted the semester system undertook to revise its programme offering in which students had to major in two related disciplines or double major in a single discipline in order to graduate ,and introduced instead a number of majors and minors for each discipline. Students now have the opportunity to be exposed to a wider range of disciplines. However the majority of students still opt to graduate with a narrow disciplinary focus since the student with a "double' major in a particular subject is considered to be of a higher calibre than those opting to do a single major with a range of other courses (minors) from different disciplines. In addition, greater emphasis is being placed on in-course assessment, which is better able to assess non-cognitive skills than the final examination, which assesses mainly cognitive abilities. In addition to applicants seeking admission to Medical Schools, there is a move to assess these "softer' learning outcomes for *graduate admission* since there has *not* been a good correlation between research performance and good GRE scores and/or first class honours, which are awarded for the most part on cognitive abilities. In addition to a sound understanding of the subject area (cognition), good research performance requires honesty and integrity, creativity, critical thinking and problem-solving skills, discipline, persistence as well as a team effort in today's scientific research.

The Distinctive University of the West Indies (UWI) Graduate

The non-cognitive qualities required to produce the distinctive UWI graduate are mentioned in several paragraphs of the UWI strategic plan (2007-2012). Principal of the Cave Hill campus, Hilary Beckles (2003) in a paper he presented to the Board for Undergraduate Studies (BUS) entitled: The new teaching and learning environment, 2000, states that the demand of the globalised, technologically driven workplace needed graduates *"who can function independently and who have advanced thinking and reasoning skills, the ability to communicate effectively, both in oral and written terms and to think and perform creatively" (paragraph 27 of the strategic plan).* These qualities are clarified further by the office of the Board for Undergraduate Studies in *paragraph 28* which states that: "*our graduates must be capable of independent learning, of educating themselves and analyzing material which may not be particularly familiar to them, and to be able to appreciate how this material may have a value in different contexts, either as possible solutions to seemingly unrelated problems or as stimuli in the generation of novel solutions to complex problems"*

While the current scientific pedagogy does not facilitate the development of these qualities, introducing critical pedagogy supported by dialogic teaching and problem-posing approaches can provide the opportunities to fulfill these objectives. Of the curriculum, Beckles (2003) emphasized, "*It must be innovative, dynamic, inter-disciplinary, and pertinent*

and that it must combine teaching and training that stimulate students to pursue and develop new knowledge."

The Revolution in Science

While the goal of science, which is to discover the laws of nature using the traditional scientific method remains unchanged, the discipline has evolved to include the development of technology and innovation. It can no longer be viewed as a set of abstract 'truths' derived through rational, objective and neutral thoughts, performed by eccentric older men in white lab coats working in special laboratories and with major not immune to cultures and values in society. It is therefore imperative that we introduce students to the world of science in such a way that they can use the knowledge to transform their everyday existence and indeed our world. It has now become necessary to teach the human side of science and scientific reasoning. Using a historical approach which would give accounts of famous experiments and which includes the philosophical underpinnings, would reveal the uncertainty and false steps that accompany the development of scientific knowledge.

Science Pedagogy

Science pedagogy has not kept pace with the revolution that is taking place in science. New disciplines e.g. molecular biology, environmental science, biotechnology, information technology and nanotechnology have all emerged less than two decades ago. Information in these newer areas becomes obsolete very rapidly and a phenomenal amount of new information is being added daily. Nevertheless, it is still taught by and large, as a *collection of facts* to be memorized, reproduced in the examination and later forgotten. The curriculum reform exercise which is currently taking place globally emphasises content as the most important aspect requiring attention, e.g. the addition of new materials in courses and removal of "old" courses and overlapping materials. The focus still remains on the "What", "Who" and How Many?" and less on the "How" and "Why?" While the mode of assessment, albeit to a much lesser extent, is also being addressed by allocating a greater percentage of the assessment to coursework and group work, little or no attention is being given to pedagogical issues. Nevertheless, it is by transforming the latter, that achieving the non-cognitive qualities for the UWI graduate, described in its strategic plan to 2012, would be realised. The current 'hot" topics which have their underpinnings in biology e.g. human genome; stem cells and genetic engineering; climate change and new reproductive technologies, all provide an opportunity to use the tools of "critical pedagogy' by including consideration of the historical, philosophical as well as bioethical issues. This would be one approach which would enable students to become critical thinkers, to reflect on their values, and to satisfy their intellectual and emotional needs, thus achieving alignment of the quality of the graduating students with that articulated in the UWI's strategic plan to 2012.

Biology, Bioethics and Critical Pedagogy

All the courses taught in the biology programme are replete with ethical issues, analysis of which would require the use of critical pedagogy. However for the most part they are not included in the course outline and learning outcomes, which remain very heavily content-driven. Therefore the opportunity to infuse the programme with 'liberal' topics which would facilitate the development of skills in critical thinking, problem -solving and decision-making is not being grasped.

For example, the use of slingshots by undergraduate students and shotguns by graduate students to harvest leaves from tall trees in forested areas is an issue that could be usefully analysed by students. Similarly, the collection of hundreds of frogs during the night by technicians for use by undergraduates to conduct physiology experiments became an ethical issue not only because of the impact of collecting such large numbers for a class which had trebled in size, but because of the trauma experienced by some students, articulated mainly by female students and those of a particular religious persuasion. They had to observe the heads of the frogs being bashed in and were then required to pin them on to the dissecting board, then cut them open to record the heart rate. Often times the frogs continued to 'writhe' while the data were being collected. Students could be asked as an additional activity to conduct an ethical analysis, identify the stakeholders, the safety and environmental issues and discuss how the experiment could have been handled differently without compromising the learning experience. While there are arguments for either mounting a separate course on ethical philosophy, theories and tools for analysis or for its inclusion in relevant courses that deal with topics which lend themselves to ethical analysis, these will not substitute for setting an example by Faculty. Inputs of both Faculty and students are required to produce graduates with the requisite non- cognitive skills.

Pedagogical Issues in Two (2) Taught Courses

My interaction with students who were either in the second or third year of the biology programme and were following the course I taught on "Gender and Science" revealed that they had been starved of the opportunity to have their voices heard. Furthermore, they were over-burdened with in-course tests which had a strong leaning towards content recall, having to spend an enormous amount of time performing experiments in the labs and in writing up several lab reports. Some indicated that the major reason they had chosen to follow the course gender and science was because there were no lab sessions in the course. Disillusionment with practical sessions is certainly not a desirable outcome for students majoring in biology. Although it was not being articulated, it was clear to me that there was a sense of disempowerment among these students, arising out of their previous learning experiences. This was gleaned from comments made during the first week of classes

(e.g. 'this is the first time that our opinions matter") as well as from their reflexive journal entries.

I decided to reflect on my experience of teaching the molecular biology class with that of the 'Gender' class, in an attempt to understand what could account for the difference in the students' evaluation of both courses. Comparisons were made of: (1) the cohort of students; (2) the course content; (3) my own preparation and passion for the subject and (4) pedagogical issues. I was aware of the biology students' motivation and commitment to perform well in the "Molecular" course which was not only a core course for the biology major but whose content was relevant for several other core courses in biochemistry, genetics and microbiology. The gender class was an elective and for many students, hence it was 'clashed" on the timetable with some "core" courses. Attendance at "Molecular" classes was therefore better on average than the attendance in the gender class.

I considered the possibility that students' enthusiasm for the gender course may have been due to their assumption that the gender course was "light" and without academic rigour. However they soon realised that in addition to reading papers on the "History and Philosophy of Science" and critiquing the scientific method they needed to apply higher order thinking skills of comparison, analysis, synthesis and evaluation in doing gender analysis.

The relevance of the materials covered in both courses, for everyday life was made explicit. I felt I had done a good job by pointing out to the "Molecular" class that had it not been for controlled gene expression in eukaryotic organisms which resulted in the differentiation of cells into tissues and organs, we would simply be a mass of cells which all look alike with the same function. I also point out the relevance of this topic to genetic diseases. And while I explained how genes may be "over-expressed" or "knocked-out" through genetic engineering or replaced with better ones through gene therapy, I was very conscious of my own ethical position on these developments and tried to ensure that my own reservations and opinions did not creep into the lectures. While this topic provided an ideal opportunity for bioethical and gender analysis in which tools of critical pedagogy, dialogue, debate, case study and constructivist approaches could have been applied thus providing students with the opportunity to analyse and synthesize opposing views and to 'personalise' the knowledge, this would not have been in keeping with the 'culture' of a science class in which the major goal is transmission of content. Further, it did not appear in the list of learning objectives; was not examinable and therefore would have been of little interest to this cohort.

The teaching method used for the "Molecular" course resembled the "banking concept" of education described by Paulo Friere in his 1970 publication, *Pedagogy of the Oppressed.* Although attempts were made to avoid treating the students as empty vessels by referring to relevant materials which they would have been taught in the pre-requisite courses, this was usually met with blank stares, nervous giggles, and in the best case, a vague remembrance of the word. I could tell that the students did not appreciate this and it is quite likely that they perceived this strategy as an attempt to embarrass them, thus lowering their self-esteem. An alternative more acceptable approach might have been to give students the opportunity to make those links between the materials from the pre-requisite course and the new materials being presented on their own. However if this did not occur, students would have little choice but to "memorise" the new materials to "regurgitate' in the exam.

Because of the large class size, dialogic practice was a challenge and even though lectures were punctuated with questions, many of these were non-dialogic. They were posed in a manner that required the students to give the right answer- the "one" that I was looking for. This mode of questioning could be intimidating to all, but the very confident students. The "what do you think?" questions, which featured regularly in the "Gender" class, were not featured extensively in this course. Research on the nature of the questions asked as well as the response time allocated for answering them needs to be conducted. The time allocated to answering the question may have been insufficient for the students to recollect the material and frame the answers. I generally ended up committing the sin of the 'rapid response.' By giving my answers I further eroded the self-confidence of the students to master the material. The classroom climate (large and impersonal) was also very different from the gender class, which was small and intimate and therefore was a factor that challenged the use of critical pedagogy.

I would begin teaching the biology course mid-way in the semester and dive straight into the course materials. Although I was meeting most of the students for the first time, it hardly seemed appropriate to spend time getting to "know" these students. This was in contrast with the gender class in which each student introduced him/herself on the first day of class and with whom I subsequently met individually during the course of the semester to discuss their research project, in-course essay and journal writings. The practical exercise in the "Molecular' class would begin with a "lecture/lab talk' which sought to link the exercise with the theory so that students were better prepared to perform the experiments. However this 'teacher-centred' approach defeated the opportunity for self-learning by the students. Although the experiment was conducted in small groups, the reporting was done separately by each member for assessment, thus reinforcing the idea of individual accomplishment rather than true teamwork.

The module in this molecular course provided a classical example of teaching methods which encourage surface

learning- it was a short unit of 3 weeks, assessed mainly by recall questions and extrinsically motivated by good grades and passing the final exam. In the gender course, "getting to know" the students and getting them to know each other during the first lecture/class was important for the success of the course, since the students belonged to different sub-disciplines, and in some instances, from different faculties (humanities, social sciences; agriculture, and natural sciences) and they were all going to contribute to each other's learning in the class. It was made clear that each one had a unique perspective that they were obliged to bring to bear on each of the topics covered in the course.

The goals of the course, the lecture topics and the modes of assessment were discussed during this first session, taking into account the special circumstances of each student, indicating that they were negotiable and could be modified with good reason. While the total marks for the coursework (40%) and final exam (60%) were fixed, details of allocation of marks for each component, the structure of the final exam and the dates and time lines for various assignments were worked out in a democratic way. The first lecture focused on a discussion on the meanings of "gender" and "science" and the differences between gender, sex and sexuality. Understandings of each word were arrived at through dialogic discussions. Each student would have had some prior concept of the meaning for each of these words, which were invariably at different levels, based on their previous experience and background. As a result of the rich contributions elicited from each student, further understandings were built, as new insights get added. Students were given the opportunity to lead class discussions on a given topic for which readings were assigned. There was no dearth of volunteers, indeed the students were quite excited at being given the opportunity to have their "voices" heard. Volunteers for each session were negotiated among themselves.

Students were given the freedom to choose the partner(s) with whom they would work as well as the topic of their research. Such pedagogy in which knowledge is constructed together by both teacher and student and which embraces democracy with little hierarchy and power play in the classroom can be very empowering to students. It promotes greater understanding of the material through dialogue and collective reflection allowing each student to transform the various opinions and observations of their peers and teacher into critical knowledge, which then becomes personalized, a necessary condition before it could be of use in transforming society.

It became clear that the major factor which accounted for the difference seen in the students' evaluation of both courses was pedagogical in nature and that the course evaluation was highly dependent on the students' experience during the first lecture when the values and norms for future classes get prescribed. While Klein (2006) acknowledges that there is a mooted need for a change in pedagogy from a teacher-centred approach to one which challenges the power relationships between the teacher and the student, emphasizing the active and productive role of the student, there remains a big gap between the theory and praxis. Klein (2006) in her study of mathematics teachers found that this change 'might be more difficult to realize in practice than anticipated'. Ball (1988) found teacher education and participation by teachers in courses and workshops were ineffective and that they needed to unlearn old patterns since they were more than likely to teach the way they were taught. The shift from teaching science to teaching about science was the trigger which allowed me to introduce an 'engaging', critical pedagogy, one that was so appreciated by the students that I was motivated to introduce it in teaching the science subjects. But to do so was not an automatic switch; I needed to make a conscious and sustained effort. While participation in instructional development courses was helpful in exposing the theory, the espousal of those theories only took place when the opportunity to teach in an area in which there had been no previous exposure, provided the opportunity for the practice of the new theories learnt. When it was shown to bear fruit, a conscious decision was then made to adopt a more 'student-centred' approach in the familiar science courses in which one generally teaches as one was taught. Such 'deep learning' of pedagogy is not easily unlearnt.

References

Ball, D. (1988). Unlearning to teach mathematics. For the learning of mathematics, 8, 40-48.

Beckles, H. (2003). The New Teaching and Learning Environment, 2000 cited in *The University of the West Indies Strategic Plan for the period 2007-2012*.

Carpenter, H.C. (1951). Emerson Eliot and the elective system. *The New England Quarterly*, 24 (1), 13-34. Stable URL: http://www.jstor.org/stable/361254

Friere, P. (2000). *Pedagogy of the oppressed* (M.B. Ramos, Trans.). New York: Continuum.(Original work published 1970).

Gardner, H., with the collaboration of Laskin, E. (1995). *Leading minds: An anatomy of leadership*. New York: Basic Books.

Klein, M. (2006). *Engaging pedagogies in early mathematics education: fostering autonomy or the cruellest regulation?* http://www.aare.edu.au/06pap/kle06329.pdf

Kyllonen, P.C. (2005). The case for non-cognitive assessment. *R&D Connections*, Published by ETS Research & Development http://www.ets.org/Media/Research/pdf/RD_Connections3.pdf