Promoting self-directed learning using a menu of assessment options: the investment model

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Rangachari, P. K. Promoting self-directed learning using a menu of assessment options: the investment model. Adv Physiol Educ 30: 181–194, 2006; doi:10.1152/advan.00001.2006.—Undergraduate science students took an Inquiry course in their second (sophomore) year. The course was designed to explore the social life of scientific knowledge. They were given a set of eight assessment options: personal logs, targeted oral examinations, commentaries, mini-lectures, individual explorations, research proposals, book reviews, and problem-solving exercises. Each option had a specific maximum mark (percentage or grade point) associated with it. Students were permitted to select any set of options to obtain their total grade for the course. From the student’s perspective, the course provided a valuable learning experience and enabled them to recognize the complexities involved in the process of generating scientific information and making it useful and relevant to the public. The opportunity given to select their own assessment options enhanced their learning. For me, as the sole instructor managing 51 students, the experience was rewarding.

Self-directed learning has the potential to engage students and has thus been promoted in a variety of programs. However, monitoring of the process is required so that both teachers and students can be assured that its promise can be realized. This is not easy. Lester (17) has argued that in such situations, any external assessment itself is problematic. Another option is to carry self-direction into the domain of the evaluation itself and challenge students to accept responsibility for that component. The most widely discussed approaches in this regard are learner’s contracts and portfolios (4, 5, 9, 13, 15, 19, 25, 27). Here, I describe my variation on that theme, as I sought to engage student’s actively in their own learning by permitting them to select their assessment options from a menu. In a sense, this was an investment model where students chose to invest their time and energies to maximal profit.

My rationale was as follows: students take courses for different reasons, with specific interest in the content or format being just one of several features. Even where a course is mandatory, a particular student may be less interested in that course rather than another and would prefer to invest their time and energy elsewhere. There is evidence that teachers cannot always assume that students see the courses that they teach in the same way as they see it themselves and that the learner’s orientation must be considered (4, 26). It has been recognized that students may enter a university for a variety of reasons, and the notion of learning orientations relates the totality of aims and attitudes that bear on a students responses to a course of study (4, 5, 26). This is not something inherent in the student or the course but rather defines a relationship. Thus, a student who may be highly involved in one course may only be marginally involved in another course and be deemed a superficial learner. So whether a student is seen to be a deep or a superficial learner is a matter of context rather than being an inherent characteristic of the student (4, 26). Astin (2), in particular, has emphasized that student involvement in higher education must be considered carefully. He notes that student time is a resource, and how they choose to spend that time may reflect on what they gain from that educational experience. His notion of student involvement draws attention to student time and energy as institutional resources that can be harnessed for successful educational practice. In relation to assessments in particular, it has been suggested that students are more likely to be interested and so motivated if they can have some say in their own assessment (24). Furthermore, it is important to recognize that not all evaluation measures fit a student’s personal learning style. So students may feel resentful if the rewards they receive may not be entirely commensurate with the time and effort they put in.

The course was an Inquiry course for second-year undergraduate science students in an Honors Program at the University of Calgary, Faculty of Medicine. The program was designed to channel students into careers in healthcare research. Students entered the program directly from high school (i.e., after 12 yr of schooling) into one of three majors: Biomedical Sciences, Bioinformatics, and Health and Society. In general, the students took courses appropriate for their chosen program (20). These courses are taught by different faculties with the expectations that students would recognize that healthcare issues require multidisciplinary approaches. All students took the required set of Inquiry courses designed to foster independence, self-direction, and critical analysis and encourage group interaction and sharing of information (20). The themes were necessarily broad to ensure that they would meld the interests of students in all three majors. Furthermore, they were sequenced so that the skills acquired by the students would be enhanced and consolidated. When I taught this course, I was the Director of Inquiry for the program, and, for this particular course, I was not only the course planner but also the sole instructor.

The term “inquiry-based learning” or even “inquiry” is not easy to define. It can be argued that practically any course taught in a university setting should have elements of inquiry, since faculty are involved in generating new information and this would be communicated to the student in the normal course of teaching. However, when terms such as inquiry-
based or active learning are used, there is an implicit understanding that it is the student who is doing the inquiring. In such a situation, inquiry becomes, to use Dewey’s (8) words, “the controlled or 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.” Dewey emphasized that the end points of inquiry may not be easy to recognize and that one should not establish a degree of finality to that process. He preferred to use the term “warranted assertibility” to indicate closure to the process. In a sense, inquiry-based courses attempt to link content (what) and process (how). The content of inquiry-based courses varies considerably, although there are some common process elements. These include the abilities to seek, synthesize, and integrate information from a variety of sources, assess the quality of that information, communicate it effectively, and monitor progress (20).

MATERIALS AND METHODS

The Students

The course described was taken by 51 students after they had completed 3 other Inquiry courses, and I felt confident that they would accept the responsibility that I was prepared to give them. In the preceding term, they had completed an Inquiry course that dealt with the Social Life of Drugs, where I was the sole preceptor, and so I knew every one of them and they, in turn, were quite accustomed to my style of teaching and grading.

The Preceptor

In my course outline, I told the students that I would function as a guide and mentor. I told them that quite apart from the scheduled time of the classes (3 h/wk), I had office hours and was also available by e-mail or phone to offer advice. They were encouraged to submit rough drafts of any written assignments. Since I did make myself available, I made it a point of answering e-mails promptly, at night or even on weekends. I had a half-time teaching assistant who helped me in collecting assignments and entering grades; she was not involved in any of the assessments.

The Course

Content. The course outline described the content as well as the rationale for the course. Students were told that the course would deal with the Social Life of Scientific Knowledge. As budding scientists, it was an important element in their education as the world economy was becoming increasingly linked to the production, dissemination, and use of knowledge (7). In particular, the Western world, which dominates the global economy, has been variously called an information, knowledge, or even experimental society (14). Thus, of all the forms of knowledge, that labeled “scientific” is particularly valued. It was noted that there was an essential difference between information and knowledge. Whereas information can “exist independently of the receiver and transmitter” (7), knowledge requires processing and translation or better transduction. Scientific knowledge is shared knowledge, and the objectives of this course were to provide students with an opportunity to explore the multiple facets that comprise the social life of scientific knowledge.

By the end of the course, they would be able recognize the complexities involved in the process of generating scientific information and transducing it to shared knowledge. Thus, they would learn that 1) modern scientific knowledge is largely produced by trained personnel often, but not always, in privileged spaces such as laboratories; 2) the information accrued is evaluated by society (through funding agencies and/or regulatory bodies); 3) the information is disseminated (through specialized publications, texts, or the mass media) to the general public; and 4) the general public either uses or misuses this information. They would realize the processes by which private information becomes public knowledge. Students were told to consider knowledge from the perspective of its producers, evaluators, disseminators, and users.

Practice. At the first session, students were given an outline of the course and a list of eight assessment options along with the maximum marks associated with each. In the Canadian system, the term “marks” refers to grade or percentage points, and, in keeping with the entire course structure, I will refer to marks throughout this report. They were told that the maximum mark for the course was 100, and they could select options in any combination to add to 100 marks. In other words, the percent contribution of each assessment option to the final grade was specified. The objectives and expectations of each option were explained to them. They were told to consider these carefully and hand in their choices on the following week. Table 1 summarizes the eight options, the maximum marks associated with each, and the deadlines established and choices made by one particular student.

These options are described in greater detail below.

Options

Personal logs (10 marks). This option permitted students to reflect on their learning. Students set their own learning goals, documented their learning with annotated references, and wrote comments on what they had learned.

Assessment. Students designed their own evaluation scheme to assess their performance. Half the marks (i.e., 5) were given by the students themselves, and the other half were given by me based on whether they had convinced me that they had evaluated themselves appropriately. These logs were periodically checked, and students were given an opportunity to discuss their logs and their marking

Table 1. Sample form

<table>
<thead>
<tr>
<th>Assessment Option Form (MDSC 305)</th>
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<td>Student name: P.W. Date:</td>
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Note that several of the options will be scheduled at specific dates based on number of students participating. Sign-up sheets will be posted.
scheme with me at any time during the course. Examples of the marking schemes designed by selected students are given later.

**Targeted oral examinations (40 marks).** Targeted oral examinations gave students an option to explore a specific area and demonstrate their comprehension by taking an oral examination (21). These exams were scheduled at the convenience of the students. Two weeks prior to the exam, they provided me with an abstract with annotated references. At the exam, they began with a brief summary of what they had studied and set the boundaries within which they felt confident to be questioned. The actual questioning period was strictly timed. The tenor was conversational, and there was no set pattern. I did not want this to become formulaic.

**Assessment.** Student performances were assessed on their abilities to 1) provide clear, cogent summaries; 2) clarify terms used; 3) their awareness of the conceptual basis of the methods used; 4) their awareness of the strengths and limitations of the approaches used; 5) their abilities to explain the implications of the information gathered; and 6) provide avenues for further exploration. The mark given was a composite. Feedback was given promptly. Immediately after the exam, students were told as to how they had performed, and written comments sent by e-mail within an hour.

**Commentaries (10 marks).** A number of guest lectures were arranged to give students a broader perspective on the central theme of the course: the social determinants of knowledge production. In response to student demand, the mini-lectures given by students were also included in this set.

Students could write structured commentaries on as many of these lectures as they wished.

**Assessment.** Each commentary had three parts: 1) a clear summary of the main points (2 marks), 2) an exploration of a particular theme that interested them (5 marks), and 3) corroboration of statements made with annotated references (3 marks).

**Mini-lectures (40 marks).** Mini-lectures provided students an opportunity to “teach” their peers about an area that they had studied. Each student provided an abstract that was circulated to the class in advance (Fig. 1). Each talk was strictly timed for 20 min, followed by an open question period (10 min). Each presenter provided their own rubric by which their particular lecture was to be evaluated (Fig. 2). Attendance at these sessions was mandatory, the marks given were gathered, and remarks were collated and handed back to the students as feedback.

**Assessment.** The assessment format varied, and specific examples are given later.

**Individual explorations (20 marks).** Individual explorations provided the students opportunities to explore issues related to the perspective(s) they had chosen and submit their findings in any format appropriate to the perspective chosen, such as essays, pamphlets, or Powerpoint presentations.

**Assessment.** The submissions were graded on content (10 marks), clarity (5 marks), and corroboration (5 marks) with annotated references.

**Research proposals (40 marks).** The research proposals were designed to give students an opportunity to practice an art that has become quite crucial to academic survival, i.e., grantsmanship. Students prepared a standard research proposal to explore an issue related to the perspective they had chosen. They were advised to 1) frame a suitable question, 2) seek the appropriate agency, 3) obtain the required forms, and 4) fill the forms out properly. Students were strongly encouraged to join together to form groups. They were

**Sample:** Abstract for Mini-Lecture

**Inquiry-based Learning in High School Science Education:**

The term “inquiry”, in all its ubiquitousness and ambiguity, is used tirelessly in current science education reform documents to set priority and focus on the scientific method, and more generally, the nature of science. It has become apparent however, even from my own experiences that any philosophical conceptualizations of the term and its applications break down at the practical level. It is thus the applications of the inquiry approach that must be reevaluated, concentrating on both the teacher and the student. In the mini-lecture I will lead on April 7, 2005, we will discuss conceptions of inquiry and the compatibility of inquiry-based learning with current educational evaluation standards. The question we must ask in this respect is whether or not we are training students as test takers and memorization hard drives, or as real people with the ability to understand, innovate, and appreciate scientific practice and knowledge.

**References:**


The publication addresses the importance of scientific education for understanding in the material world. The need for further discussion and evaluation of how science is taught and the challenges involved with incorporating inquiry-based teaching into science education are also discussed. Leonard, W.H. 2003. “Where is the Inquiry in Biology Textbooks?” The American Biology Teacher, 65:7, 485-486.

As a guest editorial, this article presents many of the problems and challenges facing science educators when attempting to establish inquiry learning in their classrooms. It serves as a good starting point for researching further organizations such as the AAAS, and their publications.

Fig. 1. Sample abstract for student mini-lecture.
Student Designed Rubric For Evaluation of Mini-Lecture

Inquiry-Based Learning in High School Science Education

Presenter: 
Date: Apr. 7, 2005

1. Presentation: /20
   - The speaker was prepared, organized, and in control throughout the presentation.
   - The speaker conveyed enthusiasm about the topic.
   - The speaker was attentive to the audience (eye contact, questions).

2. Technique: /20
   - The presenter spoke in a clear voice.
   - The presenter spoke with vocal dimension, emphasizing the most important points with tone and body language.
   - Language used by the presenter was appropriate and allowed for smooth delivery.

3. Content: /30
   - Arguments were presented in a logical sequence, and were supported by literature references.
   - The presentation integrated literature studies and information with a personal perspective.
   - The presentation slides accompanied and supplemented the arguments being presented by the speaker.

4. Overall Impression: /30
   - The speaker was poised and well prepared to answer questions from the audience.
   - Questions were answered appropriately, conveying the speaker's understanding and depth of knowledge.
   - The presentation was interesting, and aroused discussion about the application of inquiry-based learning in high school science programs.

Total: /100

Additional Comments:

Fig. 2. Student-designed evaluation rubric.

cautioned that if they did so, it was their responsibility to ensure that all members were contributing effectively.

ASSESSMENT. The following rubric was used: summary page (10 marks), body of the grant (25 marks), and ancillary information (5 marks). The summary page was assessed on the following elements: clarity/rationale/significance/methods. For the main section of the grant, students were required to provide a clear rationale (5 marks); provide sufficient background (5 marks); describe the methods to be used, including data analysis (10 marks); mention anticipated problems and timelines (3 marks); and corroborate statements with proper references (2 marks). The ancillary section included a curriculum vitae, budget, and ethics approvals.

Book reviews (20 marks). The book reviews gave students an opportunity to explore an area in depth by critically reading a book or monograph on that subject. Students were encouraged to find books that dealt with any aspect of science (biographies of individuals, institutions, philosophical explorations, controversial issues, etc.). They were told that there were many good examples of excellent book reviews available both in standard science journals (Nature, Science, and American Scientist) as well as in more literary newspapers and magazines (“New York Review of Books,” “Times Literary Supplement,” etc.).

ASSESSMENT. Assessment of the submissions was done using the following rubric, which was given to the students in advance: bibliographic information (1 mark), content of the book (5 marks), style of writing (5 marks), significance (5 marks), and their own final assessment as a conclusion (4 marks).

Tri-partite problem-solving exercise (40 marks). The TRI-partite problem-solving exercise (TRIPSE) was an exercise designed to test the capacities of students to transfer knowledge to a novel situation.
and “solve” problems under time constraints. This was the closest to a classical examination situation. This procedure has been described elsewhere (22, 23). It was a three-part exercise. In the first part (45 min), students were presented with a problematic situation and asked to provide explanations in writing. In the second part (also 45 min), they were expected to consider each of their explanations and provide possible avenues for further exploration (in writing). The third part was a take-home exercise; here, students were given more information and asked to reconsider their original explanations and explorations. In this particular exercise, there was no single correct answer, only a set of plausible ones. Since this was an unfamiliar exercise, practice exams were held to give students a flavor of the process.

** ASSESSMENT.** Each of the three parts was given equal marks.

**RESULTS**

In the sections to follow, I will discuss each of the options separately.

**Personal Logs**

The personal logs provided students an opportunity to reflect on their own learning. Seventeen students chose this option. Each set up his or her own goals and framed their criteria for charting their progress.

The following is a student’s opening comment for her log:

> Inquiry IV looks to be a promising course, I like the unique idea of each student getting to choose how they will be evaluated. I think this provides another step forward in our development of independent learning and challenges us in new ways through a variety of project, though I realize we aren’t always provided the luxury in life of how we would prefer to be evaluated.

This student then set out her own marking scheme, as follows:

Demonstration of expanding knowledge on the perspective/project (5)—provides evidence that I have made developments on my project(s) e.g., research, use of sources.

Shows insight & critical evaluation of information (5) and determine what is important, what is not, provide my own insight. This is especially important as insights made each week can be assembled for the projects.

Effort/Preparation (5). Since this course is largely independent, I must have a way to assess if I undertook initiatives each week and made a reasonable attempt to fulfill task(s).

Several weeks later, the student noted the following:

> I feel that I may have made limited progress this week on my topic. Unfortunately this week has not been the greatest which may have contributed to my minor progress, as I had the deadlines of a big biochemistry lab and midterm, not to mention the MDSC351 problem summary early on in the week . . . [She also mentions family problems].

However, I am optimistic that I will nail down an exploration soon! Demonstration of expandingknowledge on the perspective/project (5)—considering the stresses of the week, I think I made an ok effort to achieve this objective.

Shows insight & critical evaluation of information (5)—I think this area suffered this week. Although I may have found time to read new articles and search over journals/databases, I did not allow myself the time to analyze what I had learnt.

Effort/Preparation (5)—4.

In this vein, the student recorded what she had gleaned from her study for different projects and evaluated her own progress. At the end, she noted the following:

Even though the learning log is certainly more work than a commentary (though they are weighted the same), I valued the exercise as it forced me to be accountable to the course and work on the exploration for my oral each week and also helped me record all of my ideas and the information I gathered.

Another student wrote the following in the opening week:

In framing this log and a marking scheme, I will consider the following issues: (1) What is it that I want to learn? (2) What is my role in my Group and/or class? (3) What are my strengths and weaknesses.

The student discussed at length these issues and framed an evaluation scheme, as follows:

- Time and energy put into learning and effectiveness of learning (20). Contributing to the Group-meeting deadlines, participating in group discussions etc. (20). Overall Self-Assessment (10).

> Among his weaknesses, he noted that he did not often pick up on the nonverbal signals of others, i.e., social subtleties were not his forte. From my personal observations of his behavior in earlier courses, this was deadly accurate.

**Targeted Oral Examinations**

Students explored topics of their own choosing but were evaluated by an oral examination. Since students were given considerable leeway, they chose topics that not only fitted their own interest but also their majors. Thus, the students who were in the Bioinformatics stream explored issues such as immersive virtual reality, swarming and complexity, or the history and development of bioinformatics. Students who were in the Health and Society stream explored issues such as religiosity, spiritual care and healing, or global inequalities and bridging the technological gap. The majority of the students were in the Biomedical stream, and they chose a variety of topics ranging from the Orphan Drug Act, drug abuse, organic farming practices, metaphors in scientific discourse, or problem-based approaches to coaching soccer or badminton.

One student who was normally shy was quite articulate in this situation. He chose to discuss the development of bioinformatics. After the discussion, I sent him the following note, which captures what we talked about in that session:

> You did a good job at the oral exam today. You explored the early history of Bio-informatics, beginning with the protein sequencing problem in the 40s–50’s, leading to the genome projects. We discussed the essentials that underlay the development of the field, ranging from the desire to get at macro-molecular structure (proteins first, nucleic acids later), the impact of the Second World War and subsequent developments. We also discussed some of the pioneering work of Babbage and the current problems with excessive data and lack of standards. Overall I was impressed with your understanding of the issues and your awareness of future directions.

> Another student was interested in exploring the value of active learning strategies [inquiry-based learning or problem-based learning (PBL)] beyond the academic setting to what he considered the “real world,” which was the sports field. After his session, I sent him the following comment, which again gives some indication of the process and what was accomplished:

> Your performance at the oral exam was very good. You began by discussing the issues related to coaching soccer and
we discussed different approaches to imparting the skills required to produce good players. You noted that athletic abilities, motivation and willingness to learn were the minimal requirements on which to build.

You went on to compare and contrast Inquiry/PBL approaches with more structured approaches; the pros and cons of both were discussed. I handed you a paper [this student had not seen that paper earlier] and asked you to discuss one of the Figures in that paper that discussed different ways of teaching a particular skill [serves in badminton] and their effects on retention and transfer to a real game situation. We then went on to discuss the relative merits of such approaches in different contexts—soccer, baseball, University level science courses. You were flexible in adapting what you had read to new situations. I know that in the past, you have not particularly cared for this Inquiry model of learning, but hope that studying the underlying basis would give you a better appreciation of the promises and pitfalls. Well done.

A student who wanted to explore the roles of metaphors in scientific discourse was motivated by an English course where metaphors for illness had been discussed. She wondered whether transfer of scientific knowledge using common metaphors would be beneficial or not. Therefore, in her case, the discussions ranged widely from the differences between conceptual and linguistic metaphors to their value in promoting knowledge transfers to the limitations of inappropriate analogies. We discussed the use of military metaphors in certain domains of research such as cancer, where phrases such as the war on cancer or killing invading cells are pervasive. She argued that the use of such terminologies may make it easier for the lay public to understand issues but may gloss over complex issues. Thus, the notion of what science can and cannot achieve has been grossly distorted by the media, scientists, and public to focus on “fixing” a problem by high-tech therapies without considering environmental complexities. The war metaphor, thus, had many adverse effects.

Commentaries

These were written reflections on presentations by guest lecturers as well as the mini-lectures given by other students in the same course. The guest lecturers included, among others, an ethnomusicologist, the chaplain at a hospital, a pediatrician working in Uganda, a bioethicist, an anthropologist doing field work in Guyana, and a video conference with the World Health Organization (WHO) at Geneva. The objective was to provide a broader perspective and thus complement the individual explorations that the students were undertaking. These were meant to stimulate students to listen carefully to visiting speakers and reflect on their presentations. These were handed in within a week following the session.

This proved to be a popular option, with 30 students choosing to write commentaries; many writing more than one. References were well annotated and indicated that the students had not only reflected on the issues raised but read more carefully about the diverse topics covered.

Several topics sparked considerable interest. The discussion by the ethnomusicologist provoked several commentaries as did the one on spirituality. The mini-lecture on inquiry-based learning seemed to resonate with the students, who were able to relate to the issues raised (see later). The anthropologist’s talk raised some interesting issues. He had been looking at the effect of establishing a rainforest conservation and development park on the lives of a neighboring indigenous group. One student, after briefly summarizing his talk, said that she was “predominantly interested in the statistical data recorded that 35% of the children were stunted and 13% were wasted.” This led her to read books and articles on growth and development asking what were the meanings of these parameters, the measures used to assess them, and their role. She was also concerned at a comment made by the anthropologist stating that the natives had been asked to reduce fishing to conserve stocks. She felt that this would be counterproductive. She concluded that, although she believed that the conservation park and the native people could coexist, the symbiotic relationship between the two remained unclear. Another student listening to the same talk was stimulated to look at the factors underlying maternal depletion and the possible impact of introducing a market economy. Both students provided carefully annotated references, and the sources consulted included not only standard tests but also peer-reviewed journals.

The video conference with the WHO in Geneva sparked considerable interest. Several students were stimulated to write thoughtful commentaries. The general focus of the presentations related to access to information, knowledge translation, and a specific project related to acquired immune deficiency syndrome (AIDS) in Africa. Given the tenets of this course, these topics were extremely relevant. The “know-do” gap was particularly appealing to the students, as several were likely to move to careers in the applied health sector. One student evaluated available information from nursing literature on this issue, whereas another student considered the problems of a public that may not be very receptive. A third student was hypercritical of a slide that was shown relating CD4 counts to time on antiviral therapy. Although I too found that slide confusing and the comments ambiguous, I felt that the student had gone a bit overboard on this issue!

Mini-Lectures

As mentioned earlier, this option was given so that students could “teach” their peers about a specific area that they had studied. All students were required to submit an abstract 2 wk prior to their lecture as well as frame an evaluation scheme by which their peers could assess their performance.

This option was chosen by relatively few students. This required more careful planning, and only the most confident students took up this task. Once again, the topics chosen varied. Interestingly, the notion of learning and teaching sparked their interest, and three of the students spoke about inquiry-based learning, universities in the modern world, and the teaching of bioinformatics.

To give readers some appreciation of this particular option, I included the entire abstract along with the annotated references of one mini-lecture in fig.1. This student discussed the problems of instituting inquiry-based learning in high schools. The discussion was quite lively, and several students picked up on the issues raised for their individual commentaries.

Another student, who spoke on the same day, chose to discuss university education. She took a historical approach by discussing the evolving notion of a university from a collection of scholars and students through Cardinal Newman’s elitist notions to the more “massified” marketable university of today. She explored “the fundamental changes to the goals of higher
education brought about by the Industrial Revolution and the Knowledge Economy, and some of the implications and problems this creates for the present-day university.”

Other subjects for these mini-lectures included limb regeneration, cognition-enhancing drugs, direct-to-consumer advertising of drugs, hormone replacement therapy, human adaptation to germs, and the 10/90 gap. The last topic discussed a major problem in global health initiatives, where 90% of the world health problems receive only 10% of research funds; hence, the term “10/90 gap.”

As mentioned earlier, students were required to submit their own evaluation scheme by which their lectures were to be assessed. The format chosen by the student who spoke on high school education is shown in Fig. 2.

Other students submitted their own rubrics. Each was presented in a slightly different fashion, although certain general themes emerged. Among the elements that the 10 students considered important were as follows (with the numbers of students in parentheses): content (9), presentation/delivery (9), organization (9), clarity (7), use of visual aids (3), and ability to answer questions (3).

These mini-lectures were well attended and provoked considerable discussion. As mentioned above, many students chose to write their personal commentaries on the issues raised in these sessions, with those on inquiry-based learning and universities sparking the greater interest, largely because the students had already experienced high school teaching and were now studying in a university setting.

Individual Explorations

Students were given considerable license to not only select topics of particular interest to them but also to choose the format by which they could document their learning. Given the flexibility, this proved to be a popular option, with 28 of the 51 students choosing to do at least 1 exploration. Several students did more than one. Again, the topics chosen ranged widely, including, among others, patient safety, religion and science, evidence-based medicine, interactions between drug detailers and physicians, and the role of scholarly journals. They chose to document their learning in a variety of ways, such as standard essays, Powerpoint presentations, or even pamphlets. The quality of the submissions was generally high, although there were several weak submissions.

One student who chose to produce a pamphlet to explain what myopia was to patients did a neat job. My comments to him were as follows:

The information presented was simple and clear. I really liked the very careful way in which you discussed pamphlet writings and drew attention to your own pamphlet as an example. The references were very well annotated.

On the other hand, another student who chose the same approach did not do so well and handed in a weak effort. In my comments, I wrote the following:

You chose to present your information in the form of a pamphlet. It was appropriate for this course. Unfortunately the information presented was weak. I was not really sure to whom this pamphlet was addressed. For instance, you refer to a CREB protein—would any one really know what that is? The information gathered was not critically assessed. Also there was really no discussion on pamphlets themselves, their relevance and value. There is a body of literature that deals with it. Other students who chose this format were able to find that information and discuss it.

Whereas the first student received 18 marks (9 for content and 4.5 each for clarity and corroboration), the second received a total score of 12 (with a 7 for content, a 3 for clarity, and a 2 for corroboration).

Another student who chose to present her exploration of patient safety in the form of a Powerpoint presentation wrote a fairly detailed analysis of the merits and demerits of that style of presenting information.

Several students sought to explore other facets of the investigative enterprise: the role of editors in journals, recruitment of scientists to organizations, or the teaching of science in the school system. Some did an outstanding job, by reading carefully, writing clear cogent reports, and annotating references properly. Others did not.

One student wrote a thoughtful piece on what he called Wiki-Science. This was a variation of the increasingly popular Wikipedia. His argument was that one could bridge the gap between raw data and published articles by investigators contributing their information openly, so as those collaborative ventures can be facilitated. He recognized well the problems inherent in such a proposal, given the individualistic nature of modern scientific practice, which ironically is counter to the aims of the proponents of the New Learning in the 17th century. I appreciated his effort and pointed out to him that the Alliance for Cellular Signaling does attempt to do what he was proposing in a very specific context.

The student who explored the role of editors felt that it was an appropriate choice for the course; according to him, “I wanted to look at somebody who was at the cross-roads of the stage in which scientific research is evaluated and disseminated. I felt that by choosing such a perspective I would be able to understand the complexities of the issues in a larger sense.” He considered the gatekeeper role of editors and pointed out that given the pressures to publish, editors are in a powerful position to exercise control, and, since they rely on reviewers, the latter in turn can exert considerable authority. He went on to consider some of the pitfalls of peer review and the role that the state can exert on the process. In this context, he quoted an article that appeared in the Washington Post dealing with the decisions made by the editors of several major scientific journals to consider censoring material that could be potentially misused by certain groups. It was evident from the annotated references provided that the student had read not only peer-reviewed articles but books and news articles as well.

As mentioned above, not all students did well. One student chose what I felt was a very important theme in relation to the tenets of the course, namely, the recruitment of young scientists into research centers and the maintenance of the research enterprise. Unfortunately, it did not pan out. I wrote the following to him:

You chose to explore the recruitment of researchers into an organization. It was an important topic to explore given the tenets of this course. The choice of a story format was clever—unfortunately there was too little substance. It was amusing in bits and you did make a couple of good points—unfortunately, there was no corroboration of any of the points made.
Research Proposals

This option was a challenging one and gave students a glimpse into the trials and tribulations of putting together a research proposal. It required them to explore not only the topic but also gather information about ethical issues and budgetary matters. I made it quite clear that this would be more effective if they worked together in groups. I left it open to them to select their own team. This class had taken an Inquiry course earlier where group work was mandatory. Although most students had appreciated the opportunity, there had been a number of complaints, so that I made this option entirely voluntary. By this time, the students had been together for almost 18 mo and had established firm friendships, so no interpersonal conflicts emerged in this course.

The proposals submitted included designing a targeted toxin therapy for mantle cell lymphoma, teaching physicians about herb-drug interactions, optimizing conditions of oval cell proliferation and differentiation in a bioartificial liver system, assessing the impact of providing school uniforms on bullying in local schools, exploring physiological and psychological stresses in nurses on shift work, developing a vaccine against prion diseases, and exploring the beneficial effects of playing video games on the development of surgical skills. It was interesting that, in general, students sought to explore topics within their own major area of study.

Most formed groups, and the single student who chose to do it on his own unfortunately did rather poorly. The students performed admirably. I showed some of these to faculty members who were doing similar kinds of research, and they were quite impressed. Some could not believe that these were just second-year students!

I discuss below, in some detail, two proposals that would be of particular interest to physiologists.

The group working on oval cells. This group consisted of one male and three females. They were interested in designing a better artificial liver support system that could be useful as “bridging” treatments for patients waiting for liver transplants or hepatocyte replacement therapy. So their major question was framed as follows: Can oval cells be used as a cell line from which fully functional hepatocytes can be derived for subsequent use in bioartificial liver systems? They proposed to carry out their project in several phases. Since their proposal was quite detailed, I have given below my comments to them, which would give readers an indication of what they had proposed.

The question posed by the applicant is simple. Can oval cells from the liver be used to generate a cell line for deriving functional hepatocytes for subsequent use in a bioartificial liver system?

Oval cells provide an opportunity to rescue damaged livers. If the cells can be used to generate an artificial cell line, a reliable in vitro source of functional hepatocytes can be obtained. For such an ambitious proposal to work there should be a logical sequence. This has been extremely well explained by the applicant.

In the first phase, oval cells derived from Lewis rats treated with 2-acetylaminofluorine/carbon tetrachloride will be cultured. The conditions are carefully designed to promote proliferation of oval cells, but to minimize spontaneous differentiation. In the second phase, the selective differentiation of oval cells into functional hepatocytes will be explored. The applicant makes a good case for using a collagen matrix system. It is also interesting that the applicant proposes to detect possible endogenous differentiation factors using a semi-permeable coculture approach. The probability of tracking down a factor released from hepatocytes to induce oval cell proliferation is also promising.

The applicant is well aware that it is vital to characterize the differentiated hepatocytes derived from the oval cells. It is good that she [the term ‘she’ refers to the pseudonym adopted by the group] has proposed a careful metabolic characterization.

The last and final phase will be to determine whether the oval cell line derived hepatocytes are superior to isolated hepatocytes in cleansing the blood from rats in liver failure. An artificial system primed with hepatocytes derived from oval cell lines will be compared to isolated hepatocytes.

The applicant has provided careful documentation, appropriate support has been garnered and the budget is reasonable. Recommended with high priority.

Based on my assessment of their submission, I gave them the following marks:

- Summary Page (10): 9.5/10
- Body of Grant
- Rationale (5): 4.8
- Background (5): 5
- Methods, including Data Analysis (10): 9.5
- Anticipated problems/timelines (3): 3
- References (2): 2
- Other Issues (5): 5
- Total (40): 38.8

The group studying physiological and psychological stresses of nurses. Another group (a duo; one male and one female) sought to explore the effects of physiological and psychological stresses on nurses working 8- and 12-h shifts.

In their summary page, they began by describing the significance of their proposal and provided a quick overview of the available information. They pointed out that much of the available evidence had tended to focus on the real world situation, which, although meaningful, may not have been rigorous enough. So they proposed to recruit a cohort of nurses from the region and divide them into two groups: one group scheduled to work for 8-h shifts and the other group scheduled to work for 12 h. They proposed to make measurements at their place of work before, during, and after one randomly selected shift. Their assessments would include an eye blink analysis; measurements of cortisol, allopregnanolone, and peripheral benzodiazepine receptor densities as indexes of stress; blood pressure; and heart rate as well as the Maslach burnout inventory to assess psychological stress and burnout.

Less successful proposals. Although most groups did extremely well, a couple groups handed in proposals that were missing some key elements. They, unfortunately, suffered in comparison.

Here are some examples of less successful proposals; again, my comments give a flavor of what the students proposed to do.

The applicant proposes to create transgenic mosquitoes to make them resistant to dengue fever. Given that this is a serious health care problem, the enterprise is a worthy one.

What are really missing from this grant are details that would give the committee confidence that the applicant can carry the work out. The applicant wishes to follow up on the work of the Colorado group in triggering RNAi in mosquitoes.
But the authors of that paper find that none of their lines expressed ds RNA in relevant tissues. So the chances of his success are slim and he does not give us details to tell us that his approaches are likely to succeed. The information provided in the background section is also limited. The budget requests are modest.

Another group received the following feedback:

The applicant proposes to link video game playing to specific motor skills. His argument is that if playing such games clearly fosters such skills, these could provide a basis for training future personnel (e.g. surgeons) on virtual training.

The approach is simple. Select a population of students who are video gamers (play more than 1 hour a month) and compare them to those who spend much less time (less than 1 hour). These subjects will be tested for reaction time, motion extrapolation and manual dexterity. The details of these methods, particularly in relation to their reliability were given in the carefully annotated references.

The proposal is fairly limited and the applicant has requested funding just for a year. The section of the subjects is problematic. Classifying youngsters who just play over an hour of video-games per month seems odd. Would just that much playing be able to sharpen skills? Also what is less than one hour? 45 mins? These categories make it difficult to define the subject population very well.

The data analysis has not been explained. Transferring results into a computer and graphing them is fine, but what kind of statistical measures will be employed what levels of significance will be accepted etc. These details are missing. The real problem is the assumption, that IF video games enhance specific motor skills, then these people can be trained in virtual machines to produce worthy citizens.

Overall a reasonable application. It could have been stronger with more details and some discussion about anticipated problems.

**Book Reviews**

The books reviewed included biographies (Leonardo Da Vinci, Albert Einstein, Rosalind Franklin, and Linus Pauling), autobiographies (Francis Crick, Michael Bishop, Tim Berners-Lee, and Rita Levi-Montalcini), and books on science policy, anthropology, health economics, and general science. Here, again, the results quite surprised me. Students not only read widely but wrote thoughtful reviews. They were also willing to go out on a limb and write critical comments, some maybe even a bit brash, given the fact that they were second-year undergraduate students.

Here are some excerpts from one student’s submission, the review of a book by Barker and Peters (3). The submission is well over 2,000 words, and the samples merely give a flavor of what was handed in. The student followed instructions carefully and listed the bibliographic information, giving the credentials of the authors. In the section on content, he noted that the book “examines the unique relationship between expert advice and public policy-making by exploring all of the parties involved in the transfer and dissemination of advice to policy makers.” He then discussed briefly the content of each chapter, making sure to highlight what he found interesting, as follows:

Although chapter five discusses the social and political uses of science, the most interesting content is found in two sub-topics regarding funding research and the strength of a research study—the author analyses select research elements of the Black Inquiry regarding radiation and child leukemia. After showing that the research was relatively weak, the author made an extremely interesting statement outlining the low scores on such a pedigree should not be seen as something to be ashamed of but rather an affirmation of the uncertain nature of science and the limitations of research.

In the same vein, the student made the following cogent remarks on the style of the book:

“...though some chapters tend to run on a little bit, the majority of the chapters are extremely interesting and, despite being a relatively, dated book, bring up very relevant and thought-provoking issues. I particularly enjoyed the brief sections on research funding, the mass media, and ‘Big Science’ as these were very engaging and brought up issues I could relate to.

He also noted that, although the formatting was helpful as were the organizations of the chapters, the concepts were complex and a book of this length could not do them justice. With relation to the significance component, he noted that “...though the analyses of the issue of nuclear power can be questioned in light of new information, the topics of legitimacy, accountability, mass media, trans-science, expert committees etc., all remain extremely relevant even today.” The student at the end recommended the book to “not only those interested in public policy making and the nature of expert advice... but also [to] those interested in the very nature of science and the sociology and philosophy of science.” He did note, though, that “some arguments are underdeveloped which leads to unfounded conclusions... in exchange for this shortcoming, readers are treated to short, concise chapters.” Considering that this piece was written by a student who had not yet completed 2 yr as an undergraduate science student, I felt quite justified in giving this student high marks for this effort.

**TRIPSES**

This approach gave students an opportunity to test their problem-solving skills under time constraints. I had originally developed this for students in a pharmacology program (22). The sources for such problems were usually standard publications in peer-reviewed journals that were suitably modified to fit the occasion. Since one of the central themes of this course related to transfer and the use of scientific knowledge, I focused on problems that would highlight such issues. Since students were relatively unfamiliar with this process, I conducted practice runs where I gave them some TRIPSEs that had been given to students in the earlier course. The students attempted to answer these, and we had an extensive debriefing session.

In one practice session, I asked them to consider data from a Canadian study showing that in a particular Canadian province (12), the number of inappropriate antibiotic prescriptions were much higher in one group of physicians than in another. This inappropriate prescribing increased with patient load. With the limited information given, the students came up with a number of possible explanations, such as differences in patient population, aggressive marketing by pharmaceutical sales representatives, rural versus urban practices, etc. They were then given the original study, which suggested that fee-for-service physicians were more likely to prescribe inappropriately than their salaried counterparts. This trial run was very useful. Students were able to recognize that different explanations could be provided for the same data. They were
also chagrined to realize that they had been laboring under the false notion that Canada had socialized medicine. The recognition that fee for service is as prevalent in Canada as in the United States was a revelation to them.

For the final TRIPSE, I selected a problem that dealt with thalassemia control in several European countries between the years of 1972 and 1984. A preamble to the TRIPSE merely pointed out that the condition was an autosomal recessive disorder where there were mutations in the β-chain of the globin component of hemoglobin; homozygotes suffered from severe anemia and required frequent blood transfusions, treatments for iron overload, and management of infections for survival. This imposed considerable costs on countries where the condition was prevalent. Students were told that heterozygotes were symptomless, but intermarriage between them led to a substantial risk of their offspring acquiring the disease. Sufficient basic knowledge was available for countries to deal with the problem since the early 1970s.

Students were provided data (Fig. 2) from a study by Kuliev (16). This figure showed the fall in the birthrate of children with thalassemia in several countries. The greatest decline was in Ferrara (a province of Italy), followed closely by Cyprus. The declines in Sardinia and Greece were slower, with the United Kingdom having the slowest rate as well as the lowest percentage.

All the students had taken a genetics course in the previous term, although this particular condition had not been discussed. So it gave them an opportunity to transfer prior background knowledge to a new situation over which they had minimal direct knowledge. Given the limited information presented, there could be several different explanations ranging from differences in healthcare systems, awareness of the problems, resources to tackle the issue, diversity in patient profiles, etc.

Below, I discuss one student’s answer to the problem posed. In part 1, this student stated, what she felt, were the major points that needed to be addressed:

Ferrara seemed to decrease expected values very quick (sic) as of 1973, whereas the UK did not see a decrease till 1977. Cyprus and Ferrara seemed to decrease their % of new Thalassemia. major births to less than 10% of expected; whereas other areas decrease to around 50% expected (Sardinia, Greece) or 70% (UK).

The student then suggested possible explanations under several categories:
1. The existence of screening programs.
2. Gene frequency and data representations.
3. Availability of good treatments.

In each category, the student provided details as to why there would have been a differential response. Much of her attention was focused on screening programs, where she pointed out that Ferrara could have had a mandatory screening program, better counseling, and more effective publicity campaigns. In addition, she pointed out that closeknit support groups and less heterogeneity may have helped speed up awareness and access to counseling. In part 2, the student provided reasonable approaches to confirm or deny the explanations she had given in the earlier section. She said that she would do a retrospective analysis of the public campaigns, booklets, brochures provided to the public in those areas, assess whether physicians were active in providing counseling services, etc.

After the students had handed in their answers to the second part, they were provided with more information, including a set of references (1, 11, 16), and asked to reassess their answers. Having read the references, the student reassessed her own statements as follows:

Many of the explanations that I gave in Part 1 were present in the further information given. This serves to assure me that those explanations are, in fact, credible explanations of the trends on the graph presented. Extensive awareness campaigns that involved the media, high frequency of the gene among certain populations and “bold” counseling that involved discouraging the marriage of heterozygotes (As well as, the most extreme option of abortion of affected or possibly affected fetuses; which I did not explicitly mention.) are all things that I gave as possible explanations. As I mentioned on my Part 1 sheet, I think that the explanations that I gave appeared roughly in the order of their strength. The last explanation given of communities of thalassaemia affected people is the most far fetched; however, I defend it as being plausible—if only just.

I think that the explanations that I gave were credible and especially with this further information I find that the first explanations I gave had the most strength. There are, however, some factors within the broad explanations I gave that I did not fully consider. Firstly, I did not consider that areas such as Cyprus would be better places for control programs (both screening and public awareness taken together). Low birth rates, high literacy rates, high standards of health care, high standards of living and a small population all could have helped the campaign be more effective. I also did not explicitly state that ethnic groups, who seem to have a high incidence of the disease amongst them, might not find it acceptable to abort a fetus. In fact, I did not consider the abortion of diagnosed fetuses as an explanation for lower birth rates of thalassaemia affected children. That explanation would have been very affective at reducing the incidence of the disease, although debatably unethical. Lastly, I did not consider that within a smaller population that community involvement in awareness campaigns would have more of an impact on the outcome.

I could have been better at considering some details of the explanations I gave to explain them and explore them further; that would have further increased the credibility of my explanations. That being said, overall I think I did a good job at providing credible explanations that explained the data given.

I have described one student’s responses at length to give a flavor of the process. Most of the students provided reasonable answers. There were minor differences in how well they phrased their responses and prioritized them. Some answers were a bit eccentric, but even those were balanced by credible ones. All students wrote extremely well articulated reassessments. The following is another student’s answer to part 3:

Though the health prevention programs are the ultimate cause of the decline in the presence of thalassemia, it must also be noted that other factors resulted in the formation of such programs and the degree of intervention. It is almost inconceivable that in an individualistic society like Canada or the United States that the state or the church could provide pressure on couples not to get married or have children, thus culture and values should be included as a contributing factor. Small geographic areas with higher risks of thalassemia were targeted and this seems to have had a tremendous impact in the comparison, especially when contrasting Cyprus, the Italian province of Lombardy and the United Kingdom. With variances in population size, standards of health care and gross national
product it is difficult to pinpoint a single factor which led to the decisions in how to prevent and treat the condition.

Though resistance to malaria would have explanatory power in some regions with much higher rates of the disease it does not seem to, upon further examination, be particularly relevant in the case of Europe in the 1970s through the 1980s. The presence of an external mutation causing agent is also a highly unlikely explanation for decline given the additional information and the diverse and spacious areas explored.

In my initial assessment of the rates of thalassemia I offered many plausible explanations for both the decline in thalassemia and the differences in rates between the regions listed in the graph. The more relevant accounts that I offered could have been described in greater detail, especially the potential differences in prevention programs across national and/or provincial boundaries. Ultimately, this problem was an exploration of how medical information can be translated into knowledge and practice with identifiable health outcomes [emphasis mine].

Relatively few students selected this option, although, based on a questionnaire (see later), the ones that did rated this exercise reasonably high.

**DISCUSSION**

In this section, I will discuss the results presented above from two perspectives: those of the students and my own. The information on which I base the student’s perspective is derived largely from a questionnaire that students filled out at the end of the course (Table 2). In addition, students made comments in their personal logs as well as sent me e-mails about specific issues. Furthermore, the university surveys students at the end of each course with a standard form, and these universal student ratings of instruction are provided to the faculty for feedback. Although generic, the information gathered complemented that gathered by me through my own questionnaire.

**Student Perspectives**

The data obtained from the questionnaire are summarized in Table 2.

Based on those results, it appears that students were quite positive about several aspects of the course in general: the instructor, the learning experience, and the opportunity to select their own options.

**Table 2. Course evaluation**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The course helped me recognize the complexities involved in the process of generating scientific information and making it useful and relevant to the public</td>
<td>4.06</td>
<td>0.86</td>
<td>48</td>
</tr>
<tr>
<td>2. The opportunity to select our assessment options helped me learn better</td>
<td>4.33</td>
<td>0.72</td>
<td>48</td>
</tr>
<tr>
<td>3. The course provided a valuable learning experience</td>
<td>4.48</td>
<td>0.68</td>
<td>48</td>
</tr>
<tr>
<td>4. The instructor facilitated my learning</td>
<td>4.25</td>
<td>0.79</td>
<td>48</td>
</tr>
<tr>
<td>5. The assessment options (shown below) enhanced my learning</td>
<td>3.65</td>
<td>0.70</td>
<td>17</td>
</tr>
<tr>
<td>A. Personal logs</td>
<td>4.47</td>
<td>0.62</td>
<td>17</td>
</tr>
<tr>
<td>B. Targeted orals</td>
<td>4.03</td>
<td>1.02</td>
<td>31</td>
</tr>
<tr>
<td>C. Commentaries</td>
<td>4.17</td>
<td>0.72</td>
<td>12</td>
</tr>
<tr>
<td>D. Mini-lectures</td>
<td>4.10</td>
<td>0.65</td>
<td>31</td>
</tr>
<tr>
<td>E. Individual explorations</td>
<td>4.69</td>
<td>0.68</td>
<td>26</td>
</tr>
<tr>
<td>F. Research proposals</td>
<td>4.23</td>
<td>0.97</td>
<td>22</td>
</tr>
<tr>
<td>H. TRIPSE</td>
<td>4.23</td>
<td>0.73</td>
<td>13</td>
</tr>
</tbody>
</table>

Students were given a series of statements and asked to indicate the strength of their agreement with each on a 5-point scale [ranging from 1 (disagree) to 5 (strongly agree)]. The results show means, SDs, and number of responses to each statement. TRIPSE, Tri-partite problem-solving examination.
that were strongly in favor of the research proposals, no really negative comments emerged about the personal log.

The following are some comments from students regarding the research proposal option:

- “The research proposal was a lot of work, but I learnt a lot—a really good experience.”
- “The research proposal was (despite being massive amounts of work!) an amazing learning experience. In addition to learning about the actual subject, we learned a great deal about the processes and bureaucracy involved.”
- “. . .this project has been a valuable learning experience. Not only has it led me to a better understand the granting process, and the trials and tribulations that my boss must go through on a regular basis so that I can do my own research, but it has forced me to read scientific papers in a different way. After designing a whole set of experiments, I am much aware of the need for good controls in any type of experiment. Further, I now read the methods section in research papers. Until this class I would pretty much gloss over that section of a paper because I would assume that the procedure was valid and made ‘common sense’.”

The comment that students really began to appreciate the efforts that faculty made to put into keeping their laboratories functioning was echoed by others.

In general, although students scored different options high, very few added specific comments to indicate why they had scored certain options higher than others. One noted that the targeted oral examination was interesting; another noted that with that option, “Learning was not so much in the sense of learning about the content being examined but more about how I could better communicate my ideas.” Several students made favorable comments about the TRIPSE; one really enjoyed it, and another felt that it should be mandatory. Another student wrote in her log that although she was disappointed with her performance in that evaluation exercise, she was glad she chose it as it challenged her in a new way and forced her “to think on the spot.”

Teacher’s Perspective

The content of this course was loosely defined, as mentioned earlier. In terms of process, it was important to ensure that students took responsibility for their learning; sought, synthesized, and integrated information from a variety of sources; and communicated that effectively. My interest in setting up this course was to challenge students to take greater responsibility for their own learning. I was reasonably confident that they would accept the challenge as they had taken other courses with me. But, even then, I was pleasantly surprised at the degree of engagement. Soon after the first class, I had several students approach me about doing book reviews, and some of these were students who had been markedly unenthusiastic in the earlier course. I fielded lots of questions and answered dozens of e-mails, more so than in the other courses. Most students did prefer to play it safe and chose options that played to their strengths. Thus, some who were relatively tongue tied preferred written options; the more exuberant and extrovert ones chose either the oral examinations or the mini-lectures. A few tested themselves by choosing options that did not play to their strengths. A few students chose options that totaled to >100 marks, although they were clearly told that their marks would be normalized. They said that they wanted to test themselves on unusual options and still had enough marks to fall back on with the safer ones.

I was surprised at the lower ratings given to the personal logs. I had been quite insistent on this component in an earlier course and faced considerable resentment. So I decided to make it optional here. The students who chose that option took it seriously, as some of the quotes given above suggest. Interestingly, in the mini-lecture on inquiry-based learning, the issue of personal logs was discussed. The student lecturer pointed out that it was one element that fostered active learning, and there was quite a lively discussion on that score.

The commentaries and individual explorations were generally well done. Students took the opportunity to probe areas indepth. One student, who had a fairly high degree of myopia, wrote three individual explorations on the same topic but took slightly different tacks on each and submitted a standard essay, a pamphlet, and an article for a lay publication.

The mini-lectures were well received. The students who selected that option were more confident in general and seized the opportunity to test themselves. The discussions were quite lively. I was pleased that several students used the opportunity to explore active learning itself. Apart from the students who gave mini-lectures on inquiry-based learning and the university setting, others used the topic for personal explorations. They wrote very thoughtful comments. One student chose to write a newspaper item entitled “Am I Really Learning?” In that, he dealt with the evaluation problem: “What are the biggest problems with IBL? The biggest problem with IBL is the difficulty in assessing student’s progress as well as whether or not they have actually ‘learned’ anything.” He critically assessed available information and concluded that despite the problems inherent, “the value of IBL surpasses that of conventional passive learning through lecturing.”

The option that gave me the greatest personal satisfaction was reading the book reviews. There is a popular belief that the younger generation is not inclined to spend time reading books other than those strictly necessary. That these students not only read, but read wisely and well, was heartening. Their reading spanned the entire gamut from biographies to books on science policy or teaching and learning. I have quoted at length one student’s review, but there were many others equally good.

Since I had given the students considerable leeway, I had to make myself available. The flexibility actually helped me a great deal. I could manage to see students at odd hours and get many other things done. I was teaching another Inquiry course at the same time, planning a laboratory course, and had other administrative duties. A lot of that work had to be done during the working day when other people were around. By shifting my attention to this course to evenings, nights, and even on the weekend, I found that I could manage to do a lot more. Students really appreciated that promptness and flexibility. In other courses, I would end up with a pile of essays to mark at the end. In this course, that work was spread throughout the term. Since a significant number of students had completed most of the course midway through the term, I did not have a load of work at the end. There were moments that I felt exhausted, but the pleasure at reading such interesting submissions was more than adequate compensation.

There were several changes that could have optimized learning for the class as a whole. I gave students limited time, only
a week, to make up their minds as to the options they chose. This was done more for my convenience than theirs, as I had to get the course organized, rooms booked for presentations, etc. Several students felt that they may have made a wiser decision with more time. More importantly, I never really assessed the learning styles of the students to see if the options they chose were the best fit for them. Apart from the research groups that worked together and during the mini-lectures, there was very little sharing of information. In the earlier courses, there had been a lot of mandatory presentations and, in some sense, that had been overdone. In this course, many of the students became more solipsistic. Another point was raised at the final evaluation session. One student argued that it would have been better to have at least one mandatory evaluation option so that the performance of all students could be gauged on one measure. That proposal was vehemently voted against by the others, who felt that they would rather have the freedom I had given them. I felt, however, that would be a usefully option to consider for a future course.

Relevance of This Course to the Teaching of Physiology

There were two aspects to this course: the content, which focused on the practice of science and the production of scientific knowledge, and the procedure used to evaluate the students. Both can be readily transferred to the teaching of physiology. Among the basic biomedical sciences, physiology has the widest scope. Physiological research spans the entire gamut from molecular to environmental. Studying ion channels in isolated patches of the cell membrane and responses of animals to stress or adaptations in harsh climates, both natural or man made, are all grist to the physiologist’s mill. Thus, information gathered by physiologists is relevant not only for clinical and medical problems but has wider implications for the environment and society. Thus, one can readily consider physiological research from each of the perspectives discussed in this course, namely, producers, evaluators, disseminators, and users. Teachers of physiology can get their students to consider not only the production of knowledge in the domain of physiology but also its transfer into the realms of policy as well.

Nutrition is an obvious example. Nutritional physiology involves research at multiple levels, from very basic to applied. For the information obtained to be of value, it must be appropriately disseminated so that it can be assessed and translated into meaningful policy. In this course, some of these issues emerged following the discussion by the anthropologist who described his researches in Guyana. Students who chose to write their commentaries on either maternal depletion or growth delved into the physiological literature, both basic studies as well as standard texts. That also raised the issue of how research information found its way into standard texts. Physiological issues also emerged in other contexts. Two of the mini-lectures focused on topics that had strong physiological undertones, one on the signals leading to limb regeneration in lower vertebrates and another on the adaptability of humans to infectious agents. Another lecture on hormone replacement therapy dealt with the physiology of menopause. In addition, a number of the individual explorations focused on physiological issues such as bone structure, memory and cognition, and vision and brain development in relation to language acquisition.

Considerations of the practice of research can be readily applied to the teaching of physiology as well. Both the research proposals described above (the one on oval cells and the other on shift work) had strong physiological underpinnings.

In the course described, multiple evaluation procedures were used. Every one of the options mentioned, ranging from individual explorations to targeted oral examinations, book reviews, or research proposals, can be readily adapted to specific courses in any physiology program. The TRIPSEs, in particular, are flexible enough to be used for assessing abilities for students to deal with basic, clinical, or even social problems (22, 23). Far more importantly, the general approach of giving students an option to decide on how they wish to be evaluated can be readily applied to physiology courses, particularly at the senior undergraduate or graduate level. It was this component more than any specific option that appeared to motivate the students. Given the more structured nature of professional programs, such options may be limited, but even there, students can be given the option of demonstrating their competence in a format of their own choosing. I was fortunate in that I had the luxury of dealing with undergraduate science students rather than professional ones. Since I told these students that I regarded them as “pluripotent educatoblasts” who could readily differentiate in different environments, I was essentially preparing them for whatever career they chose to enter. The metaphor of being compared with stem cells was amusing to them.

Summary

This report describes my attempt to use a particular strategy to encourage inquiry-based learning. As the then Director of Inquiry, my task was to set up a series of courses that would foster that approach. I have alluded already to the problematic nature of that term. It is worth emphasizing the Dewey notion of warranted assertibility. To Dewey (8), the process of inquiry permitted one to make assertions based on knowledge accrued, which, in turn, would set the stage for further inquiry. Thus, knowing was not a spectator sport, but active engagement. So students did not accumulate detached artifacts or “pieces of the dead wood of the past,” but attempted to understand with justification; hence, the warranted assertibility. Thus, as emphasized by Boyles (6), certitude goes out of the window and teachers and students are both inquirers. From that vantage point, this course had a measure of success. Students pursued their own interest within broad guidelines. I, too, found myself engaged actively in learning by reading their abstracts and submissions, guiding them when they needed it, and being active in all the assessment options.

In this situation, the freedom given to students to select their assessment options was useful. This approach builds and amplifies the notion of a learners’ contract or a portfolio. Knowles (15) has detailed the evolution of the process and provided numerous examples as well as guidelines. He considers the key elements of such a contract to include the learning objectives, the resources and means by which these objectives were to be met, the target date for completion, the nature of the evidence to be presented, and assessment protocols. He also mentioned the categories of contracts that could be set up based on the nature of the situation. The key issue here is the individualization of such contracts, since all teachers set up implicit contracts with their students when they hand out course outlines.
Since then, a sizeable body of information attesting to the value of such approaches has been accrued, largely drawn from professional literature (4, 5, 9, 19, 25, 27). Student portfolios or learning portfolios are powerful means for encouraging self-reflection and can be tailored to fit different learning outcomes. However, in all instances, it is important to recognize that how well these measures work depend to a large degree on the learner’s orientation, which was mentioned at the outset. It is worth revisiting that issue again.

The learner plays a crucial role in the outcome of any assessment. At the outset, I discussed the studies linking learner’s orientations to performance in courses. This stems in large measure from the attitudes they bring to bear. This particular course was a required course. That by itself may have bred some resentment in some. On the other hand, these students had entered the program with high grades from school, were highly motivated, and knew full well that getting good grades boded well for their future. Their learning orientation was a combination of vocational, academic, and personal (4, 26). Nevertheless, even here, I noticed that not all students did equally well on all measures. One student, who surprised me by his knowledge of bioinformatics and argued cogently in the targeted oral examination, handed in a very poor essay for his individual exploration. So he appeared to function as a deep learner in one instance and an extremely superficial one in another. Although I did not probe this issue, it could have been in part due to conflicting demands on his time and the strategic decision he may have made to focus his energies on the evaluation exercise, which had higher marks attached. So, a proper description of his competence should take into account these variations. This would constitute what anthropologists call a “thick” description (10, 18). The standard transcript that we see provides at best a thin description, and a proper assessment of a student’s competence should take into account the context in which the assignments were completed or the exams were done. On the same token, one needs a thick description of the examiners themselves. These are far from easy to achieve and evaluation thus remains an art (8), but hopefully a defensible one.

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