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From the Editor

Wytze Brouwer

Thomas Hench, in "An Evolutionary Approach to Assessing Online Instruction," describes an innovative way of identifying potential areas of improvement in all types of course construction, including online courses and ways of monitoring the success of implemented changes.

Silas Oluka, University of Botswana, in "Constructivism in Professional Development: A Case for Capacity Building Among Physics Teachers," describes a sub-Saharan project to equip practising science teachers with the skills to teach physics in a more realistic, constructivist manner.

Wytze Brouwer, James Pinfold, Richard Soluk, Brent McDonough and Vladimir Pasek, in "The ALTA Cosmic Ray Project—Lessons Learned," describe some of the successful projects carried out in the ALTA Cosmic Ray Project and comment on some of the lessons learned while carrying out the project.

Dougal MacDonald, in "Teaching and Learning Technological Problem-Solving Skills," describes the various skills that go into technological rather than scientific problem solving.

Frank Weichman, in "Personal Assistants," calculates how citizens in modern society function with the help of energy and labour-saving devices that would be the equivalent of having many human assistants in previous societies.

Aldo Marrocco, Pisa, Italy, in "A Few Basic Principles About Comfort and Natural Climatization in Buildings," has summarized the basic principles in constructing more energy-efficient and better insulated structures of various types.

Bertram Millsap is facing retirement and has decided to become fit at last. He decides to go on a nature walk in a river valley park but cannot get his mind off physics even for a while. However, his faithful companion of many years tries to keep his mind on the local environment rather than on the physics research lab.

An Evolutionary Approach to Assessing Online Instruction

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Abstract

In evolutionary biology, the fitness of an organism—that is, the degree to which it is successful in surviving and reproducing in its environment—is determined by how strongly evolved traits provided by the natural selection process contribute to that success. The strength of the contributions is determined, in turn, by the frequency of occurrence and usefulness of these traits. In an analogous manner, the fitness of a population of courses—that is, the degree to which they are successful in providing learning opportunities in their instructional environment—may be determined by those traits identified by the instructional design process that contribute to that success. Again, the strength of the contributions is determined by the frequency of occurrence and usefulness of these traits. This article describes a general evolutionary approach to evaluating the fitness of any population of courses and its specific application to the online courses taught at the author's institution. Starting with the identification of the "instructional traits" needed to survive and the pedagogical strategies or "strategic traits" that support them, the evolutionary approach presented here analyzes the frequency, evolution and usefulness of the appropriate traits to arrive at an overall fitness for the online course population, along with recommendations for improving this fitness.

Introduction: The Basis of the Evolutionary Approach

In biology, an organism may be defined as a complex structure of interdependent and subordinate elements (molecules, cells, organs and so on) whose relations and properties are largely determined by their function in the whole (to provide continued existence and opportunities for reproduction). Furthermore, the fitness, according to evolutionary biology, is the degree to which the organism is successful in surviving and reproducing in its natural environment. This success, in turn, is determined by the strength of the contributions made by those evolved traits resulting from the natural selection process. In addition, two types of traits are possible; namely, behavioural traits and physical traits. As an example, the human behavioural trait of bidepalism is investigated. Bipedalism has been shown to be a very successful trait that contributed strongly to the survival and reproduceability of prehumans as their environment changed from arboreal to terrestrial. However, bipedalism did not arise independently; it emerged as a result of the individual contributions of selected and evolved physical traits. With a spine to support and balance the cranium, a wider pelvis and angled femur to provide balance and permit more efficient locomotion, and arched feet to absorb the impact of upright walking, bipedalism was enabled to appear (Figure 1 and Table 1).

The combined contributions of these successful physical traits enabled the behavioural trait of bipedalism to emerge and provide an enhanced level of fitness for prehumans. Indeed, human speech and toolmaking are further examples of this interdependent action of traits.

In an analogous manner, a population of courses taught at an institution may be viewed as an organism in that it possesses a complex structure of interdependent and subordinate elements (students, instructors, courses and so on) whose relations and properties are largely determined by their function in the whole (to provide continued opportunities for learning). Here, the fitness of a course population is the degree to which they are successful in providing learning opportunities in their instructional environments. As before, this success may be determined by assessing the strength of the contributions made by the "traits" resulting from the instructional design (ID) process. More specifically, this process identifies interactivity and assessment as two general "instructional" traits (analogous to the behavioural traits in biology) necessary for successful courses (Swan 2004). In particular, successful courses should include the following:

1. Interactivity—Use different pedagogical approaches to encourage student/student, student/faculty and student/content interactivity and
2. Assessment—Implement multiple strategies for the assessment of learning.

Figure 1: Physical Traits Enabling Bipedalism

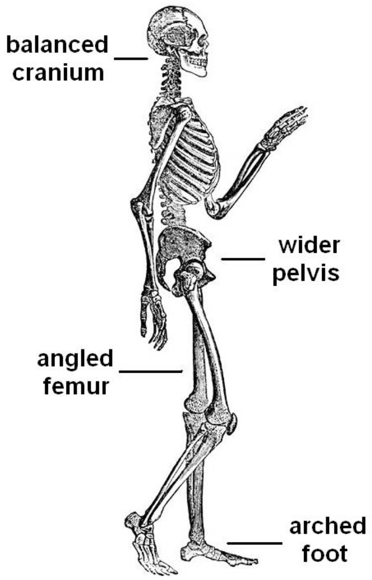


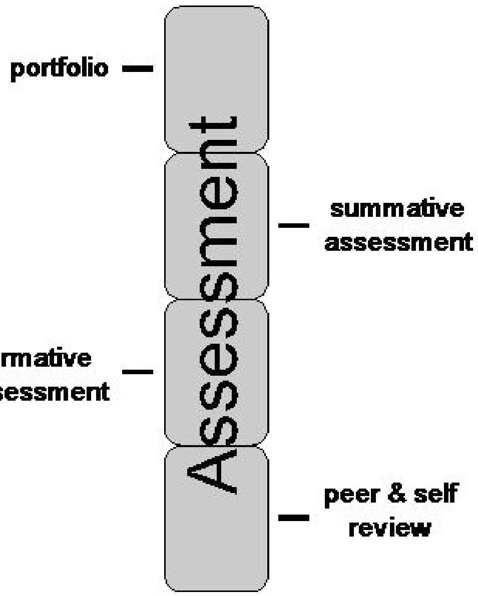
Table 1: Bipedalism Trait Summary

Behavioural Trait	Physical Traits
Bipedalism	balanced cranium wider pelvis angled femur arched foot

Just as the emergence of successful behavioural traits was enabled by the combined contributions of physical traits, the identified instructional traits arise as a result of the contributions to success of selected strategies or "strategic traits." These strategic traits consist of demonstrated techniques or methodologies and are selected to enable the emergence of the necessary instructional traits. (California State University, Chico 2004; University System of Georgia 2005). For example, Figure 2 shows the assessment instructional trait and the strategic traits that enable it in online courses. For ease in analysis, the general interactivity trait is divided into three specific, instructional traits. Again for the example of a population of online courses, Table 2 presents a complete list of the resulting four instructional traits and corresponding strategic traits.

An evaluation of the combined contributions of the strategic traits in Table 2 permits the determination of the strength of each instructional trait. Taken together, the strengths of the instructional traits are then used to determine the fitness of the population of courses under investigation. Continuing with the example previously stated, the fitness of the population of online courses at the author's institution is now evaluated.

Figure 2: Strategic Traits Enabling the Assessment Instructional Trait in Online Courses



Fitness Evaluation Strategy

The strategy used to determine the fitness of any population of courses comprises the steps as shown in Table 3.

Step 1: Identify the presence and evolution of the necessary instructional traits in the current population of courses under investigation.

The information necessary to complete this step was obtained through an online survey of the current online instructors at the author's institution. In addition to determining whether an instructional trait was present, the survey asked for responses regarding what emphasis this trait was or would be given by the instructor in past, current and future courses. From a total of 32 current instructors, 25 responded to the survey; the results and interpretations are shown in Figure 3.

Table 2: Summary of Instructional and Strategic Traits for Successful Online Courses

Instructional Traits	Strategic Traits
Interactivity Student/Student	Threaded discussions Collaborative group projects Group problem solving Resource and information sharing Peer review of projects or reports Learning style matched activities
Student/Instructor	Regular communication Icebreaker activity Course calendars Automated testing and feedback Chats (synchronous or asynchronous)
Student/Content	PowerPoint (or similar) presentations Audiovisual materials Interactive simulations Animations Games/puzzles
Assessment	Portfolio Summative assessments Formative assessments Self and peer review

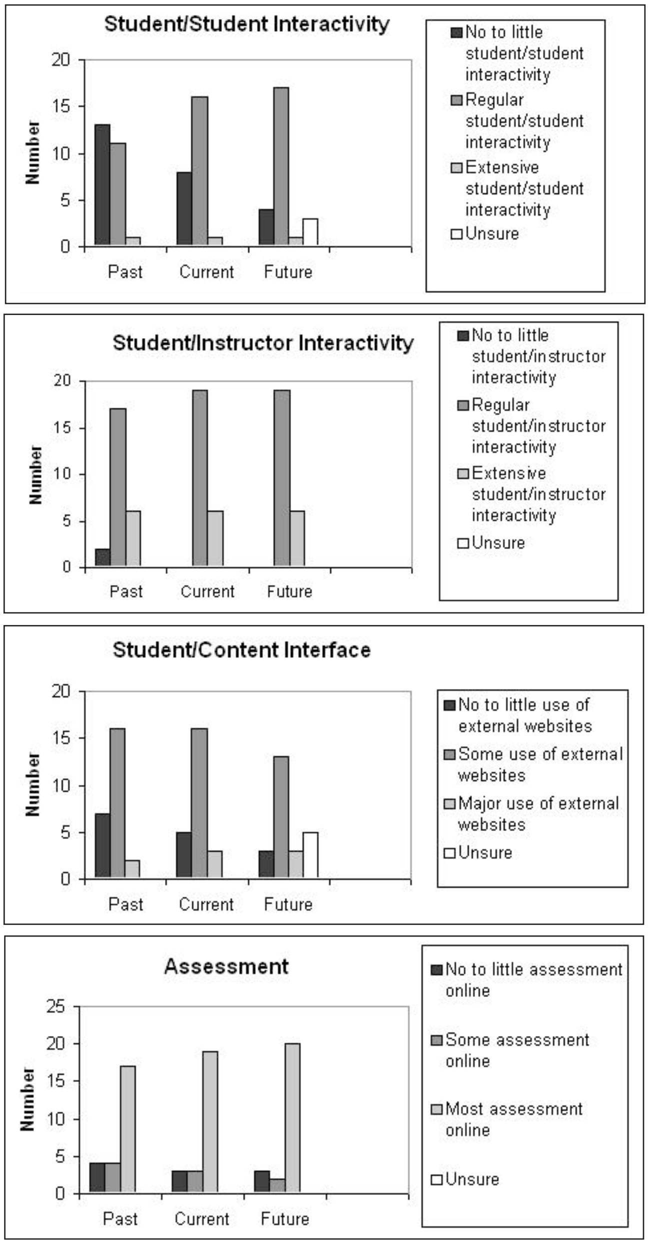
Table 3: Fitness Evaluation Strategy

Step 1: Identify the presence and evolution of the necessary instructional traits in the current population of courses under investigation.

Step 2: Determine the frequency and usefulness of the strategic traits and the resulting instructional trait strengths.

Step 3: Evaluate the fitness of the population of courses and provide recommendations to improve the fitness.

Figure 3: Presence and Evolution of the Instructional Traits for the Population of Online Courses Under Investigation



As seen from the Student/Student Interactivity data, this instructional trait is present in at least 68 per cent of current courses. In addition, this trait is evolving toward a greater than 84 per cent presence in the future.

Results from the survey indicate Student/Instructor Interactivity is present in all current online courses and will continue at this level in the future. Initially, only two courses did not have this trait.

Student/Instructor Interactivity data shows this trait presence in 79 per cent or more of current courses with the number increasing to 88 per cent or more in the future. Once again, an evolving trend toward a greater presence of this trait is observed.

The results for the Assessment trait indicate a presence of 88 per cent or greater for both current and future courses, with a slight trend toward a higher occurrence of this trait in the future.

In summation, the four necessary instructional traits were observed in greater than 68 per cent of all online courses. Furthermore, the survey results indicated the possible evolution to higher occurrence of the Student/Student, Student/Content and Assessment traits.

Step 2: Determine the frequency and usefulness of the strategic traits and the resulting instructional trait strengths.

The contributing strength of a specific instructional trait depends on two factors: the frequency at which the associated strategic traits occur and their usefulness in these courses. To obtain these data, a follow-up survey was administered. Specifically, the instructors were asked to rate the usefulness of the traits that occur in their class or classes on the scale 1—not very useful; 2, 3—useful; 4, 5—very useful. The follow-up survey results are shown in Table 4.

Table 4: Strategic Trait Frequency and Usefulness Results

Strategic Traits for Student/Student Interactivity Trait	Frequency	Usefulness
Threaded discussions	0.83	3.58
Collaborative group projects	0.52	2.33
Group problem solving	0.39	2.78
Resource and information sharing	0.87	3.16
Peer review of projects or reports	0.26	3.17
Learning style matched activities	0.17	3.00
Average	0.51	3.00
Success level S	1.5	X

Strategic Traits for Student/Instructor Interactivity Trait	Frequency	Usefulness
Regular communication	0.96	4.72
Icebreaker activity	0.91	3.67
Course calendars	1.00	4.41
Automated testing and feedback	0.91	4.00
Chats (synch/asynch)	0.74	3.41
Average	0.90	4.00
Success level S	3.6	X

Strategic Traits for Student/Content Interactivity Trait	Frequency	Usefulness
PowerPoint (or similar) presentations	0.83	3.79
Audiovisual materials	0.65	3.80
Interactive simulations	0.31	3.43
Animations	0.22	3.40
Games/puzzles	0.26	3.00
Average	0.45	3.48
Success level S	1.6	X

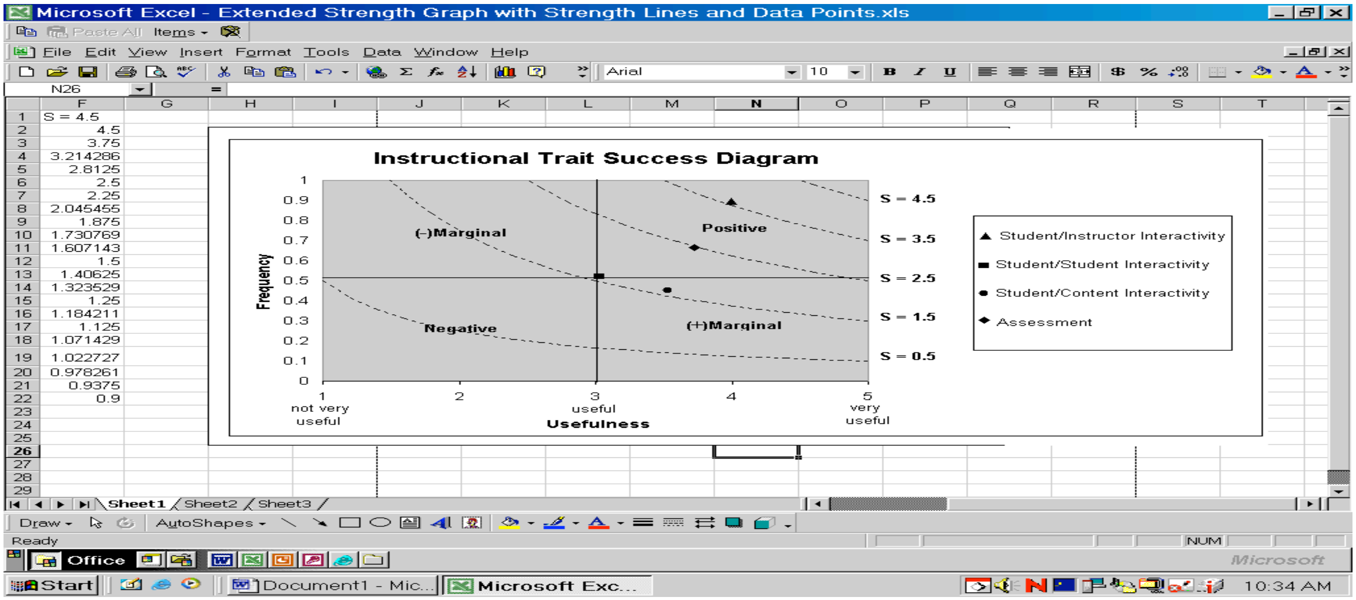
Strategic Traits for Student/Assessment Trait	Frequency	Usefulness
Portfolio	0.27	4.17
Summative assessments	0.96	4.27
Formative assessments	0.96	3.41
Self and peer review	0.32	3.00
Average	0.63	3.71
Success level S	2.5	X

Success level S = Average Usefulness × Average Frequency

Qualitatively, if the strategic traits appear at a high frequency and are deemed very useful, the instructional trait is considered to positively contribute to the success and fitness. On the other hand, strategic traits that do not occur very often and when they do appear are found to have little use, have a negative instructional trait contribution. Furthermore, strategic traits that occur infrequently but are found to be very useful may result in positive contributions, whereas strategic traits that appear with a high frequency but are not deemed useful may signal a negative contribution. Consequently, these contributions are identified as (+) marginal or (–)marginal. Graphically, any combination of frequency and usefulness is represented in the Instructional Trait Strength (ITS) diagram shown in Figure 4. As indicated, the range of frequency is from 0 (no appearance of the traits) to 1 (the traits appears in every case) and the range of usefulness of the traits extends from 1 (not very useful) to 5 (very useful). Identifying a frequency of 50 per cent or higher and a usefulness rated at three or above as the minimum criteria of a positive instructional trait contribution, the diagram is then divided into four quadrants of positive, (+)marginal and (–)marginal, and negative contributions.

As previously mentioned, the strength of contribution of a specific instructional trait depends on both the frequency at which the associated strategic traits occur and their usefulness. To quantitatively refine the ITS diagram, the strength S of an instructional trait is algebraically defined as the product of the average usefulness and average frequency of the strategic traits, or S = Average Usefulness × Average Frequency. Thus, possible strengths range from 0 (the traits were not present in any case) to 5 (the traits were present in every case and were found to be very useful in all cases). In addition, the value of S increases in magnitude in the direction from the lower left-hand corner to the upper right-hand corner of the ITS diagram. When the relationship between the usefulness and frequency for various values of S is included in the diagram, as indicated by the dotted lines in Figure 4, the ability to clarify the contribution of the instructional traits within each quadrant emerges. For example, the region on the diagram located in the positive quadrant between the S = 3.5 and S = 4.5 denotes a stronger contribution of the instructional trait strengths than those found between S = 2.5 and S = 3.5, which may include traits in a (–)marginal contribution quadrant. Just as important, the region between S = 1.5 and S = 2.5 in the (+)marginal quadrant may provide a stronger contribution than the region within these same strength boundaries but located in the (–)marginal quadrant.

Figure 4: Instructional Trait Strength Diagram for the Online Course Population



	F
1	S = 4.5
2	4.5
3	3.75
4	3.214286
5	2.8125
6	2.5
7	2.25
8	2.045455
9	1.875
10	1.730769
11	1.607143
12	1.5
13	1.40625
14	1.323529
15	1.25
16	1.184211
17	1.125
18	1.071429
19	1.022727
20	0.978261
21	0.9375
22	0.9

For each instructional trait shown in Table 4, the average frequency and usefulness of the associated strategic traits were calculated and plotted on the ITS diagram, again as shown in Figure 4. The strength of instructional trait's contribution is then determined by the criteria as shown in Table 5.

Step 3: Evaluate the fitness of the population of courses and provide recommendations to improve the fitness.

From Table 5, the Student/Instructor Interactivity instructional trait strongly contributes to the success and fitness of the population of online courses. In addition, the assessment instructional trait provides a fitness contribution of moderate strength. Taken together, the contributions of these two instructional traits confer a moderate to high degree of fitness to the online courses. The contributing strengths of the Student/Student Interactivity and Student/Content Interactivity are, according to Table 5, moderate. However, as a result of their positions on the ITS diagram, these contributions may be interpreted as weaker than the moderate contribution of the assessment trait. Thus, these marginal contributions may result in a decrease in the fitness resulting in an overall moderate degree of fitness for the population of online courses.

Table 5: Instructional Trait Fitness Ranges

Success Level	Degree of Fitness
$S \geq 4.5$	Very strong
$S \geq 3.5$	Strong
$2.5 \leq S < 3.5$	Moderate (S in positive quadrant) Weak (S in (–)marginal quadrant)
$1.5 \leq S < 2.5$	Moderate (S in positive or (+)marginal quadrant) Very weak (S in (–) marginal quadrant)
$0.5 \leq S < 1.5$	Very weak
$S < 0.5$	No contribution to fitness

To strengthen the contributions of the assessment trait, a recommendation for the use of more portfolios, and more frequent and useful self and peer review is suggested. For the student/student trait, a review of the survey data presented in Table 4 suggests that the usefulness of resource and information sharing also must be increased to provide a stronger student/student interactivity contribution. Furthermore, both the frequency and usefulness of collaborative group projects, group problem solving, peer review of projects or reports, and learning style matched activities need enhancement. Similarly, improvement in the frequency and usefulness of interactive simulations, animations and games/puzzles, when applicable, is recommended to improve the success level of the student/content interactivity trait.

Importantly, the trends observed in Figure 3 toward more inclusion of student/instructor and student/content interactivity present the possibility of future increased contributions. Following are survey comments from instructors:

> I gained more confidence in handling things online. I also wanted to get some group work started to simulate classroom discussions and activities.… As the course matured, I was able to find more materials and more course-related websites … I now require live chats … More current and updated materials available … I reworked the course so that all student questions would be answered in the syllabus.… Part of the beauty of my traditional courses is the student-student interactions. That was lacking from my online courses, so I made changes to rectify that.… Quite frankly, I wanted to design something that relieved my workload—answering redundant questions through e-mails and so on.… More sites with good/reliable information … moved to an online video lecture format that is prepared and delivered by CD-ROM to reduce long download times.…

Such comments suggest that further contributions to the overall fitness will occur. In the same sense, the consistently high occurrence of both the student/instructor interactivity and assessment traits found in Table 3 suggest that there has been greater time for the associated pedagogical traits to evolve and contribute at higher levels to the success and fitness.

Furthermore, it is noted that not all of the strategic traits listed in Table 2 are applicable to all courses. The comment by one instructor “The amount of student/student interaction depends on the course. In one course I don’t require any at this point. In another, regular forum participation is a required component of the course” is indicative of this variable applicability. For example, interactive simulations may be used frequently and be very useful in a physics course, yet may not be applicable or even available for a mathematics course. However, the lack of interactive simulations in mathematics may allow for their development in such courses where they are not currently found. In addition, a decrease in a particular trait contribution may occur, as evidenced by the instructor comment that student/student interactivity was “too difficult and time consuming to monitor.”

Survey comments identify other strategic traits that work well in courses and could contribute to the success of the assessment instructional trait, such as instructor review of assignments prior to due dates and reflection papers to identify important concepts and applications. Instructor-provided examples are identified as another useful strategic trait that could contribute to the success of the student/content interactivity trait.

Thus, the previously determined moderate overall fitness must be viewed in terms of three compensating factors: (1) the evolving abilities and needs of the instructors, (2) the applicability of certain traits and (3) the possibility of other useful strategic traits than those listed in Table 2. For those strategic traits of low frequency and or usefulness, faculty inservice, workshops or mentoring by experienced online faculty are offered as a means to improve the contributions of the instructional traits. When applied to other courses’ populations, the compensating factors mentioned above must be considered in determining the overall fitness and strategic traits identified that are appropriate to those populations.

Summary

Adapting ideas from evolutionary biology, the fitness of any population of courses was defined as the degree to which they are successful in providing learning opportunities in their instructional environments. By determining the contributions of strategic traits to the strength of specific instructional traits, the fitness of a specific population of courses—those taught online at the author’s institution—was assessed. The analysis also identified areas in which improvements may be made to strengthen the instructional traits contributions and increase the fitness. More specifically, the results show that the student/instructor interactivity and assessment instructional traits’ strengths provide a moderate to high degree of fitness. Conversely, the student/student interactivity and student/content instructional traits’ contributions weakened the overall degree of fitness to moderate. The assessment also yielded areas of improvement; namely, increases in the frequency and usefulness of collaborative group projects, group problem solving, peer review of projects or reports, and learning style matched activities. The use of faculty workshops and mentoring are recommended as means to achieve further improvements. Additionally, the course management systems (CMS) used for course delivery may have an important impact on both the frequency and usefulness of a pedagogical trait. Thus, the choice of the appropriate CMS warrants further investigation. Finally, through identification of the appropriate strategic traits, the approach as described here may be used to determine the fitness of other course populations as well.

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Constructivism in Professional Development: A Case for Capacity Building Among Physics Teachers

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Abstract

An endemic trend in low achievement levels in high school science subjects highlights the possibility that science teachers lack prerequisite knowledge and skills to activate appropriate student conceptions of the natural world, which is a foundation to students' science achievement. Because science teachers face challenges in identifying appropriate instructional goals, they use unsuitable instructional methods, strategies and resources. Therefore, there is a pre-eminence of traditional practice that undercuts a need for teachers to encourage students to systematically apply, evaluate and revise their conceptions of physical phenomena through authentic learning environments. The key concern of this study was how teachers can be guided to reconceptualize and transform teaching and learning to engender development of functional personal skills of problem solving, information gathering and critical response, which are cornerstones to solving problems in real-life situations. An action-research model among physics teachers in rural sub-Saharan Africa provides some insights to the underpinnings of professional development using constructivist approaches.

Background and Problem

Despite reform efforts among developing countries to promote basic sciences for technological development, the teaching of science has failed to evolve literate and practically oriented graduates capable of applying relevant aspects of science to improve the poor social and ecological conditions.

Cognitive psychologists are increasingly acknowledging that the behaviourist model is dominating pedagogy. In the behaviourist approach to teaching and learning, teachers provide a set of stimuli and responses that are likely to get students to respond appropriately. When the goal is to get students to replicate certain behaviours, this model works well, but when understanding, interpretation, synthesis and the ability to use information in new situations are goals, the behaviourist approach is not successful.

In the common traditional approach, classroom science is often presented as a set of truths, skills or simple activities to be reproduced and memorized by students (Rampal 1992; Oluka 1997; Milne 1998). Also noted by many authors and scholars is the examination-driven teaching and learning activities that override the need for students to engage in inquiries that connect their lived experiences with concepts and skills taught in science classrooms. In her study of Female Education in Mathematics and Science in Africa (FEMSA), Mulemwa (1997) notes that teachers are the central source of knowledge in the science and mathematics curricula. Such teachers use traditional teaching approaches, which encourage rote learning that leads to overall poor student performance because of the lack of experience and authentic science learning. The

FEMSA report acknowledges a range of factors, such as poor science facilities, lack of materials and low teacher morale because of inadequate remuneration, contribute to students' poor attitudes and performance in science, especially girls. Poor teaching approaches that emphasize theoretical exposition of science concepts have been pinpointed by the FEMSA report and other studies (for example, Oluka 1998; Olupot 1995; UNESCO 2008) as being centrally responsible for low student achievement levels in the sciences. This, in turn, leads to fewer students taking these subjects in secondary schools. These observations have three interconnected implications that are central to this paper: (1) the level of motivation among students in learning and doing science as a mode of inquiry in a self-driven, intentional way; (2) a model of professional development of science teachers to drive novel ways of enhancing the quality of teaching and learning in physics and (3) the institutional responsibility in facilitating appropriate learning and teaching of physics as a science.

In the African region for the last decades following independence (see Lange and Kiragu 1996; Wasanga 1997; Ike 1997), research in science education has emphasized cognitive science. Furthermore, many science educators and funding agencies continue to focus on curriculum frameworks that they expect teachers to use in new ways. However, new ways to use instructional materials will not be found without concentrating on instruction that is based on emerging understandings about how humans learn.

Educational goals stipulating the teaching and learning of science toward social change therefore raise many questions; for example, What blends of teaching and learning experiences in schools could be explored and emphasized to enrich and significantly enhance the quality of learning and achievement in science? and What teaching strategies could facilitate learning and practice of science among secondary school students to build a culture of scientific inquiry? Amid dominance of traditional pedagogy, critical dialogue over these questions may provide precursors to a form of transformative pedagogy.[1]

Out of the generic question on how students can be helped to learn science meaningfully has emerged a constructivist approach to the teaching and learning of science (Adey 1997; Kenway and Gough 1998). Constructivism is an epistemology that focuses on the role of the learner in personal construction of knowledge (Adey 1997; Appleton 1997; Driver 1994). The constructivist approach derives from the premise, developed in cognitive science, that learning science is a process of building, organizing and elaborating knowledge of the natural world (Anderson 1990; Baddeley 1990; Gagne 1985). Through constructive processes, students learn science meaningfully when they activate their existing knowledge, relate it to educational experiences and construct new knowledge in the form of conceptual models (Adey 1997; Glynn and Duit 1995). Relating existing knowledge to new experiences must be intrinsically motivating and requires students to be consistently guided and supported to apply, evaluate and revise their conceptions.

Amid the dominance of the traditional approach to science instruction, this study focuses on generating proactive self-reflection by prompting physics teachers to question and revise their teaching roles and responsibilities. The study seeks to contribute to an outstanding interest in and an emerging understanding of how to teach science transformatively and constructively. In the process the study hopes to generate mechanisms through which physics teachers will develop teaching competencies and mediation capacities that enhance constructive learning among students.

Constructivist approaches in teaching–learning markedly contrast with the traditional practices in which rote learning and drill feature prominently (Driver 1994; Appleton 1997). A shift to the transformative teaching platform offered by constructivism will demand much more from teachers (and students) than applying a new strategy or recipe. Because transformative teaching demands less preparation, science teachers tend to teach by the common "talk and chalk" method, in contrast to the hands-on and minds-on teaching of science. Besides, traditional classroom practice too often posits the teacher as the only expert in the classroom. This could lock out opportunities for students to voice and share their own experiences, feelings, desires and conceptions of the natural world, and could lead to rote learning. The pre-eminence of traditional practice, therefore, undercuts the tenet of constructivism, by which teachers encourage students to systematically apply, evaluate and revise their conceptions through authentic learning environments.[2] It also disempowers students by constraining their potential to take a critical stance in active learning.

Research Questions

The key organizing questions for this study are as follows:

1. On what foundations do the common teaching approaches and solicited learning outcomes in physics lessons rest?
2. How can teaching and learning be reconceptualized to develop and promote constructive processes of teaching and learning?

To answer these questions, the following specific research questions further guided the action-research inquiry:

a. To what extent are physics discourses transformative and constructivist in physics classrooms?
b. What range of relationships shape classroom practices of physics teachers during constructivist teaching practice in a science classroom? What demands at personal, pedagogical, academic and institutional platforms are required to realize constructive teaching?
c. What does this suggest about intervention demands to foster and sustain constructivist practice in physics teaching and learning?

Guiding Theoretical Constructs

This study is grounded in the traditions of critical theory alongside the constructivist process of learning science. The objectives and research design of this study are inspired by and based on the premises of development and transformative education. Among the proponents of this form of education is the late Paulo Freire, whose criticism of traditional notions of education process is driven, consciously or otherwise, by a desire to maintain a status quo. In the critical tradition, education is seen either as an instrument of oppression or of transformation (Weiler 1988; Carr and Kemmis 1986; Anyon 1981; Freire 1970). The major assumptions of constructivist teaching and learning attest to the Freirean notion that critical understanding leads to critical action (Freire 1970). In this study, therefore, transformative pedagogy is conceived of as a form of practice that seeks to reconceptualize both the epistemological and the pedagogical frames of the science classroom. Transformative practice can therefore be seen as posing a challenge to traditional practice on many fronts:

i. Classroom relationships between students and teachers and among students are redefined. By allowing student thinking to drive lessons, the classroom discourse shifts away from the teacher to all members of the classroom community. Such a shift in discourse patterns communicates powerful values about knowledge and authority. It continually brings the teacher to critically confront and appropriately deal with such questions as whose knowledge and ways of thinking are valued, who can or cannot contribute, and what is an acceptable contribution? For example, Jansen (1990) engaged students in a critical discussion about scientific knowledge and its construction. Jansen examined the most widely used biology text in South Africa, the *Senior Biology for Standard 9 and 10*. He engaged the question of scientific authority by discussing the authority of the text and its eight authors (all white Afrikaners).
ii. Alternative conceptions of the subject matter of the physics discipline in general are presented and explored. This may involve a reconceptualization of the nature of subject matter (knowledge); for example, exploring the "tentative nature of science" or the "socially determined conventions" that underlie most conceptions and operations in it. This helps students to activate and transform their conceptualizations of natural phenomena into real ones and/or encourage students to think metacognitively.
iii. An emphasis is placed on the relationship between knowledge, power and social existence. Julie (1992) provides a good example of how this can be done. He challenged students who were preparing to march on the educational authorities over the issue of overcrowded classrooms to use their mathematical knowledge to construct an "overcrowded classroom" using the concept of volume that he had explored in a mathematics lesson. Julie's example demonstrates one attempt to weave mathematical knowledge into the students' struggles to reconstruct their social experiences. Constructivist classroom settings allow teachers to look for students' alternative conceptions and to design lessons that address any of these conceptions that differ from those held by scientists. Although some educators may be clearer about the goals of transformative practice and how it challenges traditional practices, there is less clarity about what it is (that is, what

> range of possibilities exist within this broad theme of transformative practice), how to recognize it and what accounts for it in the discursive classroom-learning environment. In this regard, the study was as much about reaching out to possibilities of transformative practice through constructivist teaching and learning as it was about clearly defining and generating pathways to, and identifying contextual strategies for, their development and implementation.

Teachers and Classroom Practice

Schools have fallen short of the ideal of preparing students for effective participation in the social and economic spheres of the community. From both the radical and critical perspectives, there is some agreement that the current physics teaching practice in most high schools[3] has been less than effective in preparing students for their role in society, especially in the underdeveloped world. These critiques, however, begin to diverge when the search for explanations and analysis of the problem is started.[4] Conservative critiques define the role of schools in terms of socialization of the young to the social and economic spheres of life. Schools are to impart specific "knowledge and skills" required for participation in a stratified capitalist democracy. This trend of scholarship is exemplified by Hirsch's (1987) text, *Cultural Literacy*, which defined some of the knowledge and skills that a person needs to be considered literate in this environment. This argument is extended by Adler's (1982) *Paideia Proposal*, which describes a curriculum program that he claims would solve most of the complaints about schooling in the United States. In the case of South Africa this kind of scholarship provided the basis for government policies on black education from the introduction of Bantu education in 1953. For example, when introducing the *Bantu Education Act* of 1953, the then minister of native affairs in South Africa argued for the narrow socialization function of education. As he put it:

> The Bantu must be guided to serve his [sic] own community in all respects. There is no place for him [sic] in the European community above certain forms of labour. Within his own community, however, all doors are open. For that reason it is of no avail to him to receive a training which has as its aim absorption in the European community, where he cannot be absorbed (Rose and Tunmer 1975, 265).

Radical theorists have a different perspective on why schools fail to provide quality education; this perspective has corresponding implications for the quality of science education. To the radical theorists, education is an act of empowerment; it enables people to play a role in social transformation. This argument is premised on the interrelationship between schools and society. To the radical theorists, the conservative approach focuses on schools and classrooms as if they were isolated from wider social, political and economic relations that shape society (Apple 1979, 1982; Bowles and Gintis 1976; Giroux 1986, 1988). The power relations of everyday life, they argue, shape classroom experiences. As Weedon (1987, 26) asserts:

> How we live our lives, and how we give meaning to material and social relations under which we live depends on the range and social power of various discourses, our access to them and the political strength of the interests which they represent.

The story about the failure of schools, then, is incomplete without an analysis of the social, political, economic and historical factors that have shaped current practices in education. Habermas identifies how this view affects science education and asserts that knowledge is produced by how people orient themselves to the world (Carr and Kemmis 1986). The earlier studies by radical scholars, which proposed totalizing explanations of the processes of educational reproduction, have given way to a new chain of studies that focus on teachers' and students' experience. The earlier work often proposed a tight connection between schooling and the capitalist economy, thereby presenting social actors as passive objects of the reproductive machinery (Althusser 1971; Bowles and Gintis 1976). In contrast, later studies asserted people's ability to act and challenge the circumstances of their lives (Freire 1970; Willis 1977). These studies formed the basis for thinking about how teachers might act in the interest of their students and bring about social change. However, radical scholars did not go so far as to examine changes in practice or how individual teachers can orchestrate these. By and large, their story remained theoretical and focused more on domination and reproduction. In this regard, therefore, their contribution to the debates about quality in schools has been limited. The challenge of the reform movement of the late 1980s and early 1990s, therefore, has been to more concretely address the question of change in classroom practice and how to promote or encourage it. The strengths of the latest reforms (in the US and Canada) lie in some of their conceptualizations of the dimensions of practice that will have to change in order to transform the teaching and learning of mathematics and science. The NTCM (1991) for instance, discusses four areas that will need to change: classroom tasks, classroom discourse, classroom environment (physical, social and intellectual) and the analysis of classroom learning.

The teachers' previous careers (even as students) and life experiences shape their view of teaching and the way they approach it (Casey 1993; Goodson 1984; Knowles 1992; Middleton 1993). Their "life outside school" together with their latent identities and cultures shape their practice (Goodson 1984, 1992; Casey 1993; Middleton 1993; Nelson 1992; Woods 1986). Teachers' career cycles, whether they are beginning, veteran or even student teachers, significantly affect their decisions to change their approach to teaching (Goodson 1984; Huberman 1993; Knowles 1992). Casey (1993), Middleton (1993) and Weiler (1988), who studied different groups of feminist teachers, also highlight the role of political and epistemological frameworks in informing and shaping classroom practice. But although we are now better informed about the factors that help to determine pedagogy, we still do not understand how these factors get translated into practice.[5] As argued by Lange and Kiragu (1996), teachers' views of problems in teaching usually change based on conditions and constraints, and focus on how to improve teaching practice. Although the number of action-research-based classroom studies of teachers is increasing, they are still largely descriptive and have little or no framings based on theory coupled with practice (praxis) that improve the understanding and practice of constructivism.

Transformative Pedagogy and Constructivist Teaching and Learning

To identify and explore the images of transformative and constructivist teaching practice, I will explore particular shifts in certain broad dimensions of classroom practice based principally on mathematics and science reform literature in the US and Canada. Although such dimensions of change as developed by NCTM (1991), AAAS (1990) and other reformers for US and Canadian schools help to construct an image of transformative practice, their exact meaning and expression may certainly differ in the context of Africa. As indicated earlier, transformative and constructivist practice brings issues of power to centre stage of a teaching–learning situation. Part of the story in the development of constructivist and transformative practices is about the social power and authority of these practices relative to traditional pedagogy. The degree to which these current marginal practices (constructivist/alternative and transformative) can increase their social power is governed by social interests and power within which the challenges to traditional practices are made. In current science education in sub-Saharan Africa, there is a glaring absence of specific institutional and organized initiatives and bodies advocating for such classroom reforms.

Writing on good design in reconstructive knowledge and practice, Raskin (1971) identifies the need for the designer to live the project, a process that should seek to foster a rebuilding, bridging and healing of the rifts between consciousness, purpose of project and practice. Raskin's assertion poses a challenge to scientists and science educators about how reconstructive, or transformative, their school science discourse and applications are. Although strong in suggesting the dimensions of practice that we should look for in classrooms where teachers are engaged in transformative practice, Raskin's works are silent about what it would take to overcome some of the personal and contextual constraints faced by teachers who attempt to engage in such practice. A participatory approach to analyzing the teaching–learning situation in science classroom settings, and of planning and implementing new practices, and analyzing their effects could yield the needed transformation in professional classroom practice among science teachers.

The concept of transformative pedagogy is apparent in Africa amid the popular concern for supporting the girl-child in the gendered learning environment of the science classrooms (Mulemwa 1997; Wasanga 1997). Paulo Freire is one critical scholar whose work has probably had the most impact in developing nations. His work has been used in such countries as Angola, Mozambique, Tanzania, as well as in his own country, Brazil. Freire has attacked the very basis of traditional pedagogy: its emphasis on the transmission of and transference of knowledge. He is critical of what he terms the *banking* system of education whereby

> the teacher issues communiqués and "makes deposits," which the students patiently receive, memorize and repeat. This is the "banking" concept of education, in which the scope of action allowed the student extends only as far as receiving, filing and storing the deposits. (Freire 1970, 58)

This common feature of traditional pedagogy imposes a number of limitations on recipients. The most obvious, both from radical and conservative perspectives, is that it does not adequately prepare students for critical, proactive participation within society. Even in education systems where such pedagogy was maintained to fulfill other social objectives (for example, education in colonial Africa, or communist education in the former Soviet Union), it can be argued that its success was modest at best. This is because more and more people continued to undertake social actions and programs to undermine the social objectives of such uncritical and hegemonic pedagogy.

If we accept Gramsci's (1971) position that dominant forms of discourse are never permanent, then the development of an alternative pedagogy in response to the dismal teaching–learning outcomes of dominant traditional pedagogy should cause us to question current teaching practice. This could inspire the "desire to do good" in science education stakeholders and make appropriate provisions to ensure that classroom practice is relevant to students' needs. Questions about use of various teaching methods to get students "involved" in the learning process and about how to affirm students' life experiences by drawing examples from the life world of these students become central to a search for constructivist pedagogy, or what this study is referring to as "alternative pedagogy/practice." Transformative practice, however, goes a step further: it seeks to address issues of power both in schools and society. Its major goals are to provide students with the critical learning and understanding that they can use to effect personal, social, political and economic transformation in a democratic society.

Research Methodology

Research Design

This study employed descriptive research design using qualitative research methodology and action-research techniques. First, we organized a workshop in which we asked open-ended questions to get common meanings, purposes and assumptions from classroom teachers associated with the prevalent modes of teaching and learning physics. Brainstorming sessions teased out the teachers' views and experiences of physics teaching and learning in a secondary school. The participants provided tangential paths for reflection, which formed a basis for further discussion and reflection guided by key research questions as detailed in procedure and research tools sections below.

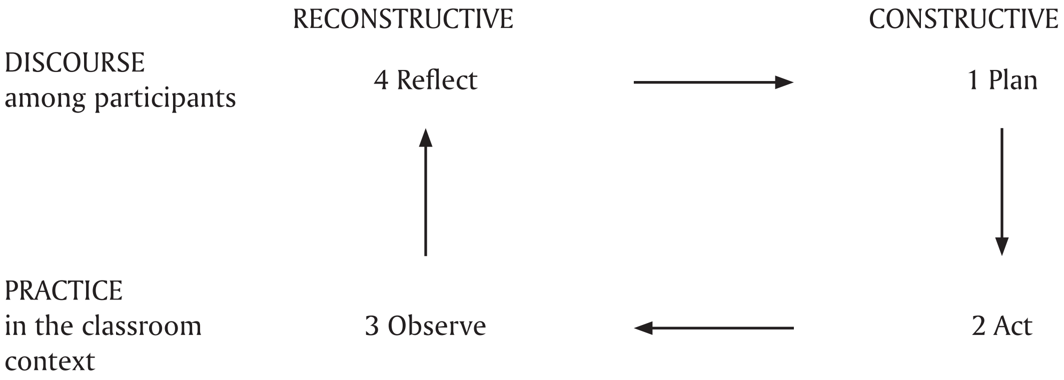
Sampling

Ten physics teachers from rural schools in Uganda were purposively selected on the basis of their willingness to participate in the project. Heath (1983) notes that for an action-research project, five participants are manageable. After orientation, five were selected from each of the research settings for the action-research phase of the project. Attention was paid to ensure the inclusion of female teachers. The selection was based on the teachers' potential and keenness to engage the rigours of the action-research project. Five students were randomly selected from each teacher's class for discussions and follow up.

Research Tools

The key research questions were rephrased and structured to guide the focus group, workshop and action-research phases of the project. A framework for the inquiry process of this study used key teaching platforms (NTCM 1991); namely, tasks, discourse, environment and analysis components of the teaching–learning process during the action-research cycles. By use of these platforms, the participant teachers generated and discussed the process of teaching and learning as it relates to physics. In this process, they got a feel for what the study was all about and what was expected of each one of them. The rephrasing of the research questions within each platform also helped to elicit participant contributions to the key themes listed in the bulleted section below. A significant spinoff from the portfolios constructed from this project is final documentation and evaluation (during a closing workshop) of exemplars for constructive teaching on a range of physics topics.

The Moments of Action-Research



The action research's self-reflective spiral of cycles of planning, acting, observing and reflecting, followed by replanning, further action, further observation and further reflection, used information generated from the workshop sessions to initiate a collaborative attempt to understand, interpret and learn from the knowledge and experiences of the participants.

During the action-research sessions, the participant teachers explored possible mechanisms through which teachers (and students) can engage in constructive teaching and learning. Some specific strategies for exploration included how to

- encourage and accept student autonomy, initiation and leadership;
- allow student thinking to drive lessons (this means shifting content and instructional strategy based on student responses);
- ask students to elaborate on their responses;
- allow sufficient time after asking questions for students to respond;
- encourage students to interact with each other and with the teacher (the gendered discourse that has marginalized girl-child participation and achievement in science classes will be a focus here);
- ask thoughtful, open-ended questions;
- encourage students to reflect on experiences and predict the future outcomes of events;
- ask students to articulate their theories about concepts before presenting the important concepts and encouraging note-taking;
- look for students' alternative conceptions and design lessons to address conceptions that differ from those held by scientists; and
- encourage students to connect ideas to phenomena in their daily lives.

The participant teachers were encouraged to field their own range of themes for inclusion in the action-research spiral. Accommodating teachers' interests and concerns for discussion made a significant component in this exploration. The back-and-forth movement, which Carson (1989) calls the hermeneutic cycle, created meaningful research interpretation and allowed participants to search for constructive possibilities of their teaching practice. Based on the bulleted domains above, the action-research project at the classroom level generated classroom observational data and interpretive accounts from teachers. These teaching and learning engagements allowed teachers to learn how to put together their own and pupils' teaching and learning activity artifacts into a portfolio during the action-research self-reflective spiral of cycles. This self-reflective spiral demonstrated the dialectical quality of action research: the dialectic of retrospective analysis and prospective action (Carr and Kemmis 1986; Carson 1989). It clarified the link between the discourses of teachers involved in the teaching action and their practice in the social and/or classroom context, and generated insights into what it is about their subjective selves that accounts for their practice. Through the process of action research, therefore, the participants became increasingly aware of themselves as products and producers of change, gained rich understandings and identified a number of factors that complicated their professional practice as science teachers. During this study, physics teachers became increasingly able to articulate their interpretations of their professional lives, their school and how they influence how they teach physics. Engaging and exploiting the methodological rigours and potentials of action research for transforming teaching practice and understanding science teachers' agency in interrogating traditional approaches to teaching and learning were enriching experiences.

Procedure

As a cautious entry point into this study, three lessons were observed for each of the five teachers selected from the two research settings. These observations guided the identification of entry points and areas of emphasis for the subsequent action-research project. Selecting and observing the 10 teachers revealed an array of teaching practices for documenting. In addition to classroom observations of the selected teachers, focus-group discussions were held to explore their beliefs, understandings and personal theories of teaching physics. Their classroom practice and struggles to improve it, their conditions of life at work (from their perspectives) and how they view quality in science education in light of their work environment were probed for elaboration and examples. Similar discussions were held with school administrators and education ministry officials. Focus-group discussions were held with five students taught by each participating teacher. These additional discussions built both a historical and a prospective understanding of the development of transformative and constructivist teaching practice under specific conditions and time.

During the action-research episodes, the five physics teachers explored mechanisms and practices to enhance constructivist teaching and learning of physics.

The action-research phase targeted and realized eight cycles, or moments, of action research for each teacher. The action-research process aimed at transforming physics teaching by establishing collaborative teaching–learning practices between participating teachers, the research team, and, most important, the students. Collaboration among this group of participants sought to elicit commitment to change what emerged as negative attitudes and practice of teaching physics, provided a greater range and variety of perceptions and competencies from which the participants could draw and increased the realms of constructivist teaching practices. To demonstrate the teachers' and students' competencies on the improved teaching–learning process, evidence was collected in the form of portfolios. At the outset, the researcher provided some guidance and examples to participating teachers and students on how to build a portfolio. Furthermore, documentary evidence (for example, schemes of work, lesson plans and worksheets, and experimental and/or demonstration activity sheets for teachers; and exercise books and reports, project reports, and test and examination scripts for students), including artifacts (materials innovatively constructed and used), drawings or any other examples of products arising from the teaching activities.

The research team evaluated portfolios on the basis of three criteria:

1. Teachers' and learners' informed conduct of the teaching and learning process in terms of knowledge and skills that are central to physics as a discipline. These included examples of evidence used to support an argument, a procedure or a decision.
2. Evidence illustrating conceptual change. The study was guided by an implicit view of teaching and learning that teachers and students are not simply receivers of information but active participants in the assessment process. The study, therefore, captured what could otherwise be taken for granted about the interests of the learners and teachers regarding the use of portfolios.
3. Teachers' and students' opportunities and challenges in physics teaching and learning, in particular, where and how they succeeded and areas of difficulty. This enables teachers and learners to provide accountability in the teaching process and plan toward self-improvement.

Data Analysis

The observation data was analyzed primarily using descriptions and narrative analysis of interview data based on what Glaser and Strauss (1967) refer to as grounded theorizing. In the analysis of narratives, the teachers' and students' reflections are being examined collectively for common themes or conceptual manifestations. The assessment and analysis of the progressively developed portfolios as per the above criteria were guided by the following questions:

- What evidence of planning, organization, programming, support of learning activities, assessment and evaluation of teaching–learning activities and their outcomes demonstrate that the teacher has a change in beliefs and professional practice about knowledge, learning and his or her role in the teaching–learning process?

- How have the teachers used their experiences, locally available materials, students' background experiences and those generated during the classroom encounters to improve their ability to engage constructivist teaching and learning?
- In which ways have teachers monitored their own performance and taken steps to improve and develop their own skills and competencies toward transformative teaching?
- How has the teacher interacted and used the other participants, including the school administration and other teachers to support the planning, implementation and analysis of the various demands and phases of the teaching–learning processes and educational experiences demanded in constructivist teaching and learning?

The process of action research pursued in this project fit well within the framework of constructivism in teaching physics because teachers (and students) became conscious participants in the development of theories of knowledge and knowledge generation that arose from their practical concerns to make fundamental changes in their practice. As Carr and Kemmis (1986) note, it is through this participation in planning and implementing new practices, and observing and analyzing their effects that teachers value and sustain change.

Study Findings

Our findings on constructivist teaching of physics in rural high school classrooms in Uganda are presented in three main themes as per original objectives that guided the conceptualization of this study and its subsequent implementation:

1. The action-research experience in dealing with physics teachers
2. Dominant teaching practice and learning in physics
3. Devising strategies for change in teaching and learning of physics

Action-Research Experience in Dealing with Physics Teachers

Beginning with questions concerning the effect of the current dominance of lecture and "talk and chalk" in teaching physics, particularly on the actual participation of students, the study participants began to open up to the need to explore alternative techniques of teaching physics. This opening up generated keen interest to search for alternative teaching approaches, how they could successfully implement these alternative strategies, and how they could monitor and understand the effect of this implementation to teaching and learning.

The participants developed a broad range of strategies that they felt could make the necessary change in enabling learners to build, develop and apply knowledge and skills in physics. Guided by the research questions, it was relatively easy to get the participants to echo a significant menu of strategies that fit with the constructivist way of teaching and learning, without the up-handed approach of telling them what constructivism is all about. In the drawn-out collaborative discussions, the participant teachers affirmed that a hands-on approach worked much better in teaching physics concepts and corresponding process skills[6] than did the dominant lecture approach. As we grappled with each cycle and its demands during the action-research project, the participant teachers increasingly felt that they had gained a much better understanding of the problems of teaching and learning physics. The teachers increasingly acknowledged the need to collaboratively work with students in getting them more enthusiastic about learning and doing physics. This new understanding came about as a direct result of teachers' involvement in the reflective dimension of the action-research project: a group of teachers working and struggling together to find answers to their educational questions.

This study demonstrated one of the fundamental strengths of action research—the breakdown of barriers of communication between educators, and between educators and learners. Previously, the participating teachers acknowledged that teaching is an isolated activity and that the issues jointly confronted during this project were brushed aside. As one teacher said:

> Being involved in this action-research project has provided me with an outlet of the challenges I have encountered alone as a teacher of physics. It has provided me with an effective way of being together with other educators rather than being alone. Now I have had an opportunity to deal with problems of teaching and learning by sharing these with my colleagues. I have always struggled to solve my challenges of being a physics teacher alone! (Reflections at the Dissemination Workshop, July 11, 2003)

This observation answers a question that a participating teacher asked at the beginning: How is this action research? A number of salient features of this study that provided insights into this focus group discussion are as follows:

1. The project was democratic in nature. All the teachers jointly owned the problems behind physics teaching and learning as well as the decisions on how and where to make changes. Because there were no leaders as such, there was no coercion to implement decisions. Each member was free to accept, reject or modify ideas that emerged from the group, and to customize the ideas to fit particular teaching situations in their rural secondary school settings.
2. The project took a systematic, collaborative approach to capturing problems experienced by the participating high school teachers during physics teaching and learning. The concerns we focused on included the need for students to construct meaning, evaluate their conceptions against testable assertions and develop skills in carrying out their own applications or experimenting on concepts and or skills. The pragmatic nature of action research led these teachers to develop a better understanding of their teaching challenges because they were able to share their experiences.

The reflective aspects of action research encouraged one female teacher and her colleagues to come to terms with their own attitudes toward physics. They were prejudiced against physics or about its teaching and learning.[7] Teachers unanimously agreed on the necessity to guide students in their struggle to make sense of the natural phenomena encountered in physics. The teachers and students alike saw physics as a vital knowledge base that would champion the national goals to meet some of the societal developmental needs. The teachers' actions—as a group and as individuals—were critically examined. It was inspiring to witness that decisions to act were increasingly reflected on and discussed with students and colleagues, although this was slow to happen. Specific details relating to the study variables are discussed below. In these, as it is evident that in action research, action is not simply an unexamined habit but rather a source of reflection, just as reflection becomes a source of action.

Dominant Teaching Practice and Learning in Secondary School Physics

This section presents the participants' responses to the following research question: On what foundations do the common teaching approaches and solicited learning outcomes in physics lessons rest?

Responses to this question were generated mainly during the first workshop in which this question formed the basis for reflective brainstorming. Further insights to the question also emerged from the subsequent action-research cycles with individual physics teachers in their respective schools.

The patterns of teachers' responses are displayed in Figure 1. An examination of Figure 1 reveals preeminence of teacher-centred teaching in both classroom and laboratory settings. Figure 1 shows the initial beliefs held by the teachers at the onset of the study. Clearly, in their view, science curricula laboratory activities are not mainstream. In other words, when laboratory work is used, there is a high level of teacher centredness. From the explanations given to the probing questions on what actually takes place, it became evident that experimentation and demonstrations held often take the form of cookbook recipes (verification labs) in which students follow prescriptions by the teacher to obtain predetermined outcomes. Furthermore, the evidence suggests that laboratory activities fail to enhance student understanding.

Technical interests focused on regimenting laboratory and classroom activities so that students attain only the predictable and measurable outcomes of each lesson appear to be characteristic of laboratory and classroom teaching activities. Both laboratory and classroom-based activities in physics lessons promise so much in terms of student ability to solve problems and construct relevant science knowledge. The participants indicated that the main purpose of these activities is to promote student inquiry and allow students to investigate. In subsequent probes on whether this is the best way to generate self-knowledge with personal meaning among students, participants eventually noted that the current emphasis was a marked contrast to using the laboratory primarily as a place to illustrate, demonstrate and verify known concepts and laws.

Laboratory activities were seen as central to effective promotion of intellectual development, inquiry and problem-solving skills. Furthermore, participants established consensus that laboratory activities can assist in the development of observational and manipulative skills and in understanding science concepts.

Despite the subsequent acceptance of the importance of laboratory activities in science curricula, the brainstorming sessions in the first workshop and subsequent observations made in the school teaching sessions exposed some underlying problems. The science laboratory has always been regarded as the place where students learn the process of doing physics as a science. But what was observed in this study did not favour laboratory over lecture demonstration. This was partly because some schools had poorly equipped laboratories; for example, two-foot square desks on which two to three students were to conduct experiments, and rooms without power and running water. Later we agreed that desks could be moved together, and students could work in groups. In general, there was an appalling lack of effectiveness of laboratory instruction. Most students gained little insight about the key science concepts involved and how laboratory activities fit into the scheme of doing science.

Observation of classroom-based instruction in physics also revealed that these teaching and learning activities are not being based on the development of meaning central to constructivist epistemology. The dominant practices give little emphasis to the purposes of laboratory activities, the content being developed and the complex nature of interactions between teachers and students. Physics teachers' awareness (from a theoretical standpoint of good teaching practice) that students must be provided with opportunities for discussion in conjunction with pre- and post-laboratory activities did not initially provide insights into the interactive and cooperative strategies that must emerge if discussions are to be effective in facilitating learning. To inspire teachers to change, the following question was posed: How would you assist students to use knowledge from a practical investigation to negotiate meaning in cooperative or individual-based learning? Participants in the study focused on a number of possibilities that they tested with their students. First is to gather data from day-to-day learning activities. Second is to share data and findings with other students in the class, or in a larger forum, such as a science club or school assembly that focuses on academic performance. The possibility of allowing learners to collect and analyze data on local phenomena, and share their data and findings with students, teachers and/or parents encourages students and teachers to open their minds to the science classrooms of other schools. At the dissemination workshop, these exciting and important new arenas, which contrast so strongly with dominant transmissive teacher-centred approaches, were acknowledged as innovative ways of making science teaching responsive to competence-based education, an area of keen interest to educators and professional development of science teachers. The dissemination workshop also cautioned that collaborative learning has clear social advantages in the classroom, but the effects on learning have not yet been thoroughly tested. More reflections on this matter are presented later in this paper.

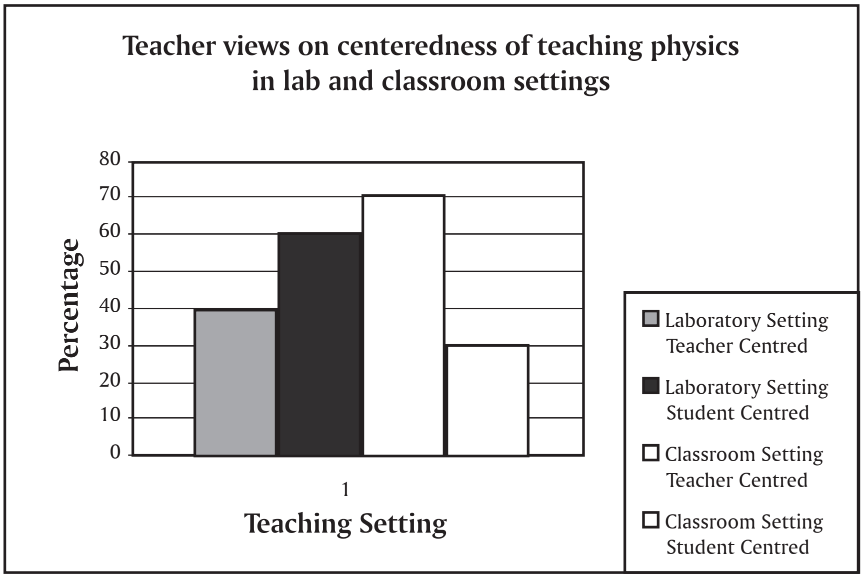


Figure 1: Pattern Depicting the Participant Teachers' Views on Centredness of Teaching Physics

Toward Strategies for Change in Teaching and Learning of Physics

The second research question dealt with how to improve the teaching and learning of physics. The study activities were guided by the following research question: How can teaching and learning be reconceptualized to develop and promote the constructive processes of teaching and learning?

Although the participant teachers did not view cooperative learning as a panacea, they considered it a valuable way to motivate students to clarify, defend, elaborate on, evaluate and question each other's conjectures. The negotiation and consensus building that occurred in cooperative groups indicated that teachers were considering employing cooperative learning strategies. These choices rested with the teachers and their students because of the interactive manner of classroom processes. Through the cycles of the action-research process, most of the teachers (7 out of 10) acknowledged that it is not possible, a priori, to predict whether cooperative learning, which is a useful aspect of constructivism viewed from the social perspective, will enhance learning. Among the factors that determine whether cooperative learning is likely to be successful are the goals of students, the extent to which students are motivated to learn and cooperate, and the degree to which the teacher believes cooperative learning to be a viable activity. The teachers realized that some tasks might lend themselves to cooperative learning and others do not, and it is surely the case that cooperative learning is feasible in some classes and not in others.

In their practice as physics teachers, participants acknowledged that they would do anything to improve their students' interest and performance in physics. However, they initially admitted at the workshop that whatever they had attempted to do in the past—drills, frequent review questions, student seminars and tutorials, providing key books to the students and other tactics, such as rewards—at best benefited the few interested students but not the majority, who often dropped out of physics in favour of other softer subjects. The teachers acknowledged that the right questions to bolster better student attitude and performance in physics have probably not been asked. This assertion is supported by the following reflective review of the participant teachers' brainstorm session:

1. Since the curriculum innovations of the 1960s and 1970s, one key possibility that allowed greater student participation in physics (and other science subjects) would be a syllabus emphasizing laboratory activities that provide students with hands-on experiences.
2. Understandings that emerge from laboratory activities depend on direct experiences and negotiations of meaning as learners solve problems and make sense of what they do. Experiences with phenomena and events allow students to construct images (simpler constructions of the real thing or process, a mathematical equation, a chart and so on) and concepts to which language can later be assigned. Social collaboration enables understandings to be clarified, elaborated, justified and evaluated, and incorrect understandings to be recognized as such.
3. Time for reflective thinking is crucial, even when psychomotor skills are the main goals. This assertion was clearly illustrated by reference to military training whereby both mental and physical rehearsal of the steps in a procedure enhanced the learning of technical skills required in combat readiness. An interesting implication of this view was the comparable effectiveness of mental and physical practice.
4. Negotiation between teacher and student leads to mutually understood specification of the tasks, making them clear to students, reducing risk and making it intellectually stimulating to do science. There was a dissenting view to this position: such an environment is not conducive to learning physics as a science to bring about its meaningful understanding. To achieve such a goal, students must be provided with perplexing challenges from time to time so that they struggle to resolve perturbations that are created in the act of experiencing and trying to figure out puzzles in an intellectually rigorous manner.

Overall, how students engage in laboratory activities also affects how and what they learn, and this needs to be coupled with giving students direct experience with physical phenomena.

One participant said that his students benefited more if they were actively engaged for at least 40–50 per cent of the allocated time; for example, planning for 5 per cent of the time, data processing for 10–15 per cent of the time; and off task for 20–30 per cent of the allocated time. The actual percentages here were a consensus figure rather than empirically sourced. The final workshop demanded and elicited the ranges[8] actually used by the teacher. During the classroom observations, we encouraged the teachers to put this time splitting into practice, and there were some indicators that summative achievement and retention were each related to the proportion of time engaged in planning and data-processing tasks.

Below is an overview of the average performance of students on short quizzes on the physics topics they were performing at the start and end of the study. All quizzes were set and moderated by the researcher in all the three schools.

The student scores are not based on an experimental design structure; likewise tests were not on the same topic in the three schools or on the same topic in each school at the testing times. The quizzes were set on the topics taught at the time of the start and end sessions of the study. The scores provided an indication of student performance (achievement) in the topics studied as a rule-of-thumb measure of impact of the learning and teaching activities. There was an increase in student achievement in all the three schools, with statistically significant improvement in schools B and C, where the difference in the mean scores between start and end were greater than 1.96 of a standard deviation.

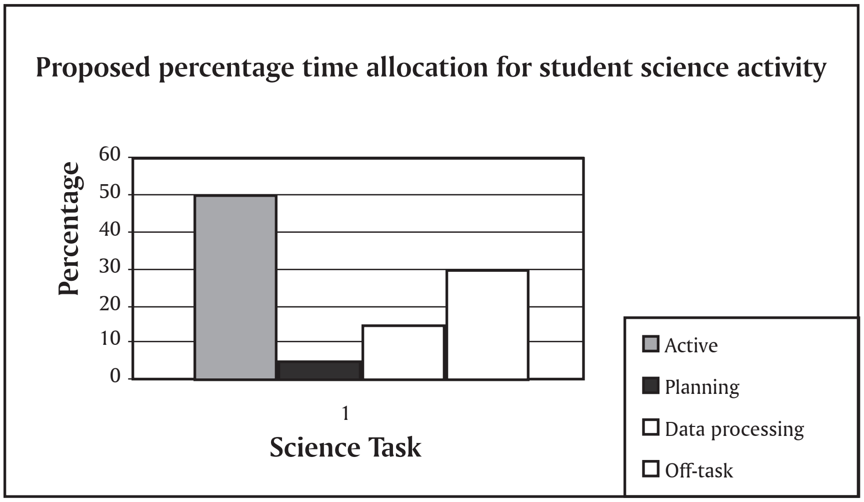


Figure 2: Participant Teachers' View of Time Allocation to a Given ScienceTask

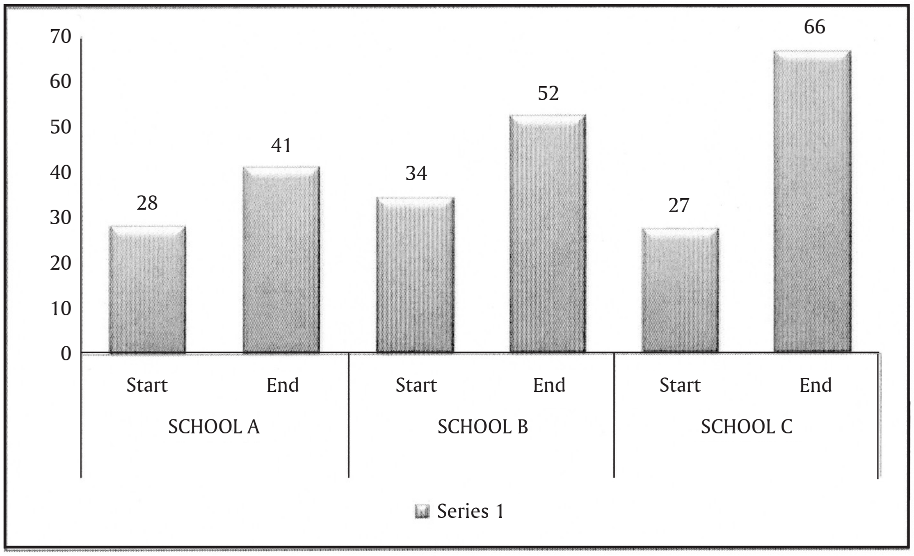


Figure 3: Pre- and Post-Test Students' Achievement Scores for 14-Year-Olds in Physics

In summary, although students undoubtedly learn by watching and listening (traditional mode of instruction), participants suggested that higher achievement may be associated with getting more overtly involved with constructivist strategies. Although we used these findings as an argument for increasing the amount of overt engagement for students in physics teaching and learning activities, causal arguments needed a protracted experimental evaluation of these claims. In attempting to put this strategy to practice, there were indicators that while some students benefited from the restructured tasks, not all had a better understanding or achievement. The teachers were thus confronted with unanswered questions about how highachieving students engage in time-structured activities (as per proposal of Figure 2) in comparison to low-achieving students and whether or not there are gendered variations to these claims. Detailed investigations of learning in classrooms are necessary to gain insights into the types of laboratory activities that enhance learning with understanding. Conduct of such studies may point to what may work in certain circumstances and how to model specific strategies to meet specific categories of learners.

Assessment of Students

Student assessment was acknowledged as crucial in determining the quality of teaching and learning. There was considerable consensus that learning activities in physics laboratory contexts can be assessed and that how and what teachers assess have a major effect on implemented curricula. During the first workshop, the teachers' observations highlighted the powerful driving force of examinations. The teachers advocated the separation of summative assessment from formative assessment of practical achievement. They argued that adherence to such a policy might help reduce the extent to which assessment focuses on the curriculum and thereby determines what students value and subsequently learn. They drew attention to other assessment issues as follows:

- What do students learn from physics teaching and learning activities?
- How can students represent their knowledge?
- How should knowledge constructed in laboratory activities be assessed?

We agreed that, ideally, an assessment scheme should allow students to represent what they know about identified aspects of physics as a science. At the classroom level, teachers must be encouraged to use various methods to assess student knowledge acquisition, including traditional pencil-and-paper methods, personal oral interviews and performance tests. The desirability of using a range of techniques was advocated, but this call was based on an assumption that much of the knowledge acquired in a hands-on and minds-on physics activity is tacit and has not been verbalized. This was a very interesting observation, because although students can apply certain knowledge when they do science, they cannot necessarily reproduce that knowledge verbally on a pencil-and-paper test or in a discussion with the teacher. A paradox associated with this point was emphasized in a review of practical assessment in science. The participants were confronted with the following paradox: many teachers place great value in physics as a practical subject. The practical nature of the subject is commonly regarded as an important source of pupil motivation. Physics is taught in laboratories, and teachers spend a considerable amount of time supervising practical work. Yet the bulk of physics assessment in secondary schools that have limited laboratory facilities is traditionally nonpractical.

These teachers' observations had several implications. First, knowledge gained from a laboratory is difficult to assess because of the tacit nature of the skills acquired. Second, practical tests reveal different abilities than those required for written tests, but different practical tests assessed different abilities. This is particularly so given the observation that practical work involves both manual and intellectual abilities that are in some measure distinct from those used in nonpractical work. Third, use of written tests could be highly inappropriate in the assessment of either complex or basic laboratory experiments. Finally, because practical skills are seen as being valid only in the context of investigations, practical tests should involve real investigations. These implications highlight the need to research the use of alternative assessment tasks (that is, not multiple-choice, pencil-and-paper items) to determine what students have learned from laboratory activities. What have students learned and how can they apply their knowledge to solve problems? To what extent is knowledge learned in laboratory activities interconnected with prior knowledge? How can practical assessment tasks be incorporated into district and state-level assessments of science achievement? These questions are just a sample of those that teachers and researchers need to investigate as educators endeavour to implement strategies to form science education. During the research and dissemination participants said that because of the demonstrated driving force of assessment on the curriculum, methods of assessment must be reformed at the same time that approaches to teaching and learning science are changed.

In the action-research phase of the study, one teacher's experience illustrated the problems associated with assessment practices that are built on a metaphor of assessment on a level ground. Even though Medi (a pseudonym), the teacher in the study, had gained control of his unruly students, they developed negative attitudes toward him because he was holding the line on what he considered to be legitimate standards of learning, which he based on a consideration of the discipline rather than the students' knowledge. The students' negative attitudes were widespread in the class and manifested in hostility toward the teacher and physics as a science subject. In terms of the metaphor of carrot and stick, bargaining work in exchange for grades, Medi was negotiating too hard a deal and the students were not taking the bait. Medi had no alternative ways to think about or practise assessment. He had only one conceptualization of assessment, and when it didn't work, he had no options to fall back on.

Medi reflected on his teaching and solved some of his management problems by reconceptualizing his management role by constructing a new metaphor. By doing this, he was able to focus more on the needs of learners and a system of simple rules that emphasized student responsibility. Once the new strategies were implemented, his classroom transformed strikingly. Accordingly, Medi was open to the idea that further improvements would be possible if he could reconstruct his understanding of assessment. He also had strong beliefs about what he did not know, until this project, as constructivism: a way of trying different approaches advocated by those whom he respected in science education. He tried concept mapping, oral interviews and problem-centred learning. None seemed to be successful. The essence of the problem seemed to be how he viewed the nature of science and how he thought about assessment. His beliefs about the nature of science were evolving in relation to his beliefs about constructivism. Because he could not construct a metaphor for assessment, a research team member suggested that it was like a mirror. Although the metaphor appealed to the researcher (students looking into a mirror and seeing their knowledge displayed in their mind), it made no sense to Medi. Subsequently, the researcher suggested a window into the students' minds, an opportunity for them to show the teacher what they knew. Medi saw how this might work in his situation. Using the metaphor, Medi rethought his assessment policies and practices. He implemented a new approach in his class and matters began to improve. The curious aspect of the metaphor he built was that it transferred power from the teacher to the students. The students now had the responsibility to make decisions about what they knew, how to represent what they knew and when to schedule time with the teacher to show what they had learned. To Medi and his students this seemed like a reasonable approach to assessment.

From participant encounters and sharing of their struggles on assessment, there was enthusiasm in exploring a different conceptual framework from which to view meaning, purposes and modes of conducting assessment. Previous to the study, their emphasis had been on determining what students know or recall from lecture notes. A shift to a point of reference for assessment to meanings gleaned by a student under a specific concept became more appealing. New questions in relation to assessment thus assumed significance from a constructivist perspective. For example, how can a specific concept or physics principle be represented? To what extent should students be given control of assessment? Ultimately, as teachers attempted to change their assessment practices, they negotiated with each other over wider issues, such as what a science curriculum should be in order to become a constructivist epistemology and practice.

Conclusion

To help students learn science meaningfully, teachers should ensure that learning is constructive. The constructive learning of science is a dynamic process of building, organizing and elaborating knowledge of the natural world. This study affirmed that students learn science meaningfully when five conditions are present: (1) existing knowledge is activated, (2) existing knowledge relates to educational experiences, (3) intrinsic motivation is developed, (4) new knowledge is constructed and (5) new knowledge is applied, evaluated and revised.

What we have found in the research on science teaching is that there is no shortage of possibilities for rethinking teaching and learning strategies, as long as we reflectively tackle each issue and challenge we encounter in the process. We noted, however, that solutions to many of the issues on learning, teaching and the mediational role of teachers are not easily achieved. We had difficulty fitting many of the emergent issues into the constructivist framework we were using to make sense of teaching and learning physics as a science. When any aspect of a teaching and learning is simply regarded as a variable for measurement and characterization, and undertaking research to obtain objectified and generalizable knowledge, this study is focusing on learning. Accordingly, problems are conceptualized differently, the questions that arise to be studied require new methodologies and the purposes of research are distinctive. Common to both good experiences and good classroom and laboratory stories are feelings of independence, freedom and responsibility. They differ in the intensity of the satisfactions produced by the initiatives used, by contrast with the more muted pleasure and enjoyment associated with good experiments. This particular study is one of the rare learning situations when the students, participant teachers and the research team derived satisfaction from being totally involved. In most African classrooms, authority is highly invested in the teachers, and this has not worked well for students and the expectations of the education process. The described experiences in this study presented all of us, including the students, with an enjoyable challenge and opportunity.

From the contexts experienced in this study, the goal of enhancing understanding of the nature of physics as a science, especially how scientists (should) work, and the associated goals of developing scientific attitudes and interest among students and teachers alike, calls for what the teacher participants in the study dubbed "project work." In the context of our joint experience, project work is an approach that involves teamwork, joint accountability to the process and outcomes, continuous critical reflection and focus on achieving what is truly an educational goal in physics learning and teaching.

Notes

1. The concepts of *transformative pedagogy* and *alternative pedagogy* are developed further in the theoretical framework.

2. An authentic learning environment is herein posited as one that engages students in important activities with real-life applications in real-world contexts.

3. High school and secondary school will be used interchangeably to refer to a post-elementary school level for the 13–16 year olds.

4. My reference to both conservative and radical critiques is not intended to suggest a coherent and monolithic perspective espoused by each group of critics. I use these terms to differentiate and capture only the dominant discourses within each broad and multivoiced perspective.

5. Most significant about the majority of these studies is their finding on the marginal influence of teacher education on practice, which suggests the need for us to think differently and/or probe further about current programs for preparing teachers or those who help teachers (staff development and inservice education).

6. These include performing (observing, measuring), investigating (hypothesizing, designing experiments) and reasoning (drawing conclusions, explaining, making predictions/deductions), communication and report-writing conventions.

7. At the initial workshop, the teachers saw physics as a difficult subject for students (later they also acknowledged that it presented difficulties for some teachers too, depending on the teacher's own physics schooling background). Both teachers and students initially held a view that only textbook-prescribed equipment or materials should be used to demonstrate or conduct experiments, lest the results be wrong. Experiences of subsequent sessions and reflective cycles slowly changed some of these previously held beliefs about teaching and learning physics.

8. The teacher who presented this investigation acknowledged that he did it once during this study, but had investigated once before based on his reading on the topic two years prior to this inquiry. The final workshop endorsed the need for further inquiry into this matter that also measured (quantified) the student benefit against the differential time allocation of tasks.

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The ALTA Cosmic Ray Project—Lessons Learned

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The ALTA Cosmic Ray Project came into being about 10 years ago and was designed to measure the incidence of cosmic rays over as wide an area as possible. The existence of high schools throughout northern Alberta, widely spread apart, provided an attractive set of experimental sites at which to station cosmic ray detectors. Besides the fundamental research role these detectors could fulfill, there could also be an important educational goal—that of allowing individual students, or groups of students, to pursue small, elegant and quite up-to-date research problems in cosmic ray physics right at their own school.

It was decided therefore to involve a number of high schools with physics teachers interested in the detection of cosmic ray bursts at different locations in Alberta. The research involving cosmic radiation relates directly to Physics 30, Unit 4—The Nature of Matter, and to Science 30, Unit 3—Electromagnetic Energy, and Unit 4.3—Nuclear Reactions. Currently, three cosmic ray scintillation counters have been placed on the roofs of at least 15 high schools throughout the northern half of the province (and in Medicine Hat). The three detectors at each site are placed in local coincidence mode so that only when the three same-site

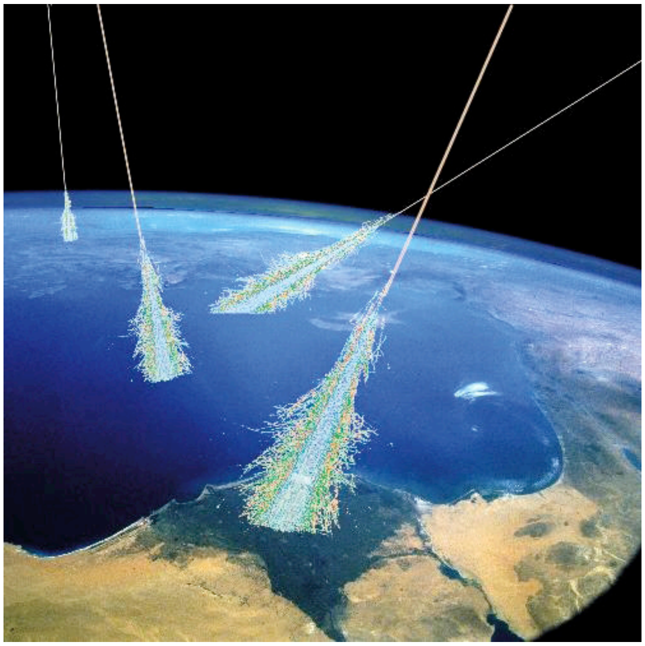

Figure 1. Artistic Rendering of Cosmic Ray Showers (James Pinfold)

Figure 2. Typical Array of Detector Boxes on School Roofs

detectors acquire a signal above threshold within the same-time window will the "hit" be considered detected at the site. The data collected is beamed to the central site at the University of Alberta, but the analysis and interpretations of the data are available to the schools' science classes throughout the project. The physics teachers have been trained to monitor the local counting stations and have become coresearchers in the project. The research group, including the teachers, have been brought together periodically to discuss the scientific and educational implications of the research.

Currently funding sources are being pursued to extend the cosmic ray detectors to the roofs of up to a dozen technical and university colleges across northern Alberta in order to open the possibility of cosmic ray research to interested undergraduate students.

What follows is a report on some of the successes of the ALTA project and some lessons learned from the experience.

Student Projects

Over the decade many classes completed the Cosmic Ray Module (1), accessible on the ALTA website, as class projects without generating new class, or individual, projects involving local observations. Perhaps as many as 100 students have been involved in the generation and analysis of locally obtained cosmic ray data. Some of the projects involved students from different schools, and several of the projects involved students from Edmonton and the Czech Republic. The projects fell mainly into the following categories:

1. The relationship between cosmic ray bursts and the thickness of the ozone layer
2. The relationship between the incidence of cosmic rays and atmospheric pressure
3. The sun as a source of cosmic rays
4. The relationship between the incidence of cosmic rays and the thickness of the Earth's magnetosphere
5. The relationship between the incidence of cosmic rays and the incidence of severe weather
6. The relationship between the incidence of cosmic rays and sunspot activity
7. Day/night variation in cosmic ray activity
8. Latitude and longitude effects on the incidence of cosmic rays

Most of the research projects involved several weeks of data collection at one or more sites and a detailed statistical analysis to determine the validity of any relationship found.

Cosmic Ray Bursts and the Thickness of the Ozone Layer

This project was carried out over a three-month period in 2004. Students obtained data on the thickness of the ozone layer above Edmonton from the Meteorological Service of Canada and graphically and statistically correlated these data to the locally measured incidence of cosmic rays on top of the school involved.

The students were able to show quite convincingly that the incidence of cosmic rays increased as the ozone layer became thinner. The students suggested two possible explanations, both of which were consistent with the statistical results:

- When the ozone layer is thicker, more cosmic ray particles are prevented from reaching the earth's surface.
- When there is an increase in cosmic ray activity, the ozone layer is degraded and becomes thinner.

The students and teacher showed considerable maturity in recognizing that statistical relationships do not necessarily imply a causal relationship. More scientific research is required to show that the first explanation is the likely one.

Cosmic Rays and Atmospheric Pressure

This project was carried out over a period of six weeks in 2005. The data obtained by the students showed a clear relationship between the two variables with the incidence of cosmic rays declining as the atmospheric pressure increased. The students suggested that the increase in collisions between the cosmic ray particles and the higher density of air molecules was responsible for the effect. (See Figure 3.)

The Sun as a Source of Cosmic Rays

One student decided to investigate whether or not the sun was a major source of cosmic radiation but designed a quite complicated way of investigating a question. The design of the study involved plotting the variation in the earth–sun distance over a year and correlating this variation with the incidence of cosmic rays. In principle, if the data were accurate enough this design should help to answer the question. However, the variation in the earth–sun distance is so small that great accuracy in the measurements would be necessary to show an effect. The student involved concluded properly that the analysis of his data showed that the sun was not a major source of cosmic rays. However, a more straightforward research design would involve measurement of the day/night differences in cosmic ray incidence to obtain a measure of what fraction of the cosmic rays measured by our detectors is due to particles emitted by the sun. This research design would show that the sun does, in fact, emit a rather large fraction of the cosmic ray particles hitting the earth with low to medium energies. Another group of students did measure the difference in the day and night incidence of cosmic rays and concluded that there was indeed a major difference. However, these students did not investigate the reason for this difference, which perhaps shows a lack of understanding of the nature of science. To become a fully scientific study, a statistical analysis or result is not enough.

Cosmic Rays and the Earth's Magnetosphere

Since about 90 per cent of the particles in cosmic ray bursts are protons, these particles are obviously going to be affected by the earth's magnetic field. A group of students spent three months investigating the relationship by comparing the average strength of the earth's magnetic field above Edmonton for a number of hours each day and relating these data to the incidence of cosmic rays during the same periods. In principle, this design might yield analyzable results, but the differences in the thickness of the magnetosphere at a single point on the surface of the earth are not great enough to make the investigation fruitful, and the students were unable to determine a relationship. A better design would be to compare the cosmic ray incidence for schools at different latitudes (say Grande Prairie and Medicine Hat) and obtain the magnetic data for these sites. Because of the large differences in the earth's magnetosphere at different latitudes, students from separated schools can obtain very

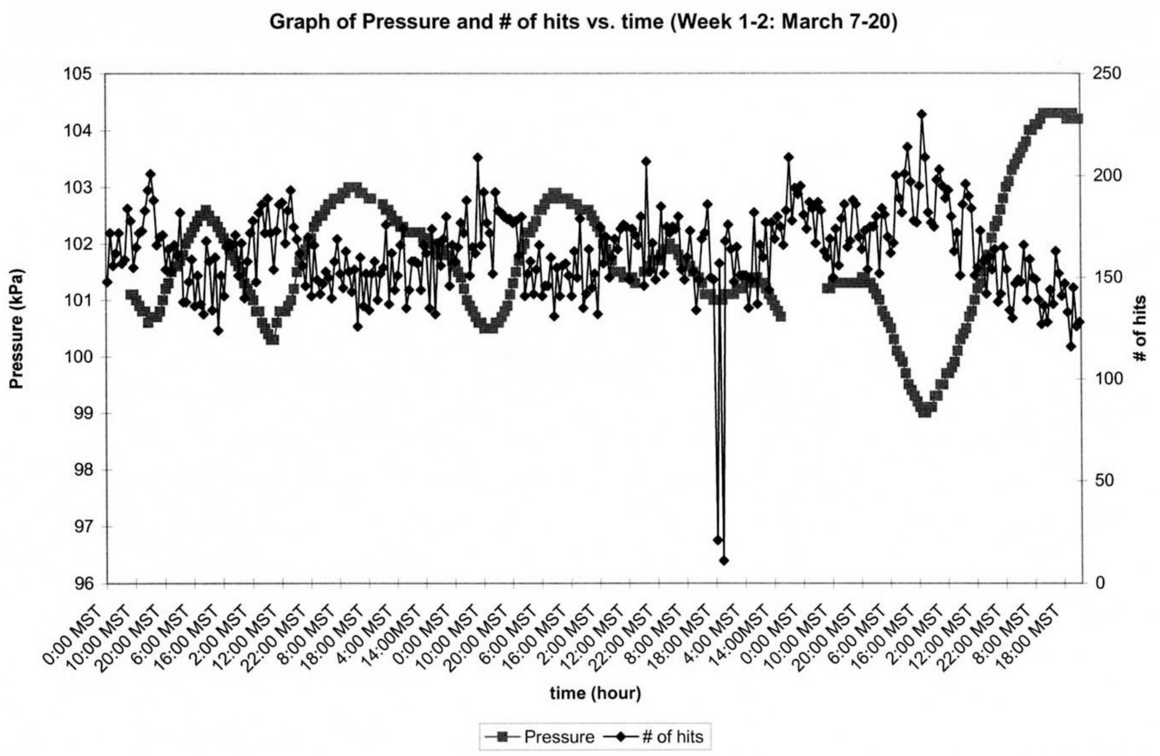

Figure 3. Student Graph of Atmospheric Pressure and Cosmic Ray Hits

good data that shows large differences in cosmic ray incidence at different latitudes during the same time intervals. A number of student groups did investigate differences in cosmic ray hits at different latitudes, in Edmonton and in the Czech Republic. However, these students did not investigate the reasons for this effect.

Cosmic Rays and Severe Weather

Several groups of students investigated the relationship between cosmic rays and cloud cover, temperature, humidity, and severe weather in Edmonton. The students expected a relationship between cosmic rays and cloud cover and possibly severe weather. One hypothesis might be that a thick cloud cover might prevent cosmic ray particles from reaching the detector, thereby causing a decline in cosmic ray incidence. Conversely, because cosmic ray particles tend to ionize the earth's atmosphere by breaking apart the molecules in the atmosphere so that many positively and negatively charged particles are created. These charged particles can act as centres of condensation, forming clouds and therefore showing an increase of cosmic ray hits with increasing cloud cover. However, students found no clear relationship between thickness of cloud cover and cosmic ray incidence even though research has shown that there is a detectable effect. This should encourage the students to investigate this relationship further. The students did find a slight indication of a relationship between cosmic ray incidence and severe weather. Prior to the one thunderstorm that occurred during the period studied, there was a sharp increase in cosmic ray hits at the local school. The students probably did not feel confident to generalize all severe weather situations. This is also a fruitful area for further study.

Cosmic Rays and Sunspot Activity

During sunspot activity the sun emits large numbers of particles, mainly protons. A reasonable hypothesis for students to investigate is the possible increase in cosmic ray incidence during a period of increased (or decreased) sunspot activity. A group of students did, in fact, investigate this hypothesis. They determined, from Internet sites, the number of sunspots on the surface of the sun and correlated this with the number of cosmic ray hits at the school. The students concluded that cosmic ray incidence correlated slightly with an increase in sunspot activity. Since variation in sunspot activity requires a fairly long measuring time, the students could have augmented their study with a literature review that would reinforce their tentative conclusion. In fact, historical data is available on the Internet on the relationship between solar activity and cosmic ray incidence.

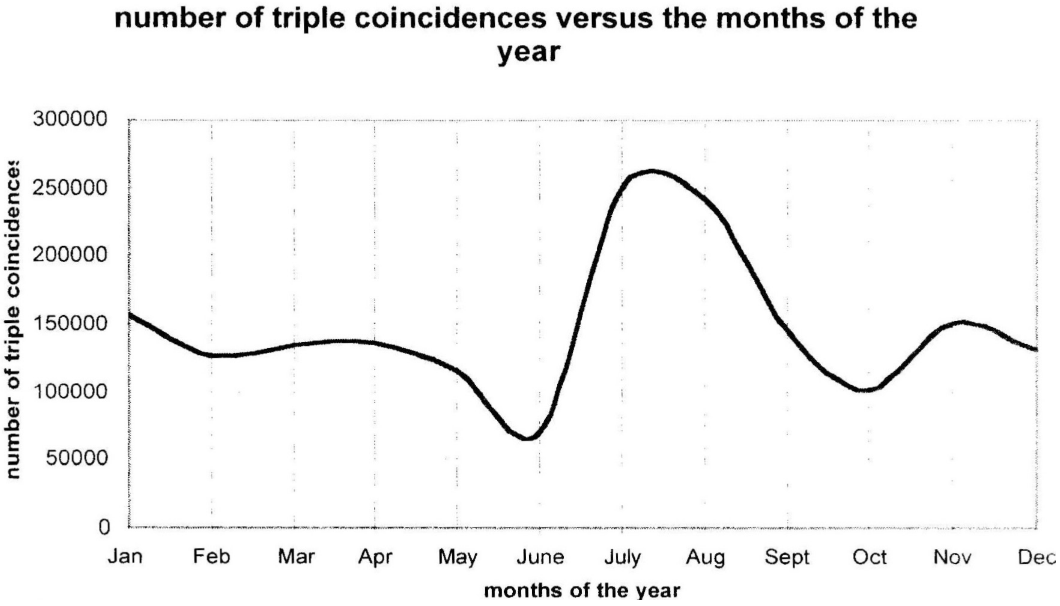

Figure 4. Student Graph of Cosmic Ray Hits Versus Time of Year

Other questions students might investigate:

1. Does the rotation of the sun have any effect on cosmic ray incidence?
2. Is there a seasonal effect on cosmic ray incidence? (See Figure 4.)
3. Does the 11-year solar cycle have an effect on cosmic ray incidence?
4. Are there health effects because of cosmic radiation or other background radiation?
5. What is the impact of cosmic radiation on our understanding of elementary particles?
6. Is there any antimatter in cosmic radiation?

There are many more research topics, either experimental or theoretical (library research and so on) that students can carry out in the context of cosmic radiation.

Lessons Learned

1. It has proven difficult for teachers at isolated locations to get their students or classes involved in cosmic ray research projects. A number of these teachers have had interested students complete the Cosmic Ray Module on the ALTA website listed below, but the lack of interaction with other teachers or accessibility with university researchers has prevented full engagement with the project. Perhaps some teacher–teacher pairing between rural schools and urban schools would allow students from these different locations to work together on research projects.
2. Student reports have been very interesting, but some students have a fundamental misunderstanding of what constitutes a physics research project. In a number of student reports, the conclusion of the statistical relationship between the variables studied was considered the "end of the study." In these cases the scientific reasons for the relationship or correlation were not pursued and, as a result, the topic did not reach its proper scientific conclusion. Students and teachers are encouraged to contact Wytze Brouwer (wytze.brouwer@ualberta.ca) for advice and consultation on scientific or research design questions.
3. Technical, university or college instructors and classes need to be involved in the cosmic ray project. In many cases these colleges are very near the otherwise isolated rural schools and could provide valuable interaction with local high schools. Even more important, university or college physics undergraduates have much more opportunity to engage in individual research projects, and quite a few more research reports could be generated and circulated to participating teachers.
4. Some important educational research needs to be carried out to ascertain how effective the ALTA project has been in influencing student understanding of the nature of scientific research and how the project has positively influenced student attitudes toward science and careers in science. There is anecdotal evidence that students have been influenced in their choice of university major, or even toward future careers, but without a systematic study, no clear picture of the positive impact of ALTA is available.
5. A major effort to secure more funding is required to ensure that up to 10 more detectors can be installed on colleges across Alberta. This, with more continuous consultation, should give the project a richly deserved shot in the arm.

The ALTA Project is accessible at http://csr.phys.ualberta.ca/~alta/Pages/ALTA_School_Program/teacher/teacher1.html, or at http://csr.phys.ualberta.ca/~alta.

Teaching and Learning Technological Problem-Solving Skills

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One context for science teaching in Alberta is technology, which encompasses the human-made world. Technology has a knowledge base expressed as concepts, involves skills associated with designing and making, and is created in conjunction with attitudes such as perseverance. The intertwining of these elements is important both as a teaching strategy and in presenting an authentic image of technological problem solving.

In classrooms, technological problem solving refers to an instructional strategy that focuses on having students design and make a model of a technological object or device (for example, boat, tower or vehicle) according to a set of requirements (for example, the tower should be 60 cm high and support a weight of 1 kg). Technological problem-solving lessons involve

- identifying a design problem,
- developing a design plan,
- implementing the design plan and
- evaluating the finished technological design or product.

Educators believe that having students participate in technological problem solving will help them understand technological concepts (for example, triangles are strong shapes), learn how to use important manipulatives (for example, joining materials), develop cognitive skills (for example, planning), and develop helpful attitudes (for example, inventiveness).

Technological Problem-Solving Skills

Skills are an integral part of technological problem solving. A technological problem-solving task cannot be successfully completed without the use of certain skills. It should be noted that the skills themselves are not the main aim of classroom instruction but are the vehicles by which students develop a more effective understanding of technological concepts. In this sense they are parallel to the designated "science process skills" (for example, hypothesizing and inferring), which have been part of classroom science education since the early 1960s.

Technological problem-solving skills, then, are a set of general guidelines for carrying out technological problem-solving work in the classroom. In the same way that "science process skills" are based on what scientists do, technological problem-solving skills are based on what designers do. An important teaching and learning goal is for students to come to understand how to use these skills thoughtfully and effectively to solve technological problems.

What Skills?

While descriptions of science process skills can be found in many references, it is more difficult to find the equivalent in terms of technological problem-solving skills. This is partially because the open-ended nature of technological problem solving means that the skills involved are both quite numerous and somewhat imprecisely defined.

One approach to capturing many of the technological problem-solving skills is to classify them into four main groups loosely corresponding to the four phases of the classroom technological problem-solving model (above). The model is cyclical and iterative, so any skill may be used in any phase of the model. The list of skills is not exhaustive and others may be identified.

Figure 1: Categorizing Technological Problem-Solving Skills

Technological Problem-Solving Model	Related Groups of Skills
1. Identifying a design problem	Analyzing
2. Developing a design plan	Planning
3. Implementing the design plan	Synthesizing
4. Evaluating the finished technological design or product	Evaluating

Specific Skills

Within each of the four groups of technological problem-solving skills noted in Figure 1, specific skills can now be identified and described.

1. ANALYZING: Collecting and considering information relevant to the design problem and its solution.
    - **Investigating**: Inquiring into a problem, question or situation.
    - **Researching**: Conducting inquiry under controlled conditions.
    - **Testing**: Evaluating under more or less controlled conditions.
2. PLANNING: Working out design ideas in advance, especially by drawing.
    - **Visualizing outcomes**: Seeing pictures and possibilities of situations in the "mind."
    - **Drawing**: Illustrating in two dimensions by hand.
    - **Recording information**: Keeping track of data and ideas in written form.
    - **Preparing materials**: Readying materials for use by measuring and marking.
    - **Problem solving**: Defining a situation that needs changing, considering alternative courses of action, and taking action to bring about change.
3. SYNTHESIZING: Expressing the design solution in concrete form.
    - **Selecting**: Choosing among materials, ideas, designs and courses of action.
    - **Producing**: Using techniques to alter materials so they can be combined to create objects and devices; for example, by drilling, cutting, joining, shaping and finishing.

- **Modelling**: Forming in two or three dimensions.
- **Using trial-and-error**: Coming to know or accomplish something by attempting possibilities rather than by following pre-established methods.
- **Troubleshooting**: Solving specific problems within a restricted range of possibilities.
- **Compromising**: Being willing to make or making concessions in terms of design solutions.
- **Refining**: Making more specific or effective; for example, ideas or designs.
- **Prototyping**: Creating a three-dimensional model of an object or device.

4. EVALUATING: Making judgments about the design solution.
    - **Reviewing**: Going back and reconsidering in a purposeful way something previously known or done.
    - **Fair testing**: Testing under controlled conditions.
    - **Proposing improvements**: Offering for consideration suggestions as to how a design might better fulfill its purpose and/or meet established criteria.

Communicating in the form of drawing (especially), modelling, talking and writing, infuses the entire technological problem-solving process in all four phases, particularly at the points where collaborative work is involved.

Conclusion

While it is necessary for students to use various skills in the context of technological problem solving, just using a particular skill does not necessarily lead to its improvement, nor does it necessarily lead to a better understanding of that skill. Teaching skills requires:

- Setting explicit skill-teaching goals; for example, in a lesson plan.
- Focusing on the identified skill-teaching goals during the lesson.
- Explicitly teaching students what the skill is and how to use it effectively.
- Providing practice with the skill.
- Being aware of ways to assess students' abilities to use and understand the skill.

The main goal of technological problem solving is to improve students' understanding of technological concepts. The classroom tasks through which this is achieved inevitably involve the use of technological problem-solving skills. Identifying the various skills and teaching students how to better use and understand them will improve students' ability to consciously and effectively carry out their technological problem-solving tasks. This, in turn, will improve the chances that they will be able to successfully complete the task and thus achieve the teacher's intended conceptual goals.

Personal Assistants

Frank Weichman, *Department of Physics, University of Alberta*

I have long been interested in our fossil fuel use and its impact on the world around us. Mostly I have looked at the availability of fuel over the long term. For example, more than anything else I have been alarmed at the rate we are currently using crude oil because it, in turn, relates to even the most optimistic estimates of world resources. At the current rate of extraction, all evidence points to barely another generation's worth of available supply. And that does include our tar sands.

Coal deposits are far more plentiful than oil reserves, but these too are nonrenewable and could supply our current energy appetite for only a few more generations.

The third major contributor to our electricity demand is nuclear power. One-sixth of worldwide electric power consumption comes from nuclear power plants, and except for the nuclear industry, very few people are eager to increase that fraction. Although nuclear fuel, in the form of freshly mined uranium, is, like oil, in limited supply, new fuel can be generated by well-established technology.

"Clean" renewables do exist but are either considered unsightly, like wind turbines, or too expensive, like solar cells.

What should we do? What should we teach our children to do?

Andrew Nikiforuk, in an article on page D15 in the June 28, 2008, *Globe and Mail*, described fuel consumption in terms of the calories that a human being consumes per day, and that figure shook me enough to do my own calculations.

I have turned those calculations into an ecology/economy/physics problem, with solutions, as shown below. The general point is that, however you slice it, we in the developed world have a lot of strong personal assistants at our disposal, who do some heavy lifting for us. In the problem I have called them labourers.

North America, the US and Canada are voracious users of fossil fuels. How many labourers does our use of fossil fuels replace? Let us do some "back of the envelope calculations."

The old-time farm labourers ate a lot of food, likely 5,000 calories per day, as compared to today's office workers who, it is suggested, restrict themselves to 2,000 Cal per day. Keep in mind that the old food energy unit Calorie is 4,200 J, a litre of oil has an energy content of approximately 40 MJ, and a barrel (of oil) contains almost 160 litres.

The US uses about 1/4 of the world's oil production of 80+ million barrels per day. The population of the US is about 300 million people. The per person use of energy in Canada is very similar to the US use.

1. What is the average daily crude oil use per inhabitant of the US in litres? Strictly based on the crude oil use, how much chemical energy does the average inhabitant of the US use per day?
2. Based on the figure quoted above about the appetite of the old-time farm labourer, how many assistants, in farm labourer equivalent, does the average American have at his or her disposal because of oil consumption?
3. The US obtains just as much energy from coal as it does from oil. How many more assistants does that represent?
4. Nuclear power in the US is used to generate electricity at a rate of about 2 million kWh per day. How many more assistants does that add?

Answers

1. 11 litres per person per day; 400 MJ/day
2. 20 assistants
3. 20 assistants
4. Less than 1 assistant

Detailed Solutions

1. 20 million barrels per day for 300 million people implies an average of 20 million barrels/300 million

persons per day or (20)(160 litres per barrel/300) = 11 litres per person per day. At 37 MJ per litre of oil, we can conclude that 400 MJ of oil energy is used per person per day in the US.

2. The farm labourer at 5,000 Cal per day uses (5,000)(4,200) = 21×10^6 J per day. That means that on average each American can count on 400 MJ/21MJ = 20 labouring assistants in the form of oil.

   Note: The human body converts food energy into mechanical work at 20 per cent efficiency at best. Diesel engines on cars and trucks don't do all that much better, so food intake CAN be directly compared to fossil fuels powering an engine. (Large modern electric power plants, however, can reach 40 per cent conversion efficiency).
3. Coal is used for heating and for electricity production. Just like the use of oil in electric power plants, it can have a higher work to energy efficiency than our farm labourer, but it is also used just for heating. With the precision required for this problem, the use of coal is likely to be similar to the use of oil, therefore representing another 20 assistants.
4. 2 million kWh of electricity is 2×10^6 kWh × 3.6×10^6 J/kWh = 7.2×101^2 J. Spread over a population of 300 million people gives 24 kJ of electricity production per person per day from nuclear power plants. That is not even the equivalent to a single farm labourer per person in the US.

There is another way of looking at the same data from a more personal viewpoint. The energy use per day of our one labourer at 5,000 Cal per day is really one labourer at 20,000,000 J, or 20 MJ per day. For oil or gasoline, that translates into understanding that each time we burn one litre of fuel, we use the equivalent of two days of hard labour.

A few words on the possible substitutes. A modest nuclear power station produces 3 GW of heat, one-third of which is converted into electricity. How many barrels of oil per day can one of these plants replace? 3 GW over 24 hours generates 3×10^9 (24)(3600) J of heat and electricity. One barrel of oil contains (160)(40×10^6) J. So a typical nuclear power plant can substitute for the energy output of (3×10^9 (24)(3600) J)/((160)(40×10^{6} ° J) = 40,000 barrels of oil per day. A wind turbine comes in at 1 MW, so you need roughly a thousand of them to replace a nuclear power plant that replaces 40,000 barrels of oil per day.

What do we conclude from the calculations? Yes, there are environmental concerns, be it carbon dioxide from burning the fuels, or pollution from how the energy is used. But aside from damage to the environment, we must conclude that we are living high off the hog, more opulently than our richest ancestors could have hoped for. More comfortably in our homes, richer in our diet and more mobile in our travel. But how much longer can we, as a society, make those last trillion barrels of oil last?

A Few Basic Principles About Comfort and Natural Climatization in Buildings

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In Europe, about 40 per cent of energy consumption is required for the climatization of buildings. The environmental and economical consequences of this suggest the necessity of concentrating on the possibilities of energy saving in houses.

Because many complex phenomena are involved in this subject, this article introduces a few basic principles dealing with the study thereof.

Goals of the Teaching Unit

- Open the way to a knowledge of thermal comfort and related concepts (air temperature, radiating temperature, air moisture and air change in rooms).
- Study physical concepts in relation to daily life in buildings, particularly heat and its transmission, specific heat, heat capacity, latent heat of vaporization and features of solar radiation at different times of the day and year.
- Understand that the knowledge of the laws that rule natural phenomena offers the means to save precious natural resources.

To Select, Refit or Build a House

To make an energy-conscious selection, the knowledge of some basic principles is essential. Dampness in the walls may increase heat loss by 50 per cent. Moreover, dampness evaporates from the walls while heating the house. This entails heat absorption, thus opposing the room heating. A practical example that can help pupils to understand and remember this phenomenon is to think about the quick feeling of cold experienced when one puts on humid clothes. The quick heat transmission and moisture vaporization simultaneously remove a lot of calories from the human body. These situations not only waste energy, they are also unhealthy. The heat transmission is proportional to the difference between internal and external temperatures. Cold winds subtract the heat very quickly from the external surface of the walls, thus intensifying heat losses. A house located in a sunny place is warmer than a house that is not hit by the sun's rays. The heat transmission is in inverse proportion related to the thickness of the walls and to their insulating performances. These different situations are comparable to the personal feelings that everybody can experience outside when the weather is more or less cold, windy or not, sunny or not, wearing thick and warm clothes or not. These comparisons could help students interiorize the concepts. The heat dispersed through the walls can account for approximately 25 per cent of total heat losses, 25 per cent through the roof, 25 per cent through doors and windows, and 5 per cent through the floor. Air infiltration accounts for further 20 per cent heat losses.

It is relatively easy and inexpensive to insulate the roof with a light insulating material. Double-glazed windows improve thermal and acoustic comfort. Reducing heat transmissions through the walls is not as easy and economical as improving the situation of the windows and roof. An insulating material can be added to the exterior of a masonry wall. In this way the insulating material shelters the masonry mass from the winter cold as well as from the summer heat. A diminished heat transmission through the externally insulated wall is not the only benefit. More benefits follow:

- The humidity of the living space, even permeating through the walls, does not condense there because the temperature in winter is not low.
- If the walls are insulated, the radiating temperature of the internal surface of the walls is higher. This is very important because its contribution to the thermal comfort equals approximately that of the air temperature. For this reason, in winter, higher radiating temperatures feel comfortable at lower

thermostat settings. It should be said that homogeneous radiating temperatures of the objects surrounding the people (walls, ceiling, floor, furniture and windows) contribute to a better thermal comfort.

- The heavy masonry wall, externally insulated, thanks to its thermal capacity, keeps internal temperature rather stable, despite external changes.

It must be considered that externally insulating the walls entails a large investment both economically and energetically. Therefore, the investment should be decided after pondering how long the insulation will last. Adding an insulating material to the interior surface of a masonry wall could be easier and cheaper, but in this case the temperature of the masonry mass, not sheltered from the insulating material, will be high in summer and low in winter. As a consequence during the cold season, unless there is a vapour barrier, the atmospheric humidity of the living space permeated through the masonry walls meets temperature conditions that may provoke unwanted condensation. If our house is still to be built, the problem would be solved by using insulating bricks and avoiding thermal bridges.

Shape of the Building

According to traditional architecture, houses in cold regions have a compact shape; sometimes the plan is nearly square shaped. A square-shaped plan allows the same living area with a shorter perimeter compared with a rectangular-shaped one. The outcome is that the walls through which the heat is lost have a smaller length, hence a smaller surface.

Another benefit is that less energy and fewer materials are required for building the house. Hence, construction costs can be even lower for the same living area. To help pupils deal with the shape of the building, some easy problems could be suggested through Figure 1.

A special case is represented by the igloo; the hemispheric shape allows the most favourable volume/surface rate among any other sort of dwelling. Zoologists say that in cold environments, large, compact shapes are the best size for animals. This is easily verified when one thinks of polar bears and of the notorious scarcity of reptiles in cold environments.

From the above-mentioned viewpoints, a building's compact shape is not only favourable but also can be safer in case of earthquakes. A compact, regular and symmetric shape, both in plan as in elevation, is recommended for the security of the building in seismic areas. For the same reason doors and windows are recommended to be not too big and not close to each other. This is also favourable from the energy point of view, considering the higher heat dispersions through doors and windows as compared with the heat losses through the walls. Furthermore thick walls may contribute to a safe building as well as to lower heat transmissions. It is not aim of this article to offer a complete treatment about antiseismic buildings, but some interesting websites follow:

1. www.planseisme.fr/IMG/pdf/DDE65_Maitres_d_oeuvre.pdf
2. www.planseisme.fr/IMG/pdf/3._Le_seisme_et_les_batiments.pdf
3. www.argenco.ulg.ac.be/pdf/SE/Sismique/Risque-Prevent-RW.pdf
4. www.argenco.ulg.ac.be/etudiants/Plumier/Chapitre05.pdf

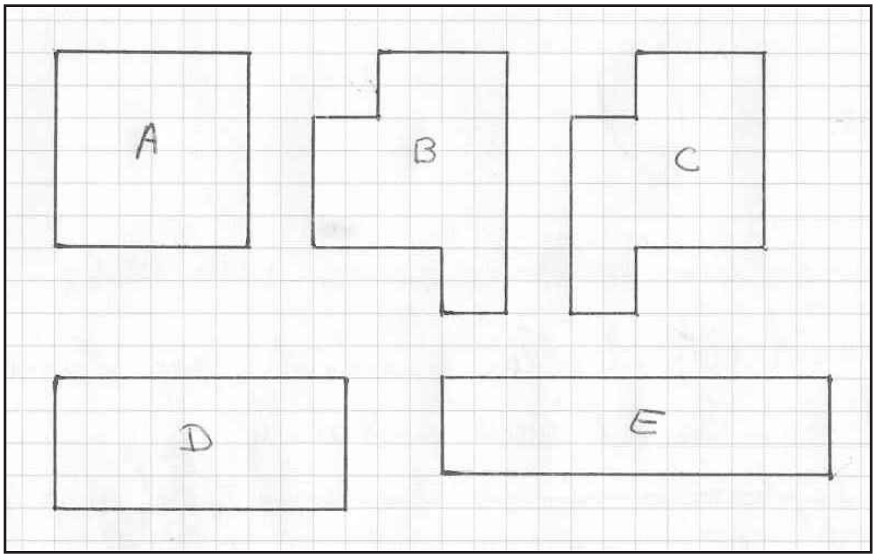

Figure 1. Shown here are different plans of buildings having the same area. In A, B and C, the square is the most regular and has the minor perimeter; in D and E the shorter rectangle has the minor perimeter.

In some places in the world rammed earth dwellings are common, and they are very cheap to build. They provide good thermal comfort, thanks to the considerable thickness of the walls and the insulating properties of the earth. This material produces healthy living conditions. According to experiments at the Building Research Institute of the University of Kassel, Germany, loam absorbs and desorbs humidity from the air faster and to a higher extent than any other building material. It has been demonstrated in a newly built house in Germany that suddenly raising the relative humidity in a room from 50 to 80 per cent, unburned bricks absorbed 30 times more humidity than burned bricks in a period of two days. Moreover an eight-year-measurement period showed that in a new built earthen house in Germany the relative humidity was constantly around 50 per cent throughout the year, fluctuating by only 5–10 per cent. (Visit the University of Kassel's website at www.asl.uni-kassel.de/~feb/wissenswertes/facts.html.)

Generally, however, earth houses are not resistant to earthquakes. There are techniques that permit the building of safer earth houses (better one-storey houses), with reinforcements made of bamboo, wood poles, metal nets. (Go to www.asl.uni-kassel.de/~feb/wissenswertes/facts.html, click on Publications; and visit the *World Housing Encyclopaedia* website at www.world-housing.net/uploads/WHETutorial_Adobe_English.pdf.)

Orientation of the House

The amount of solar radiation hitting the rooms, windows and walls depends on the orientation of the house. On the 40th parallel north, the solar altitude at 12 hours is about 70° at the beginning of the summer and about 30° at the beginning of the winter.

In addition, the projection on the ground of the apparent path of the sun covers an arch of approximately 240° during the summer solstice and 120° during the winter solstice.

A rectangular plan house at the middle latitudes of the northern hemisphere in winter is hit by more of the sun's rays if longer in the direction east–west and fewer rays if north–south since the only wall that receives a large amount of solar radiation is the south facing one (Figure 2, right). In fact, on December 21 at 10 AM, the solar azimuth is about 30°. For this reason rays mainly hit the south wall and very few touch the east wall.

Something similar happens at 2 PM when the solar azimuth is again 30° (see Montana State University Solar Physics website at http://solar.physics.montana.edu/YPOP/Classroom/Lessons/Sundials/sunpath.html); the sun mainly hits the south wall and very little of the west wall. This means that during the hottest hours of the day the solar radiation is mainly hitting the south facing wall; therefore, the greater its surface, the greater the benefits.

The solar altitude is measured from the horizon to the sun, while the solar azimuth is the angular deviation from the true south. During the summer the opposite problem is to be tackled, but even in this situation the same orientation of the building is the most favourable. In fact, at latitudes exceeding 40° parallel, east and west walls receive in summer

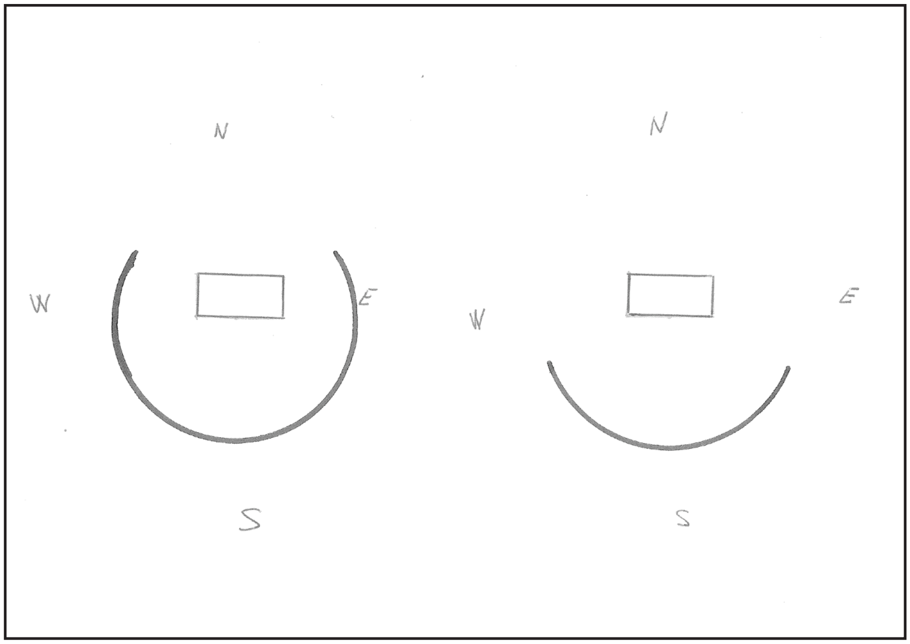

Figure 2. This draft shows the projection on the ground of the apparent path of the sun, in summer (left) and in winter (right). The rectangles represent the plan of the house.

much more light than in winter because mornings and afternoons are very long. For this reason the smaller their surface, the less the heat gained (Figure 2, left). During the central hours of the day, the sun is very high, and the solar radiation is very intense on the roof, regardless of the orientation of the building.

Still in summer, when solar rays arrive from southern quadrants, the radiation hitting the south wall is less than in winter. In fact, the rays reach the wall with a narrow incidence, and the radiation is spread out over a larger area (Figure 3).

The overhang of the roof and balconies favourably shade the south wall when the sun is high. Therefore the greater surface of the south wall doesn't pose problems for thermal comfort, even in summer. Of course, all these comparisons are considering sunny days.

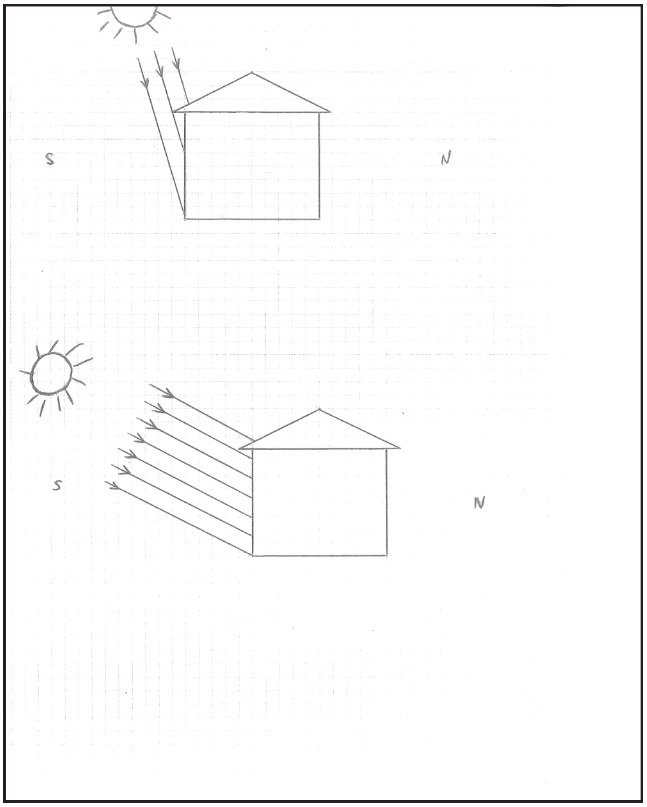

Figure 3. This figure shows the different amount of solar radiation at midday in summer (above) and in winter (below). The overhang of the roof shades the walls differently according to the seasons because of the different inclination of solar rays.

In California, the Davis Energy Conservation Building Code mandated that streets run predominantly east–west to ensure that houses have their major walls on the south and minimal exposure to the east and west. In the old Arab towns, the narrow streets allow the buildings to shade each other and the street itself.

In the classroom, dealing with this subject may open the way to deepening concepts about photoperiod, solar height and azimuth, year-round and during the day.

Protection from the Wind

According to American authors a good protection from the cold winds on three sides decreases heat loss from a building with energy savings as great as 30 per cent. In towns, other buildings protect the house from cold winds. In the countryside, hills, woods and evergreen plants protect the house from northerly winds. It would be best if these windbreaks don't block the cooling effect of prevailing breezes in summer.

Heating Plant

Good maintenance of the heating plant is essential for security and energy saving. Air pollution is also decreased. It is also essential that external air be fed directly to the combustion chamber through a pipe to avoid the warm air being taken from the living space to feed the stove. A stove working with air taken from the living space would consequently attract cold external air infiltrations to replace the air that is burned. Of course this system is not effective and wastes energy.

Air Change in the Building

In some situations, it may be important to preheat the air before it enters the living space for the necessary air change. A heat exchanger allows thermal energy transfer from warm stale air to the cold incoming air. Their flows do not mix together.

In more complex systems the cold air enters through a subterranean duct. Here it undergoes the first preheating underground where temperature is relatively constant year-round. The incoming air then goes to the formerly mentioned heat exchanger for further temperature increase before entering the living space. This avoids the loss of energy during the air change operated by opening the windows. It must be said that the underground temperature, a few metres deep, equals approximately the annual average temperature of that place.

The air flow is forced, but the natural warmth from the underground is transferred to the air, then further heat is recovered from stale air and transferred to the air entering the house. Even the condensation of the vapour, which may occur when the stale air is cooling, releases heat (latent vaporisation heat), which is transferred to the incoming air.

Glasshouses

Solar radiation hitting the walls of a house could be enough to keep the house warm if there is no strong heat loss at the external surface. In fact, the external surface becomes hot when hit by the sun and simultaneously quickly loses the heat because it is exposed to the cold air. This is why just a small amount of this heat will be transferred to the living space.

The south wall of a glasshouse improves solar heat capture. The glass is crossed by the visible short-wave light, but the long-wave thermal radiation that is generated after it has hit the wall does not return through the glass. Fundamentally, the energy is not reradiated out, and the hot air is kept inside the glasshouse or conveyed to the rooms for heating them. The wall, which is warmed during the day, will radiate the adjacent rooms during the night.

In summer, the glasshouse should be shaded, knocked down or kept open to avoid overheating. In the classroom, this subject may open the way to concepts inherent in the amount of light that passes through the glass and the amount that does not because of reflection by the glass itself, according to the incidence angle.

Summer Situation

Thermal insulation and double-glazed windows, as well as a suitable orientation of the building, perform favourably in winter as well as in summer. Deciduous trees shade the walls only during the warm months when they simultaneously absorb heat through photosynthesis and foliar transpiration, but in winter their bare crowns leave the house exposed to the sun's rays. Thick and heavy masonry walls help keep the temperature nearly constant for 24 hours. Leaving the windows open mainly during the night contributes to cooling the walls; the coolness is then maintained during the day owing to the thermal capacity of heavy masonry walls.

A house can be cooled by a solar chimney, which is a black painted chimney. The chimney and consequently the air within it are overheated by the summer sun, thus creating an updraft of the air and a suction at the base of the chimney. This promotes the air change in the house.

To increase the cooling effect, this house may have a subterranean duct. The external air flows in this duct, is slightly precooled, and then enters the living space attracted by the suction provided that doors and windows are closed. To maximize the cooling effect, trees can be planted around the air intake of the duct to further cool the air. A glazed surface on the side facing the sun of the solar chimney increases overheating of the air, hence the suction.

A simple experiment based on the working principle of the solar chimney can be conducted in some buildings by just leaving open the trapdoor connecting the staircase with the attic. The sun overheats the attic, and the air continuously flows outside through a window. This creates a suction attracting cool air from the cellar (Figure 4), provided that external air can flow through the cellar and staircase scale to the attic and other windows and doors are closed.

In these situations the sun provides the energy, which is necessary to move the air. The natural underground temperature is the condition that cools the air during its flow in the cellar. Because underground

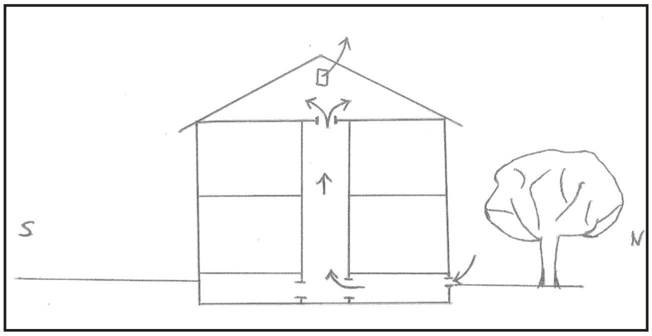

Figure 4 shows the air flow in a building from the cellar to the roof, overheated by the summer sun.

temperatures are strongly related to the average yearly temperature of the site, this cooling method is probably more effective in continental climatic areas than in tropical ones.

Research on Internet

A research of texts and images could be interesting. *Badgir*, *malqaf* and *salsabil* refer to traditional Islamic architecture. The first two consist of structures located over the roofs of houses to catch the wind; this air then flows through the living space and improves the thermal comfort. The air then flows away from the opposite side of the building. If there is no wind, the *badgir* can take advantage of the solar heat for the same purpose. In this case, the working principle is the above-mentioned solar chimney. Several types of *badgir* exist, according to the prevailing climatic conditions. See www.inive.org/members_area/medias/pdf/Inive%5Cpalenc%5C2005%5CAzami2.pdf, the International Conference of the "Passive and Low Energy Cooling for the Built Environment," May 2005, Santorini, Greece.

Salsabil can be found in some traditional Arab houses. It consists of an inclined slab of marble on which a thin layer of water flows. The continuous vaporization of the water humidifies the air. The process absorbs the latent heat of vaporization, thus lowering the temperature in the living space.

These traditional structures, during low-cost energy times, hardly stood up to a comparison with modern air conditioners; nowadays there is a trend toward their re-evaluation.

In hot and humid regions, such as Southeast Asia, the rural traditional houses provide the thermal comfort by means of some peculiar features. The temperatures here are steadily high; the temperature differences between day and night are small. Consequently, the thermal mass of heavy masonry walls does not contribute to the thermal comfort as it does in desert areas. Rural houses in Southeast Asia are built of wood and other locally available vegetal materials. They benefit from the shade provided by the nearby trees. The overhang of the roof shades the walls.

For several reasons the houses are elevated two to three metres from the ground; this magnifies the benefit of even a light breeze. The windows, as well as the walls, built with vegetal material that allows some air infiltration, further improve the situation for the people living within. Sometimes the floor itself, made of wooden boards slightly installed slightly apart from each other, allows air infiltration (for example, go to http://eco-web.com/editorial/070201.html). A thick roof made of vegetal matter provides thermal insulation when the sun is very high.

Conclusion

A sustainable house may also have the following:

- Solar thermal collector for water heating.
- Solar photovoltaic collector for producing electricity.
- A tank for rain water collection, which can be used for flushing toilets (WCs) and garden irrigation.
- The materials for houses chosen for durability, so that the energy cost is very low over the life of the objects.

Of course every investment should be carefully pondered, and should take into account local situations, problems and opportunities. The cost of building a sustainable house is not necessarily much higher than a standard one. The difference is probably recovered within a reasonable time through the savings realized.

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Passive House Institute

http://solar.physics.montana.edu/YPOP/Classroom/Lessons/Sundials/sunpath.html
Montana State University Solar Physics

The Bertram Millsap Series

Millsap, the Fitness Buff

Wytze Brouwer

Bert Millsap and I had decided to hike Edmonton's river valley trail system. Surprisingly enough, it was his suggestion that we abandon our offices and do a fitness walk through one of our river valley trails.

It was a beautiful May day, still cool but with the traditional clear blue Alberta skies, and we had decided we couldn't waste one of the first really promising days of spring after a long winter. We might have some papers to write, but they would probably not suffer from a one-day delay. So we packed a lunch and drove to the local horticultural conservatory, parked my car and walked across a walking bridge over a very busy road into the Mill Creek Ravine.

"Now just a minute," I can hear a few of my loyal readers say. If pressed I could name anywhere up to seven people who could be classified as being loyal readers of the misadventures of my colleague, Bert Millsap. "Just a minute," I can hear them objecting. "You can't convince me that Millsap is actually going on what might well turn out to be a three-hour hike."

I sympathize with these readers. Nothing in the first 60 or so years of Millsap's previous existence is consistent with his decision this late in life to finally get in shape. Millsap's current shape is frankly still round. But today was the first day of turning his good intentions into actions, and I was eager to help him on the way.

For the new readers, a word of explanation may be in order. "Who is this Bert Millsap, and why should we be interested in his belated attempts to become fit," I hear them saying. Hoping not to bore my seven loyal readers, I need to give a brief description of my colleague.

Bert Millsap is my fairly distinguished colleague from the Psychology Department at a local university who has a history of getting me into difficulty with my administrative masters. Bert has the distinction of having me ejected from a faculty meeting due to his boredom-inspired experiments with coffee balls that can be created on the surface of the coffee served in Styrofoam cups at the faculty meeting. (If you don't believe me, check the archives.) Bert also has the unique distinction of having presented groundbreaking research into the after-effects of sleep deprivation at an international psychology convention, sporting a beautiful black eye presented to him by one of his sleep-deprived subjects. Bert has one more habit, one that exasperates some of his colleagues but excites others; he often dabbles in fields other than psychology, especially in physics, which happens to be my field. And dabbling in other fields, though laudable, has some drawbacks if one is not careful. My regular readers will remember the time the fire department flooded his basement after Bert's experiments with high-temperature superconductors filled his house with a mixture of cold nitrogen gas and air, which made it appear as though heavy smoke were pouring out of his windows.

Physically Bert is about 5½ feet tall and weighs around 230 pounds, clearly still round. He has now reached retirement age, but he has, after much thought and encouragement by the dean, decided not to retire, but to continue on with a post-retirement contract. Now, not to misunderstand the phrase "encouragement by the dean," the dean actually encouraged Millsap to retire, thereby removing, as he expressed it, "a millstone around his neck." However, the dean no longer had the right to enforce retirement, so he will have to cope with Millsap for at least another five years.

By this time we had left the busy city behind and were walking into the ravine. Mill Creek Ravine owes its name to a certain Englishman William Bird, who in 1870 decided to build a flour mill at the mouth of the creek. After three years of trying to cope with the chaotic flow rate of the creek, ranging from a raging torrent in the spring to tepid flow in late summer, he gave up the battle, but the name stuck.

For the first half hour we sauntered contentedly along the walking path, passing stands of white spruce, alternating with balsam poplars and aspen. Some of the mountain ash still carried the dried up orange berries of the previous summer. A number of Bohemian waxwings were feeding on these berries and probably flying under the influence of the small amount of alcohol from the fermented sugar in the berries. Slowly Millsap's pace slackened a bit, and when we reached the old railway trestle of the Yukon and Pacific Railway, which had been established in 1902, was initially absorbed into the Canadian National Railway then finally disappeared into history around 1948, Millsap decided that this was a good time to stop and have a little lunch.

Actually I had lived for a few years with my parents near the Mill Creek Ravine and remembered the small spur line that used be the Gainer's Express, which serviced a small meat packing plant until the early seventies.

"You know, Brouwer, I read an article last week that some of your colleagues in the States are doing some new research on cold fusion. It seems that we won't need all the oil resources of Alberta, since room temperature fusion is simple to create and will be cheaper than oil and gas."

"Oh, Bert, here we are sitting in this beautiful valley on a perfect spring day. Let's leave physics alone for one day."

"What, Brouwer, you can see the seams of coal in the valley wall, and the remnants of old coal mines, and you don't want to talk about energy?"

"See that magpie nest, Bert? It's probably home to a family of falcons, which stay around here all year. And there's a blue jay flying around probably looking for a nest with eggs or small birds to feed on. Isn't that more fascinating than wondering about physics on a beautiful day like this?"

"Brouwer, you're getting mentally lazy. You don't want to expend any mental energy to discuss topics that may have a tremendous economic impact on the world. If this new research on room temperature fusion actually works out, all the energy problems of the world will be solved."

"You know me better than that, Bert. I love to discuss these things, and I agree that the latest research on this much maligned topic is very interesting, but right now, I'm more interested in walking on toward the end of the valley."

"How far is it yet to the end? Twenty minutes or so?"

"Dream on, Bert, we're only one-third of the way, and then we have to walk back to the car, so count on two-and-a-half hours yet."

Bert sighed deeply as he compared the distance to be travelled with the energy he had left. "Don't you think, Brouwer, that we've walked far enough for the first day? I don't want you to overdo it."

I looked at Millsap and noticed the droplets of perspiration running down his cheeks. Here was my opportunity to rub it in and to comment on his appalling physical condition. After all, I don't get that many opportunities to cut Bert's self-esteem down a notch, but, well, …

"You're right, Bert, I probably couldn't make it all the way. Thanks for being so considerate. And next time we have a drink at the Faculty Club, I promise to go into a discussion on fusion in as much detail as you want."

Bert's audible sigh of relief was all the thanks I needed. We could always return to Millsap's fitness program another day.

$500 Bursaries to Improve Knowledge and Skills

The ATA Educational Trust is a charitable organization dedicated to the professional growth of Alberta teachers. The Trust encourages Alberta teachers to improve their knowledge and skills through formal education. The names of 30 (or more) eligible teachers who apply will be entered into a draw for bursaries of up to $500 that they can apply toward tuition.

In January of each year, the Trust posts all application forms for grants and bursaries on its website. Visit www.teachers.ab.ca/Professional Development/Grants, Awards and Scholarships/ ATA Educational Trust for details.

The ATA Educational Trust

AR-ETF-24

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In January of each year, the Trust posts all application forms for grants and bursaries on its website. Visit www.teachers.ab.ca/Professional Development/Grants, Awards and Scholarships/The ATA Educational Trust for details.

The ATA Educational Trust

AR-ETF-25

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In January of each year, the Trust posts all application forms for grants and bursaries on its website. Visit www.teachers.ab.ca/Professional Development/Grants, Awards and Scholarships/ATA Educational Trust for details.

The ATA
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