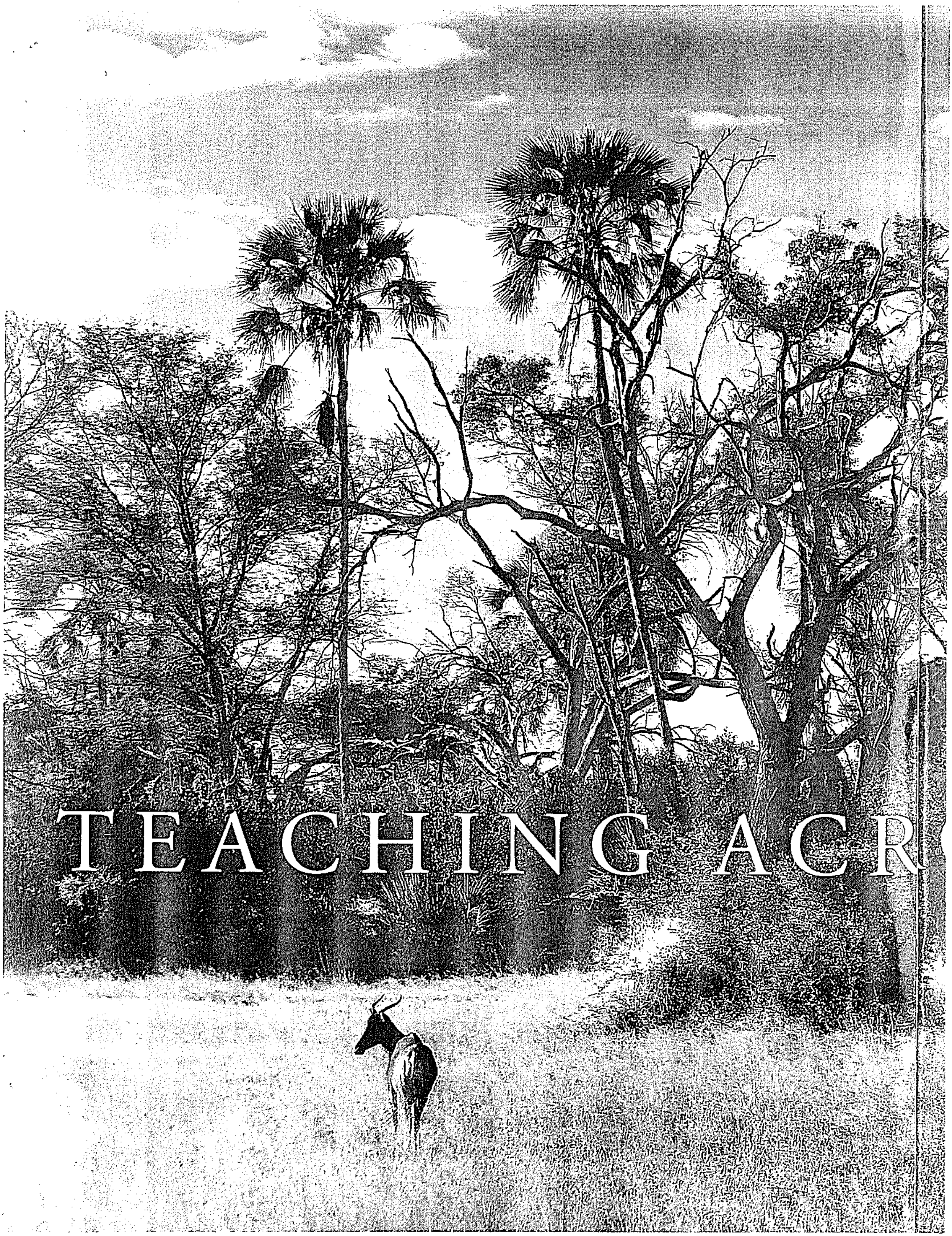
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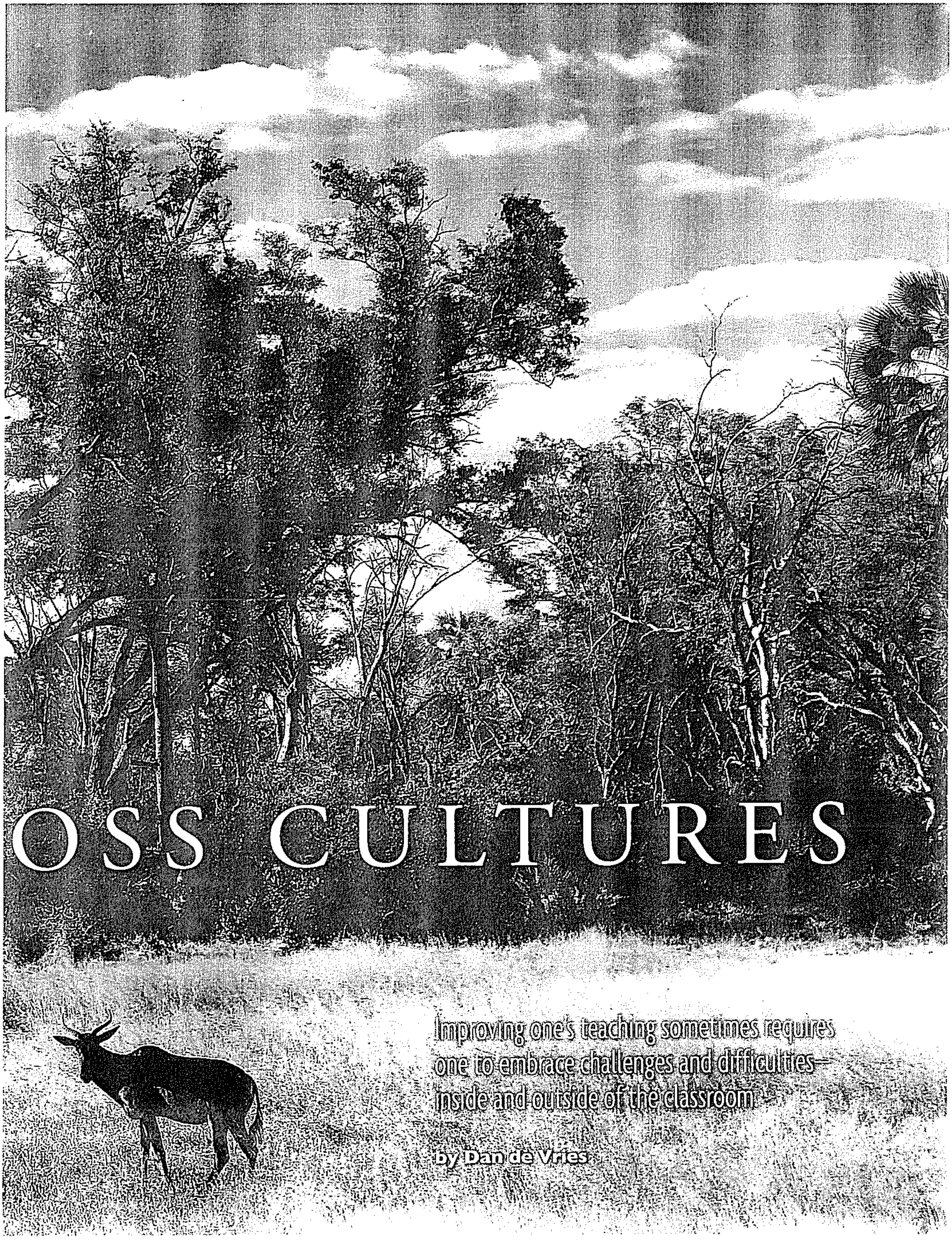


OSS CULTURES

Improving one's teaching sometimes requires one to embrace challenges and difficulties—inside and outside of the classroom

by Dan de Vries

After responding to an advertisement for a physics faculty position in the *Chronicle of Higher Education* and subsequently being recruited, I left for the University of Botswana under a contract that included round-trip airplane tickets for my family, private schooling in Africa for my children, and a generous bonus upon successful completion of my contract. It seemed like a once in a lifetime opportunity: I was going to be paid to do geophysics, my specialty within physics, in a country whose whole economic development was tied to physics, and I was going to be able to live in an exotic culture I had only read about in magazines.

"Botswana's history is surprisingly tied to physics."

Botswana is in southern Africa. It is the northern neighbor of the Republic of South Africa, the wealthiest country in the region and the former home of apartheid, the iniquitous political system. Botswana used to be part of the British Empire, so one of its two official languages is English (the other is *Setswana*, a Bantu group language). The land is dominated by the famous Kalahari desert, in which daytime temperatures can soar to 120 degrees and where only the most adaptable living beings (e.g., the famous Bushmen, more properly known as the *San* tribe) can survive from season to season. Consequently, population density in the country is very low. Although Botswana is about the size of Texas (my current home), there is only one Botswanan for every dozen Texans. One of the clearest signs of Botswana's sparse population is the fact that the local telephone company publishes one phone book for the entire country, and they manage to include in it a section of yellow pages!

The highly uninhabited region is also a boon to astronomy. The lack of ambient light and human noise, in all its forms, makes Botswana an excellent venue for telescopic research.

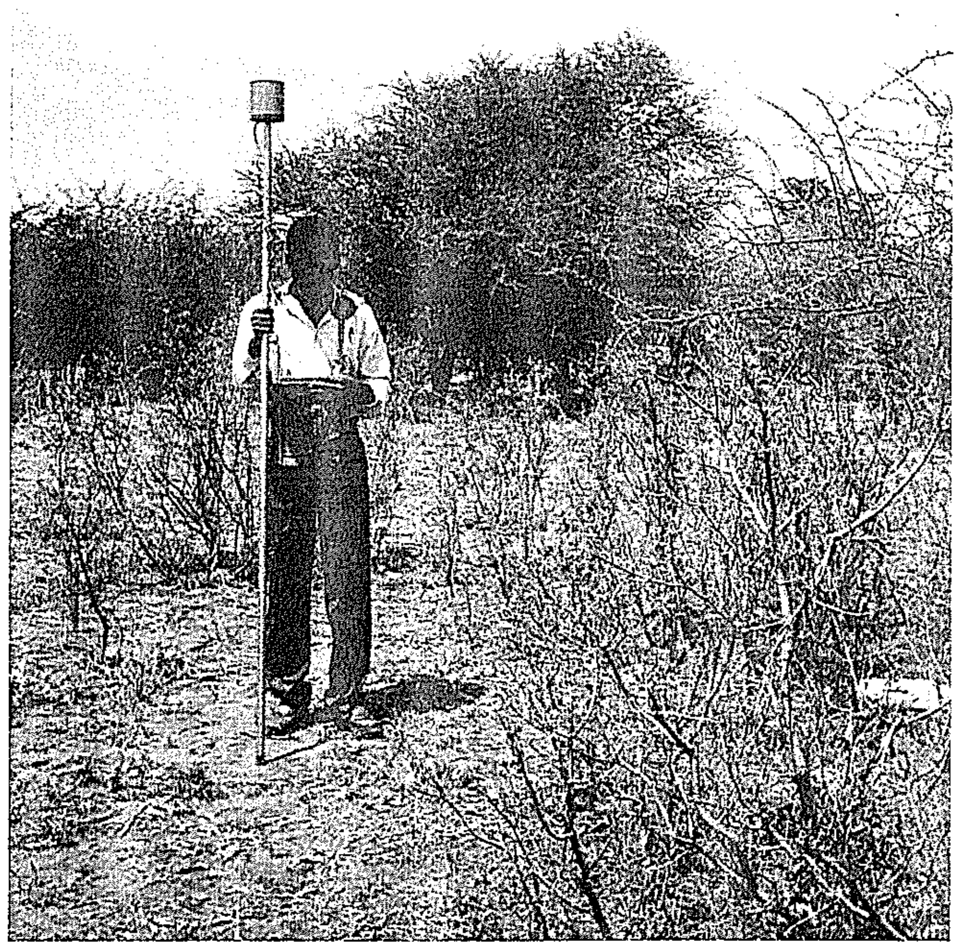
In this brief essay, I will discuss the changing economic forces in Botswana and the central role that physics plays in this transformation, the emerging University system, and the pedagogical adaptations that a physics professor must make to teach effectively the pupils of the Kalahari.

Cattle and Physics

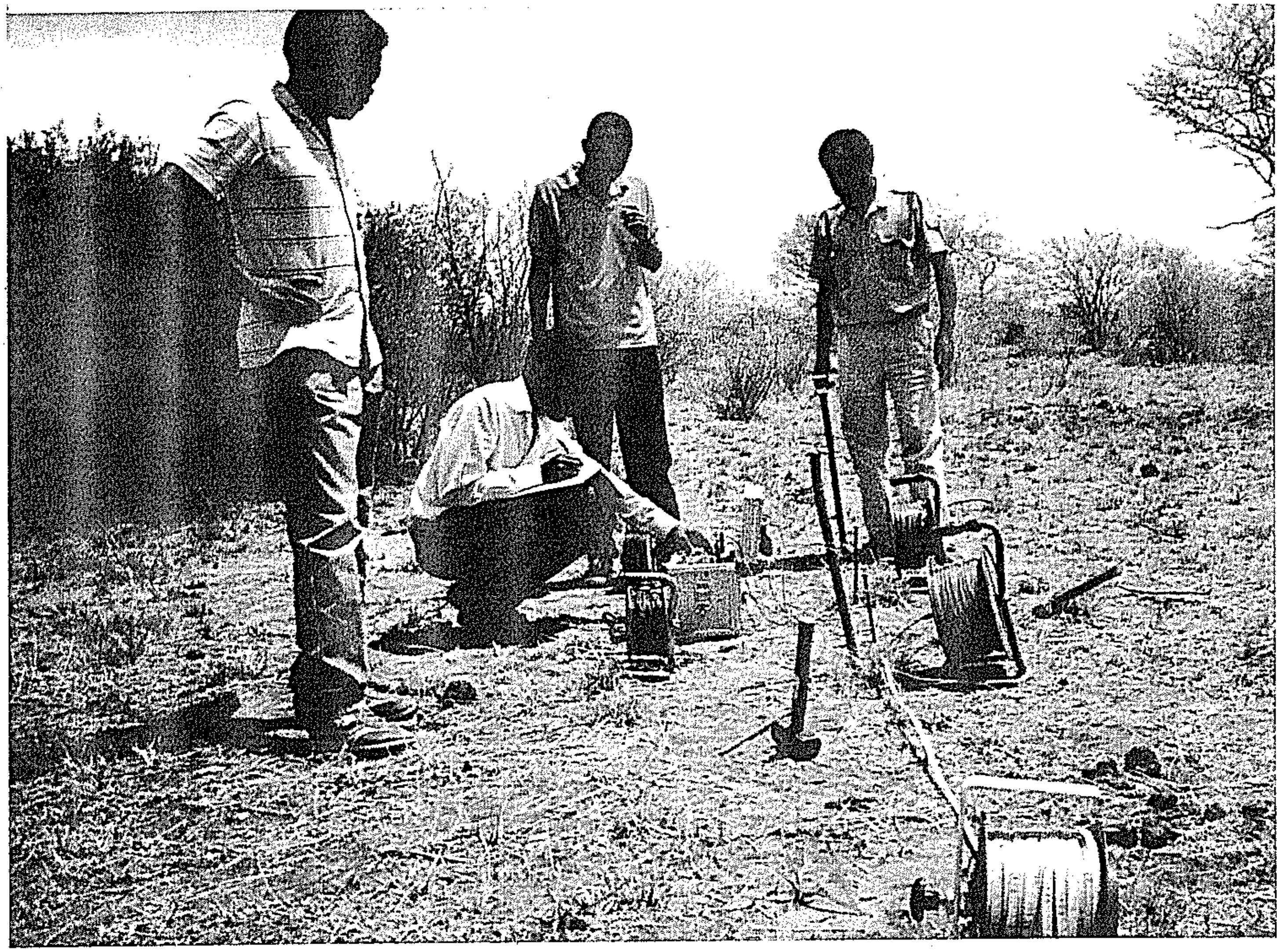
The financial, political, and social aspects of Botswanan life are centered on one theme: South Africa. The Botswanan currency is tied to the South African rand, most consumer goods come directly from the southern neighbor, and many families have members living in South Africa. The border between the two countries is so frequently crossed that some people think of Botswana as a "suburb" of South Africa.

Botswana's history is surprisingly tied to physics, and this relationship was one of the principal reasons I was interested in working there. The traditional form of wealth throughout the country's history was cattle: a man's place in society was, for instance, measured by the number of cattle he owned. This social emphasis remains, but more "westernized" forms of wealth have started to supplant it.

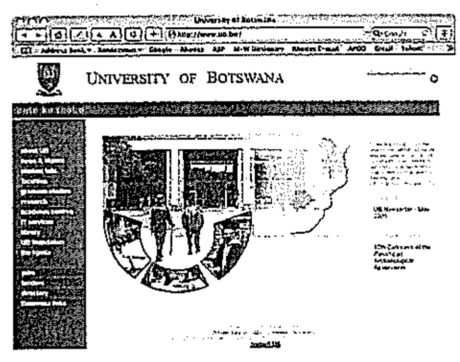
The change is due to the relatively recent financial successes that Botswana has achieved, and these accomplishments are the direct result of work by geophysicists. DeBeers, the huge international diamond company, is headquartered in South Africa and has long been interested in developing the natural resources of Botswana. A DeBeers geologist, Gavin Lamont, led an arduous search for mineral wealth in Botswana for almost two decades before having any success. A major obstacle was that any type of potential treasure was buried under a deep layer of Kalahari sand,



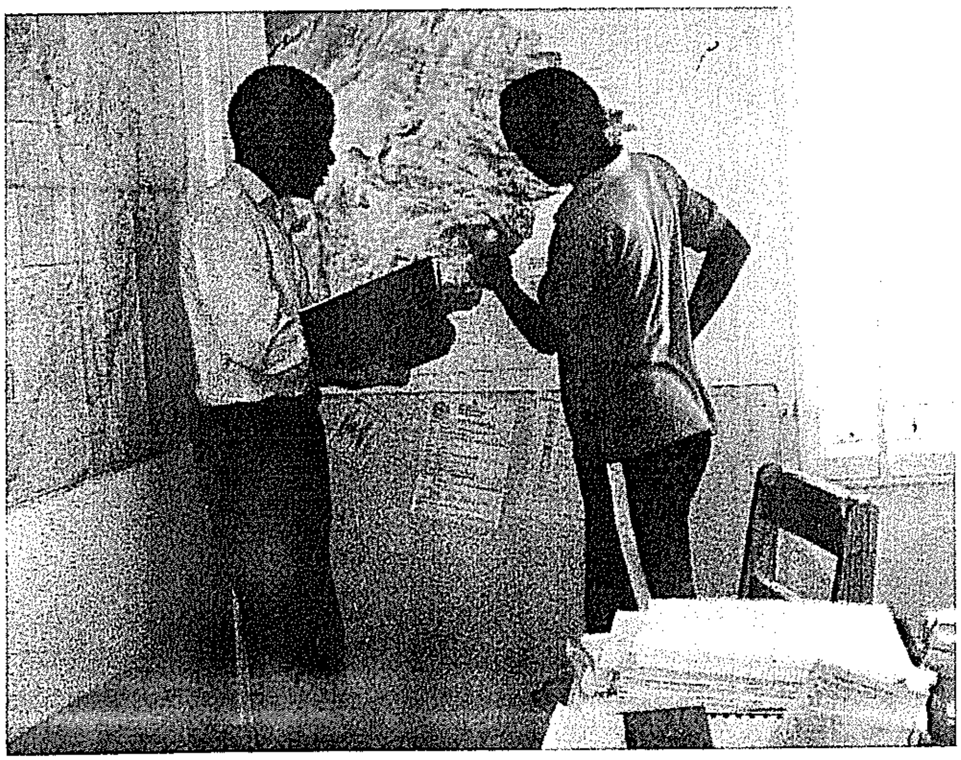
A University of Botswana science student holding a proton magnetometer while participating in a geomagnetic survey in Botswana. Students work in pairs under the supervision of a professor. Photo courtesy of the author.



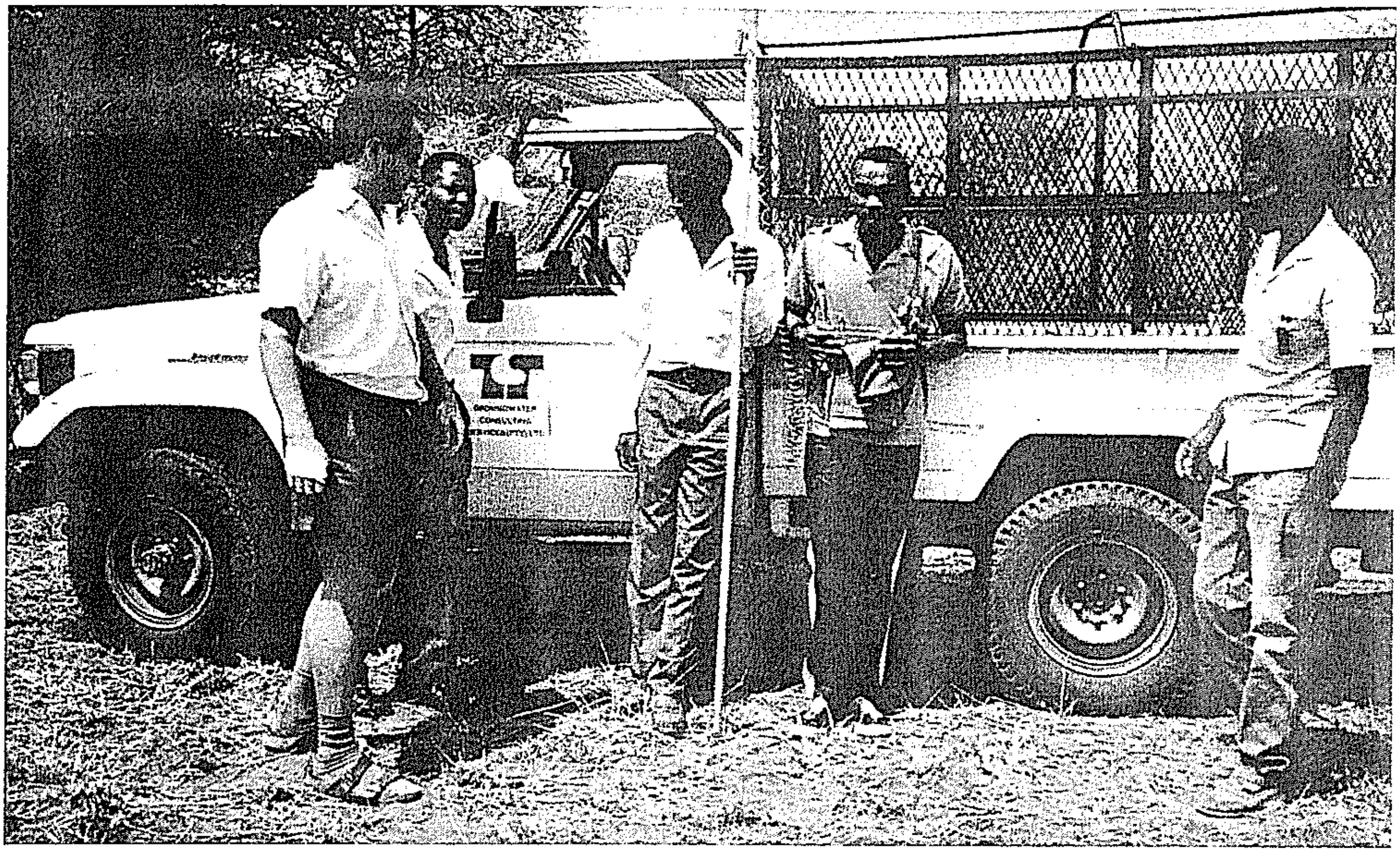
University of Botswana science majors doing fieldwork in geophysics involving electrical resistivity. The University emphasizes hands-on learning techniques. Photo courtesy of the author.



Website for the University of Botswana, located at URL *www.ub.bw*.



(Left) Two University of Botswana science majors plan their physics fieldwork on a survey map of the country. Students are encouraged to participate in all aspects of projects: planning, implementation, and assessment of effectiveness. Photo courtesy of the author.



A group of University of Botswana students with their professor, the author, preparing to take data. Hands-on training is favored by the institution in hopes of providing needed skilled workers to help in the country's rapid economic development. Photo courtesy of the author.

in some places as much as a hundred meters thick. This situation rendered the usual geophysical exploration surveying techniques relatively ineffective. Mr. Lamont, luckily, had two allies: the then-emerging geophysical theory of plate tectonics, and the ubiquitous presence of termites in the Kalahari.

Previous exploration surveys had uncovered a small cache of surface diamonds in a bed of the Motloutse River in eastern Botswana, but further searching for the underlying diamond veins had been unsuccessful. Lamont looked at the previous finding in terms of plate tectonics, which was then, in the mid-1960s, only a promising theory. The river's headwaters had most likely shifted considerably due to plate-tectonic effects since the uplifting of the diamonds to the surface. He calculated a prior location for the river's source and then went about taking ground samples in that spot.

The presence of termites is obvious in the Kalahari: one sees protruding mounds, up to several feet high, throughout the Kalahari. Termites burrow out the interior of a tree and carry off the residue to build a small hill nearby. They also dig as far as one hundred meters down into the sand to find water. When they come back up, they inadvertently carry small pieces of underlying rock on their backs. The termites had brought back up indicator minerals for diamond sources in a location near where Lamont had deduced that the Motloutse had had its headwaters.

The discovery in 1967 of the Orapa kimberlite, a deep diamond vein, by Lamont sparked a massive transformation of Botswanan life. Large amounts of foreign currency poured into the treasury and were used to develop the country's needs. For some Botswanans, the thirst for western consumer goods, which could now be bought with the hard currency brought in by the diamond business, replaced the old appetite for amassing large herds of cattle.

"Lamont's discovery in 1967 of the Orapa kimberlite sparked a massive transformation of Botswanan life."

The New University

One of the beneficiaries of this new prosperity was the national university. It expanded the size of its student body rapidly. Correspondingly, new buildings, such as a science building, and new programs, such as a Master's degree in physics, were put in place. The faculty was enhanced by international recruitment—and I was one of the fortunate recruits.

Along with increased funding, another factor entered into the growth of the University of Botswana: politics. The University implemented a "localization" program whose main focus was to train Botswanans to run their own country as quickly as possible so that jobs would be handed over from foreigners, such as myself, to qualified citizens. As most of the skilled workers at DeBeers, in both the scientific and business divisions, were expatriates, my immediate mission became the training of science students to explore for and process mineral resources.

The physics program at the University of Botswana is a combination of the British

In our study of the birth of the Universe, many students looked on with wide-eyed curiosity. I began with an explanation of Hubble's law, from which we may infer that the Universe is expanding in such a way that all of the galaxies are moving apart from each other. This approach logically leads to the Big-Bang "conclusion": the Universe had a definite beginning from which all matter and even space came. And this expansion continues to this day.

This line of reasoning, however, raised an issue that I had to handle with significant delicacy. Most of my students had heard creation stories from their extended families. These stories typically involved deities who took the form of animals, such as serpents or chameleons. These supernatural beings are credited with creating Earth. As a result of their upbringing, many of my pupils were initially skeptical of the Big Bang account of the birth of the Universe. I only managed to convince them of the worthiness of the Big-Bang model by stating that the scientific and religious views need not be mutually exclusive; it was my role as professor to convey the scientific view, but they did not necessarily need to reject their traditional view. — *D. de V.*

"As a result of their upbringing, many of my pupils were initially skeptical of the Big Bang account of the birth of the Universe."

and American higher education systems. The University was established by the British in 1982, but many significant American elements have crept in. For examples, the academic calendar is the traditional American semester system of August-December and January-May, and many American textbooks, such as Halliday, Resnick, and Krane's general physics book, are used. Yet in keeping with the British tradition, my position was called "lecturer," rather than "assistant professor," and my students' eyes bulged when I announced at the beginning of a semester that there would be an "exam" in four weeks. Though I had been unaware of it at the time, the British reserve that term for a final examination. After some inquiries to my anxious pupils, I re-announced, to their relief, that a "test" would be given in four weeks.

The physics curriculum is similar to ones in the United States: it lasts four years and leads to a Bachelor's of Science degree. General physics and its associated laboratories are taught in the first two years. In the third and fourth year, students take the standard physics majors' courses—such as classical mechanics and electromagnetism—and also choose from electives such as computational physics and nuclear physics. However, one difference from the American approach is that most students are obligated to take a "foundation year" before they officially enter the Bachelor's degree program. This extra year, which extends the total requirement to five years, is intended to strengthen their basic academic skills, such as computer literacy and algebra.

The New Pedagogy

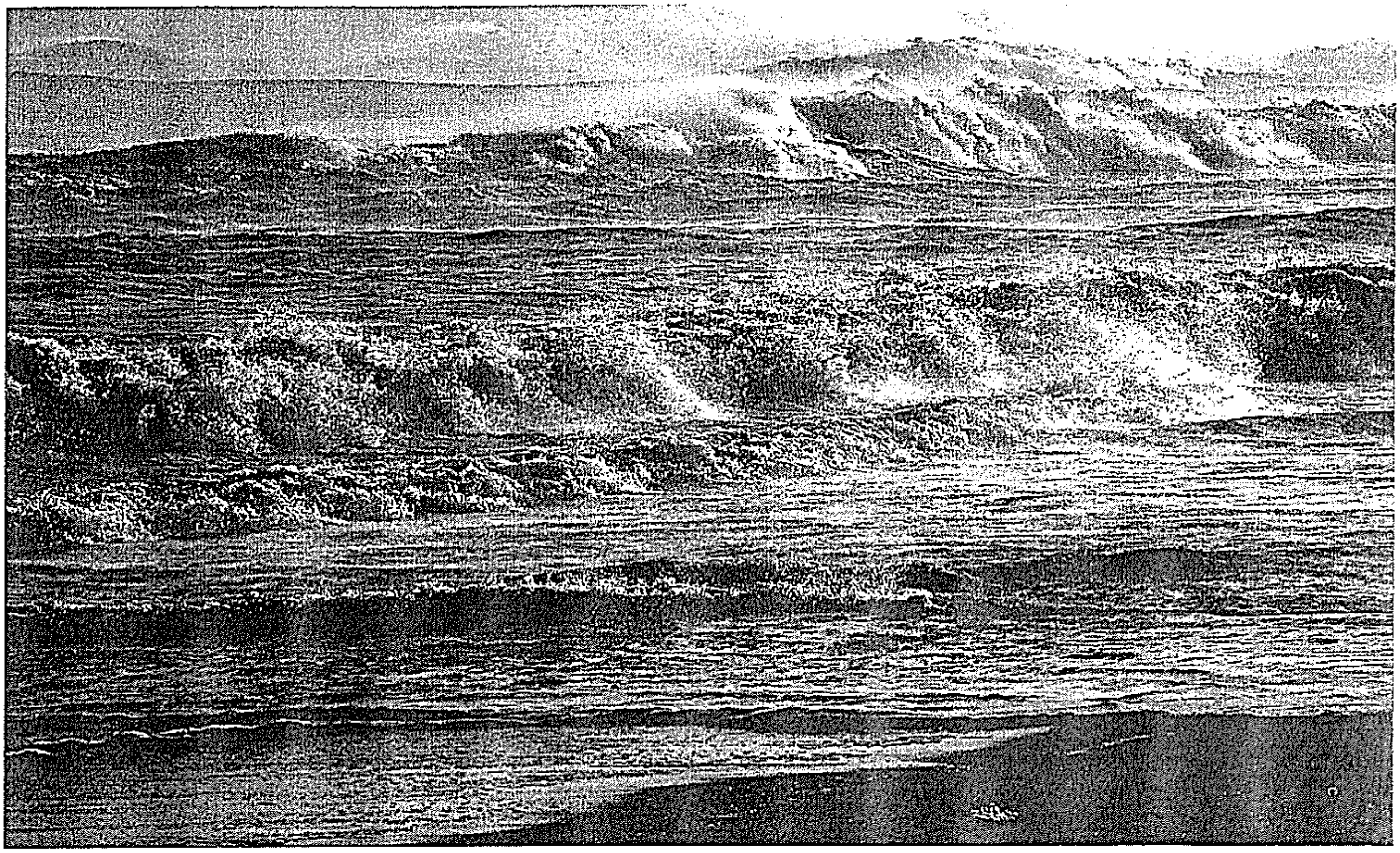
Over ninety percent of my students were African. Almost all of the others were from the Indian sub-continent. I learned that some of the large cultural differences between Botswanan and American students necessitated a change in my approach to teaching physics in Botswana. Consider, for example, that many of the experiences familiar to American physics students (e.g., using the accelerator pedal in a car and being in a vehicle that starts to roll over while going around a curve in the road too fast) are not sufficiently familiar to African students to be useful in aiding their comprehension of concepts. This situation led me to consider alternative ways of presenting and illustrating physics concepts. My attempts to adjust my lecturing to suit my new audience ranged from the hilarious to the unnerving.

"As most of the skilled workers at DeBeers were expatriates, my immediate mission became the training of science students to explore for and process mineral resources."

In making these adjustments, I was careful to avoid any tendency towards aloofness: that in supplanting my conventional American approaches, I was "stooping down" to the level of my new students. Rather, I viewed my new pedagogy as a broadening of my teaching repertoire to encompass students from different cultural backgrounds.

When I discussed acceleration in my general physics course, for instance, I initially gave the example of a car accelerating from 0 to 60 mph in eight seconds. When I noticed little sign of comprehension in the eyes of my audience, I was puzzled. After the lecture, I realized that I had used an unfamiliar example. In my next lecture, I called upon my knowledge of local culture. I illustrated the concept of acceleration by detailing how one could change the velocity vector of a (stubborn) cow's path with an appropriately applied external force.

With this success at hand, I utilized similar approaches. In a presentation of rigid-body dynamics, I related the idea of the location of the center of mass to how difficult it is to push a cow over onto the ground (in order to brand him). This illustration, too, was successful as it relied on an experience with which many of my students were familiar. The students initially found my references unusual for the classroom—and, therefore, humorous—but



Differing cultural perceptions — even of basic substances such as water — may require that we rework analogies that help us teach.

gradually came to accept them. It was at this point that, I felt, I had become a much more effective instructor.

A particularly curious cultural issue with which I had to deal was the Botswanan students' difficulty in studying what is to American students a very straightforward topic: water. Botswana has had a number of serious droughts over the past forty years. As a landlocked country with primarily a desert terrain, it has depended on rain as its main source of water until recently when modern methods of irrigation and water storage were introduced. Tribes traditionally used the famous "rain dances" to try to end droughts. Water is such a precious quantity that the Setswana word for rain, *pula*, is also used as the currency of the country and as an exhortation in political speeches.

My students had little knowledge of water waves, so I could not use my example of a body surfer's bobbing up and down at the beach in a direction perpendicular to the landward bound ocean wave to illustrate the concept of transverse wave motion. To my surprise, some of my students thought that water waves behaved completely differently than seismic waves, acoustic waves, or pulses along a string. Over time, I discovered that water held such significance for many Botswanans that they initially found it difficult to think of it as an ordinary physical substance subject to the same physical laws as, say, wood or sand. I modified my instructional techniques by substituting demonstrations sending pulses down a stretched string for water waves in a flow table. Whenever I discussed properties of water, such as its electrical conductivity or viscosity, I emphasized that it obeyed the same physical laws as other materials.

Cultural dissimilarities which affected my teaching extended to outside the classroom. Occasionally, it was necessary for me to call a student into my office to discuss an academic problem, such as poor performance on a test. Invariably, the student would show up at my door with almost the entire class at his side. When I asked the others to leave, there was some initial resistance from the group. Then, after the student and I were alone, I noticed that he typically acted very uncomfortable while conversing with me. I learned that this was not simply explained from the point of view of "strength in numbers," but was actually a manifestation of a cultural trait, the collectivist mentality. As an African faculty member confided to me, a Botswanan growing up in a traditional village normally does not seek privacy. Personal matters, even serious ones, are discussed openly in front of a group. In an individualist society, by comparison, members often deal with each other on a one-to-one basis and the "rugged individualist" is often viewed with reverence. After I explained to my Botswanan students this fundamental cultural distinction, they gradually became more relaxed about coming to my office individually. I remarked to them that the University of Botswana encompassed both the individualist approach and the traditional collectivist approach. Private discussions, I pointed out, were typical situations they would encounter if they later found a job with an international company.

"My attempts to adjust my lecturing to suit my new audience ranged from the hilarious to the unnerving."

Not a Walk in the Rain

The difficulties of using water as a teaching aid in a land parched periodically by drought extended to the study of astronomy. For instance, when we discussed astronomical aberration (also known as the aberration of starlight), I was forced to amend my typical explanation: astronomical aberration, which leads one to alter the direction one points a telescope in order to see a particular star at different times of the year, is caused by Earth's orbital motion relative to a reference frame tied to the distant stars. I initially used the umbrella analogy, typically used by American professors, to convey the concept. If it is raining, the most efficient position to hold an umbrella is obviously vertical. When walking in the rain, the umbrella must be held more and more inclined away from the vertical as the walker speeds up.

My pupils had difficulty comprehending this notion. Since rain is not frequent in Botswana, umbrellas are most commonly used by women as parasols to deflect sunlight. Tilted umbrellas are not generally evident. I had to bring to class an American video rented from the local video retailer, and show a scene in which a character runs with his umbrella tilted at an angle through the driving rain. After replaying the scene, my students grasped more firmly the underlying idea behind astronomical aberration. — *D. de V.*

Trying to explain to students in an arid land the aberration of starlight using the customary example of walking in the rain with an umbrella is difficult. Image courtesy of *iStockphoto.com*.

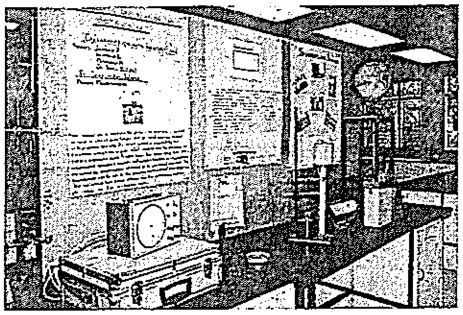
Dealing with certain other cultural differences was easier. I noticed in the optics lab, for example, that many students confused the wavelengths for the colors blue and green in their calculations, but not other pairs of colors. The source of this difficulty was, I learned, due to the local language: the same word is used for the colors blue and green in Setswana. In other words, Botswanans think of blue and green as the same color. When I sat down with this new knowledge in hand and talked to the students about their confusion with the conventions of optics, the hurdle was removed. I was pleasantly surprised by the creative approach which some of them employed to overcome the cultural gap: they gave, as a mnemonic device, new Setswana names for each of the two colors to keep them distinct in their minds. Back in the United States, I learned that this situation, in which an individual does not have a word for a certain idea and therefore the concept is difficult to grasp, has been studied by linguists. The Hopi Indians, for instance, do not distinguish between blue and green, and consider them as one color.

When I introduced special relativity, I encountered another cultural obstacle that was relatively easy to overcome. When I lectured on length contraction, the African students reacted in a manner not altogether different from their American counterparts. They thought, for example, that the relatively high rate of speed necessary to make an observable change in length must cause a "wind" which causes the mass to shrink in size. There were similar miscomprehensions in conveying the Twin Paradox, in which the spaceship-traveling, identical twin has aged less than the farmer identical twin who had stayed back home on the family spread.

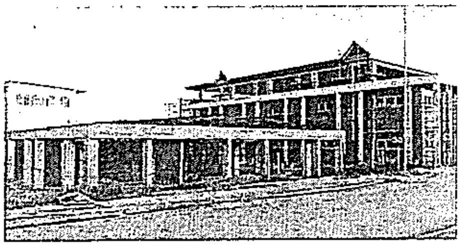
"I discovered that water held such significance for many Botswanans that they initially found it difficult to think of it as an ordinary substance."

However, cultural issues actually helped to untangle the difficulties of the Twin Paradox. During my stay in Botswana, the country's robust economic fortunes had substantially increased demand for growth of the national airline, Air Botswana. Consequently, some of my African students were interested in working for the national airline. These future pilots and navigators were able to apply the Twin Paradox to an identical twin pilot-rancher pair. The students reasoned that the pilot should be somewhat younger than his rancher brother after having flown at relatively fast speeds for thirty years. When I explained that tremendously accurate atomic clocks had been placed on international aircraft and experimentally verified this concept, the mistaken ideas about the Twin Paradox were removed.

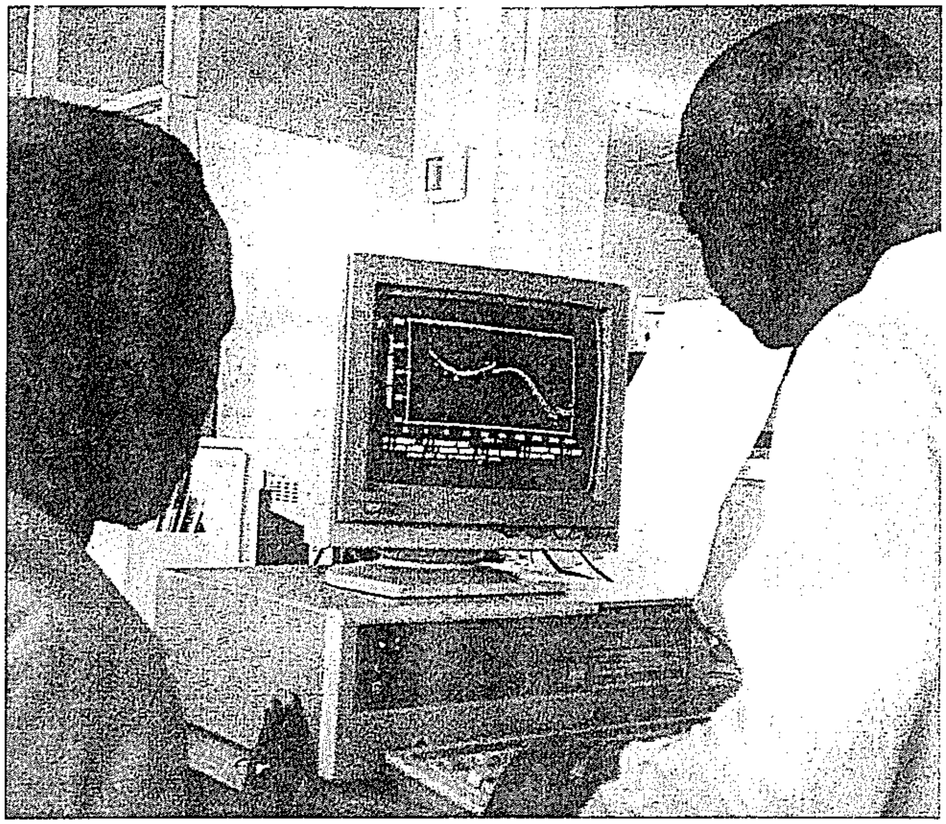
The influence of yet another culture added to the challenges I faced: almost all of my students came from British-style high schools. One particularly nettlesome difficulty arising from the differences in British and American high schools involved mathematical notation. When I wrote 2.718 as the value of the number *e*, the base for natural logarithms, many of my students complained that this figure was too large by a



Poster presentation of field equipment at the University of Botswana. All scientific research is shared with classmates and faculty at university colloquia. Photo courtesy of the author.



Construction of a new academic building at the University of Botswana. The rapid economic growth of the country, due principally to contributions from physics researchers, has enabled the University to expand rapidly. Photo courtesy of the author.



Two University of Botswana students analyze data they have recently taken in the field. Almost all field research equipment is interfaced with computers. Photo courtesy of the author.

factor of a thousand. As I found out, in the British system one substitutes commas for periods (e.g. the price, in U.S. dollars, of a Toyota pick-up truck in Botswana might be $23.456,95). To make matters worse, some of my students owned calculators calibrated in the British mode and, for them, the notation was a repeated source of confusion. Though this impediment was relatively easy to overcome, it still had the deleterious effect of distracting my students' attention from the already difficult task of mastering physical concepts.

Fortunately before I left, I was given the opportunity to participate in resolving the dispute about numerical notation. I was elected by the University's sciences departments to serve as their representative to the National Science Panel, an advisory board to the Minister of Education about science pedagogy at all levels (primary through higher education). I received this honor in part, I believe, because I had done physics outreach programs to local primary and secondary schools, an "unusual" undertaking for a University of Botswana faculty member. We were charged with choosing a single numerical notation for the entire country's education system. Unfortunately, I left Botswana before this challenging issue was brought to a conclusion.

Despite the challenges, and their associated frustrations, which I faced, I feel fortunate to have been placed in a position that led me to re-evaluate some of the fundamental aspects of my approach to pedagogy. I was strengthened by having to check constantly how well my lessons were being comprehended by my audience and by learning how to adapt my teaching style to students from very different cultural and educational backgrounds. Now when I lecture to my students in the United States, I take much less for granted and seek out illustrations of ideas that are relevant to the students' lives.

"I viewed my new pedagogy as a broadening of my teaching repertoire to encompass students from different cultural backgrounds."

Indeed, I cannot help but recall Aldous Huxley's thoughts in the *Jesting Pilate*:

> So the journey is over and I am back again where I started, richer by much experience and poorer by many exploded convictions, many perished certainties. For convictions and certainties are too often the concomitants of ignorance. Those who like to feel they are always right and who attach a high importance to their own opinions should stay home. When one is traveling, convictions are mislaid as easily as spectacles; but unlike spectacles, they are not easily replaced.

DAN DE VRIES

University of Colorado in Boulder. His favorite proverb, which is generally attributed to Confucius, hung outside his door at the University of Botswana: "If you think in terms of a year, plant a seed; if in terms of 10 years, plant a tree; if in terms of 100 years, teach..." One Botswanan student commented that the saying was similar to one that the Chief of his tribe in his home village used frequently.