EXPERIENTIAL LEARNING AND GLOBAL PERSPECTIVE IN AN ENGINEERING CORE COURSE

Daniel J. Lacks[a], R. Mohan Sankaran,[a] and Clever Ketlogetswe[b]
a Case Western Reserve University • Cleveland, OH 44106
b University of Botswana • Gaborone, Botswana

The typical engineering course is aptly described by Rugarcia, et al.,[1]

> *"The professor stands at the front of the room, copying a derivation from his notes onto the board and repeating aloud what he writes. The students sit passively, copying from the board, reading, working on homework from another class, or daydreaming. Once in a while the professor asks a question: the student in the front row who feels compelled to answer almost every question may respond and the others simply avoid eye contact with the professor until the awkward moment passes. At the end of the class students are assigned several problems that require them to do something similar to what the professor just did or simply to solve the derived formula for some variable from given values of other variables. The next class is the same, and so is the next one, and the one after that."*

We are exploring teaching environments that are diametrically opposite to this description, and have attempted to create such a course. We have chosen to apply our ideas to a core engineering course required by all engineering students regardless of major. This type of course faces the greatest challenge for effective teaching since students generally have low interest in the course content, and the course content is rigidly defined.

Broadly, our strategy draws on two thrusts of educational research. First, controlled studies show that students learn more deeply when they are *active* participants via group work, discussions, and hands-on activities, as opposed to passive participants in the audience of a lecture.[2,3] Second, experiential learning theories put forth by Kolb[4-6] and others suggest that optimal learning occurs when the students traverse a cycle in which they first experience something concrete, then have an opportunity to reflect on what they have observed, then develop an abstract model or ideas to explain the experience, and then carry out some sort of test of their ideas, which in turn generates new concrete experiences and starts another cycle operating at a more advanced stage of knowledge. This "Learning Cycle" approach is illustrated

***Daniel Lacks** is the C. Benson Branch Professor of Chemical Engineering at Case Western Reserve University. He received his B.S. in chemical engineering from Cornell University and his Ph.D. in chemistry from Harvard University. His research interests are in statistical mechanics and molecular simulation.*

***Mohan Sankaran** is an associate professor of chemical engineering at Case Western Reserve University. He received his Bachelor's degree in chemical engineering from the University of California at Los Angeles and his Ph.D. in chemical engineering from the California Institute of Technology. His research interests include plasma chemistry and processing, nanomaterial synthesis and characterization, and triboelectric charging of insulating materials.*

***Clever Ketlogetswe** is a senior lecturer and the head of the Department of Mechanical Engineering at the University of Botswana. He completed his B.Eng. and M.Sc. from the University of Portsmouth (UK) and his Ph.D. in combustion processes from the University of Manchester (UK). His research interests are in renewable energy resources including biofuels.*

in Figure 1. In the context of technical fields of study, this cycle has a clear resemblance to what is commonly referred to as the "scientific method."

The basis of our approach is that we teach the course in a foreign country, and intertwine technical content with societal issues of the foreign culture; this connection is used to launch an experiential learning approach to the course. There are two key consequences of teaching the course in a foreign country. First, students are able to experience a direct connection between technical content and societal issues. Second, students take only one course over a few weeks (rather than multiple courses spread out over several months); this format creates opportunities for experiential learning, as the longer class meeting times allow for a range of activities throughout the complete Learning Cycle, and the absence of other commitments enables extended field trips for experiential activities.[7-9]

While much of engineering education is thought to be experiential because it deals with laboratory work and real-world applications, experiential learning in its full-blown form, as can be seen from its description, requires somewhat more structure. In this paper, we explicitly connect the learning activities to the elements of the cycle, to provide a template that can be adapted to other teaching contexts.

In addition to the pedagogical benefits, our approach also broadens the global perspective of the students. Study abroad is difficult for engineering students, due to the large number of required courses (which usually must be taken in a particular order) and the importance of summer internships. We confine our course to a three-week period in May, where it does not disrupt either the academic year or summer internships.

We implemented our idea for the first time in 2011, teaching a core engineering course that is required at Case Western Reserve University (CWRU). The technical content was connected to societal issues in sub-Saharan Africa, and the course was taught at the University of Botswana (UB) in Gaborone, Botswana. Botswana was chosen because it is among the wealthiest countries in Africa, has a stable democratic government and low crime rate, and English is the official language. We had 21 students enrolled in the course in 2011 (all from CWRU).

IMPLEMENTATION

Our course is a special offering of a core engineering course in thermal sciences at CWRU. The regular offering is taught in the traditional lecture format over a full semester. The course covers heat transfer (20% of the course), fluid flow (30%), and thermodynamics (50%), and uses the text *Fundamentals of Thermal-Fluid Sciences*, by Cengel, Turner, and Cimbala.[10] The technical content in our offering is the same as that in the regular offering. The workload is also the same, as quantified by the total number of contact hours, the number of homework problems, and the number of exams.

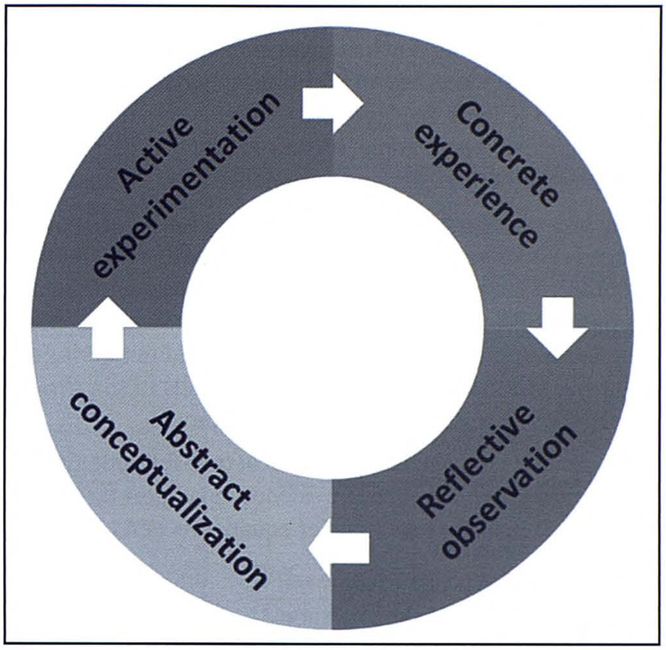


Figure 1. *Schematic of Kolb's learning cycle.*

The course runs during a three-week period in May. Classes are held an average of five days/week, but are dispersed throughout all seven days of the week in order to accommodate field trips. A typical class meets for 3.5 hours in the morning in a classroom at UB, but additional problem-solving sessions are held on an ad hoc basis during field trips in venues such as airplanes, buses, and hotel lobbies. Homework assignments are given each day the class meets and are due the next day; usually a significant fraction of the homework could be completed during the problem-solving segments of the class period. The students live in dormitories on the UB campus and have meals in the campus dining halls. While our course does not include UB students, we run a concurrent research program that does include UB students[11]—the students in our course have significant interaction with these UB students, as these two programs share housing, dining, and most activities.

The driving force behind our teaching is the Learning Cycle. We introduce a topic through concrete experiences associated with Botswana. These experiences are discussed in class, to facilitate reflective observation. Abstract conceptual models underlying the phenomenon are next developed, usually via mathematical derivations in class. Results of these models are obtained with various parameters—this active experimentation generates insight and intuition on the behavior. Often, various parts of the Learning Cycle are repeated. Detailed examples of this approach are given below.

Heat Transfer: The traditional African mud hut

Botswana's semi-arid climate leads to large temperature fluctuations between day and night. From their first day in Botswana, our students experience this first-hand—it is uncomfortably hot during the day while wearing shorts and a tee-shirt, but it cools down at night such that long pants and a sweatshirt are needed. In addition, we visit a traditional African hut (Figure 2a), and the students are told that while the hut appears very simple, it is actually a good design that responds well to temperature variations.

These concrete experiences serve as a lead-in to a discussion (reflective observation) on the engineering design of dwellings to optimize thermal comfort. At first thought, it appears that the optimal dwelling would have heavily insulated walls, to keep the heat out during the day and the cold out during the night. We tell the class that actually the walls of the African hut work even better than heavy insulation.

An abstract conceptual model of heat transfer through a hut wall is necessary to generate evidence to support this claim. The time dependent heat transfer equation is derived,

$$\frac{\partial T}{\partial t} = \frac{k}{\rho C_p} \frac{\partial^2 T}{\partial x^2} \qquad (1)$$

where t is time, x is the position in the wall, T is temperature at position x at time t, k is the thermal conductivity, ρ is the density, and C_p is the heat capacity. To determine the temperature inside the hut, we use as boundary conditions an oscillating temperature on the exterior side of the wall and zero heat flux on the interior side of the wall. The equation is solved numerically, using a finite difference method that is easily implemented in a spreadsheet.[12]

With this model, we carry out "what if" experiments to explore what factors influence heat transfer. Figure 2b shows the solution for the temperature inside the hut as a function of time, using thermal parameters for a mud brick[13] and a wall thickness of 20 cm. The temperature inside the hut oscillates with time, but these oscillations are out of phase with the oscillations of the outside temperature—the hut walls act as passive "air conditioners" in the day and passive heaters at night. Experimentation with the thermal parameters shows that a "modern" Western-style insulated wall is not nearly as effective in controlling the temperature, and that a wall thickness of approximately 20 cm is optimal.

Further reflection shows that the effect is an inherently unsteady state phenomenon, and the key parameter is the large thermal capacity of the walls (the product ρC_p). What happens is that the walls begin heating up during the day, but by the time the heat reaches the inner surface of the wall it is already nighttime; at night the walls begin cooling, but by the time the cooling reaches the inner surface it is already daytime. The mud brick wall is only effective when large daily temperature swings straddle the most comfortable temperature; if the temperature is always "too cold" or "too hot", then the wall material with the lowest k (modern insulation) is optimal as it minimizes heating or cooling costs.

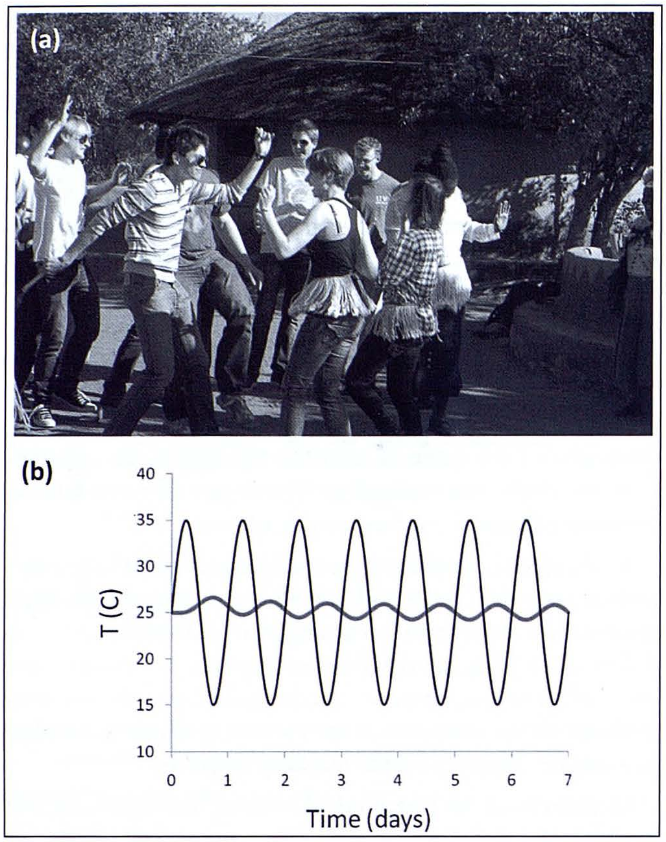


Figure 2. *(***a.***) Our students enjoying themselves in front of a traditional African mud hut. (***b.***) Model results for the temperature inside the hut (thick grey line) when there are daily oscillations in outside temperature (thin black line). Results obtained using thermal parameters found in the literature for a mud brick wall (k=0.37 W/mK, ρ=1780 kg/m³, C_p=1190 J/kgK) and a wall thickness of 20 cm.*

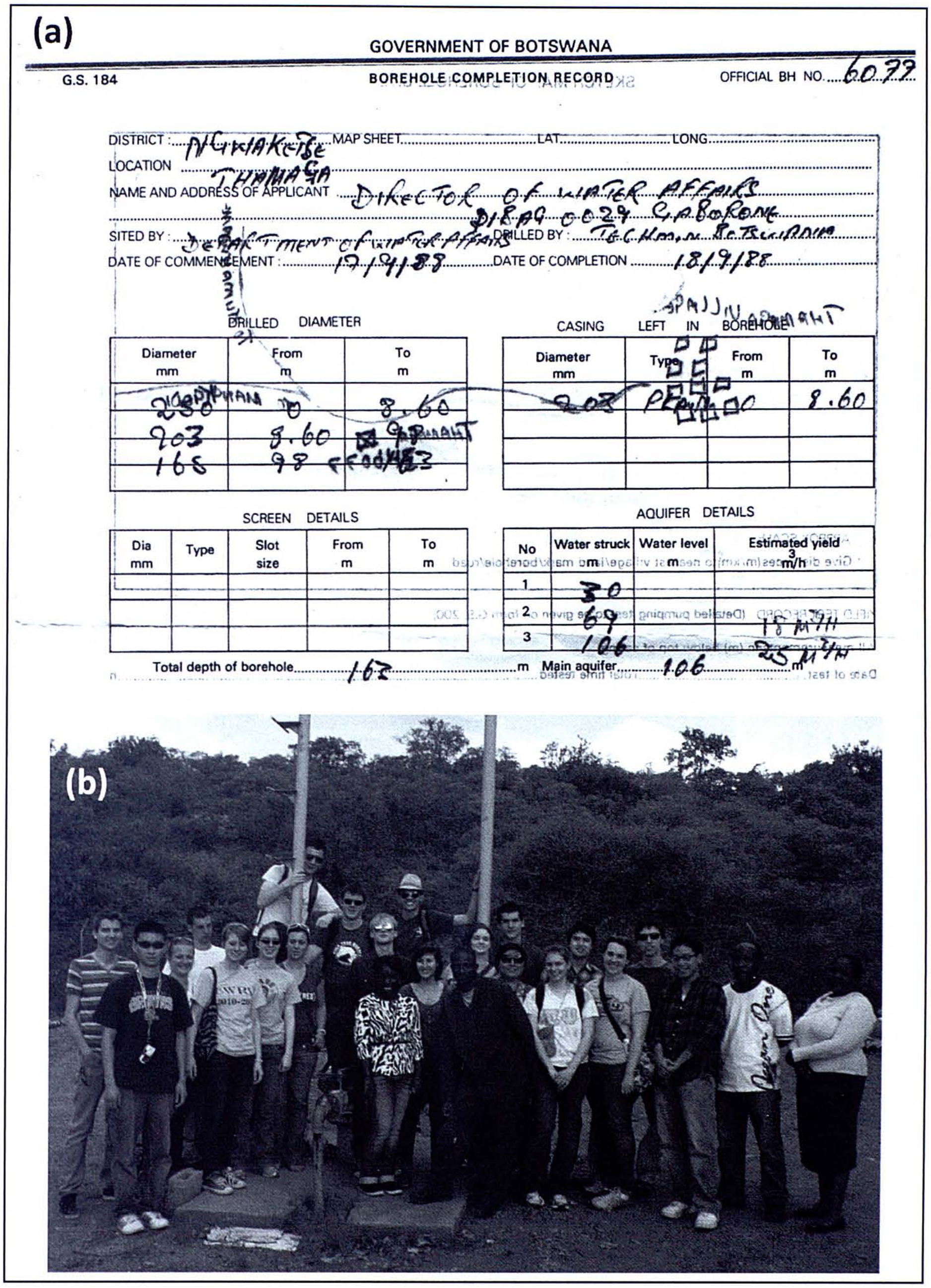
Fluid Flow

i. Providing water for villages in the Kalahari desert

Botswana is largely covered by the Kalahari Desert, and deep wells are needed to reach water. To give the students concrete experience in this regard, a data sheet for a water well in the village of Thamaga is obtained from the Botswana Water Authority and given to the students (Figure 3a). This enables students to see actual parameters for such wells, including the well depth (163 m), aquifer depth (106 m), well pipe diameter (165-230 mm, depending on depth), and water flow rate (25 m^3/h).

What factors affect the cost of providing water to the villages? A discussion facilitates reflective observation of this question. Of course, power is required to lift the water from the bottom well against gravity. Other factors, however, such as frictional energy losses at pipe walls, could also affect the necessary power.

An abstract conceptual model is developed to quantify the power needed to pump the water. We derive the energy bal-



GOVERNMENT OF BOTSWANA

G.S. 184

BOREHOLE COMPLETION RECORD

OFFICIAL BH NO. 6077

DISTRICT : NGWAKETSE MAP SHEET LAT LONG

LOCATION THAMAGA

NAME AND ADDRESS OF APPLICANT DIRECTOR OF WATER AFFAIRS
P/BAG 0029 GABORONE

SITED BY : DEPARTMENT OF WATER AFFAIRS DRILLED BY : TECHMAN BOTSWANA

DATE OF COMMENCEMENT : 17/9/88 DATE OF COMPLETION 18/9/88

DRILLED DIAMETER

Diameter mm	From m	To m
230	0	8.60
203	8.60	[illegible]
165	98	[illegible]

CASING LEFT IN BOREHOLE

Diameter mm	Type	From m	To m
203	[illegible]	0	8.60

SCREEN DETAILS

Dia mm	Type	Slot size	From m	To m

AQUIFER DETAILS

No	Water struck m	Water level m	Estimated yield m^3/h
1	30		
2	69		18 M³/H
3	106		25 M³/H

Total depth of borehole 162 m Main aquifer 106 m

Figure 3. (a.) Specifications of borehole well in Thamaga village, Botswana. (b.) Class visit to the well, guided by engineer from the Botswana Water Authority (at front center).

ance for flowing incompressible fluids, which leads to the expression for the power needed to pump a fluid from point 1 to point 2,

$$\dot{W} = \left(\left[\frac{1}{2}\dot{m}v_2^2 + \dot{m}gh_2 + \frac{1}{\rho}\dot{m}P_2\right] - \left[\frac{1}{2}\dot{m}v_1^2 + \dot{m}gh_1 + \frac{1}{\rho}\dot{m}P_1\right]\right) + \dot{E}_{loss} \qquad (2)$$

where $\dot{m}$ is the mass flow rate, and v_i, h_i, and P_i are the velocity, elevation, and pressure at point i, ρ is the density, g is the gravitational constant, and $\dot{E}_{loss}$ is the rate of frictional energy loss.

> ***In regard to the use of concrete experiences related to a foreign culture, the students overwhelmingly felt that this experience got them more interested in the technical content . . . .***

We follow the development of the model with active experimentation—we estimate how much power would be needed to pump water from this well, using the parameters given in the well data sheet (frictional losses were neglected at this point). We find that 7 kW of power is required to pump water at 25 m^3/h. Since the cost of electricity in Botswana is 0.6 Botswana Pula (BWP) per kWh,[14] the cost to pump the water is approximately 0.2 BWP per cubic meter of water (1 BWP ≈ 0.15 USD).

The same day, the class travels to visit this well, guided by an engineer from Botswana Water Authority (Figure 3b). As further concrete experience, the students see firsthand the well they analyzed earlier in the day (and also learn about other aspects of water systems in Botswana). Thamaga village is charged 1 BWP per cubic meter of water. Our calculation of the cost required to pump the water from the well accounts for about 1/5 of this charge; other factors contributing to the charge include the inefficiency of the pump, water treatment (we visit the water treatment plant), and transport of the water from the well to the village.

The visit to a second water well near Thamaga, which provides 20 m^3/h of water to a village approximately 40 km away via a 90 mm diameter pipeline, provides concrete experience for the role of frictional losses in fluid flow—power is required to pump the water through the pipeline, even though there is no significant change in elevation. In class the next day, we discuss how this power is needed to overcome frictional losses due to the moving fluid interacting with the stationary pipe wall (reflective observation). An abstract conceptual model for fluid losses is introduced,

$$\dot{E}_{loss} = \frac{\dot{m}}{\rho} f \left(\frac{L}{D}\right) \frac{\rho v^2}{2} \tag{3}$$

where L is the length of the pipe, D is the pipe diameter, and f is the Darcy friction factor ($f=64/Re$ for laminar flow, and $f=0.316/Re^{1/4}$ is the Blasius approximation for turbulent flow in smooth pipes). Active experimentation shows that frictional losses are negligible in the case of the first well, but significant in the case of the second well. For the second well, 18 kW of power is needed to overcome the frictional losses for 20 m^3/h of water, which corresponds to a cost of 0.6 BWP per cubic meter of water (this calculation was given as an exam problem).

ii. Victoria Falls

Fluid flow is also addressed in the context of Victoria Falls, one of the world's largest waterfalls. Victoria Falls is located on the Zambezi River between Zimbabwe and Zambia, about 80 km outside of Botswana. Active experimentation with the energy balance equation [Eq. (2)] shows that the falls release $\dot{W} \approx 1$ GW of power, based on a height of 100 m (the highest point is 108 m) and a flow rate of 1100 m^3/s (the annual average). Reflective observation puts this value into context: the available energy could power *10 million* 100 W light bulbs. The class visits Victoria Falls as part of a three-day excursion to the north of Botswana midway through the course (Figure 4)—this visit provides concrete experience of the power corresponding to 10 million light bulbs.

Thermodynamics

i. Thermodynamics of diamonds

The high standard of living in Gaborone, the capital of Botswana, is obvious to our students. For example, shopping malls in Gaborone are indistinguishable from "upscale" malls in the United States. This wealth is recent. When Botswana became independent in 1966, it was among the poorest countries in the world. In 1967, diamond was discovered in Botswana, and diamond mining began a few years later. Today, Botswana is the world's largest producer of diamonds (by value),[15] and the diamond industry has transformed the country to one of the richest in Africa. The students visited the diamond mine in Jwaneng (Figure 5), which produced over 10 million carats of diamond in 2009 and is the richest diamond mine in the world.[16]

These concrete experiences motivate reflective observation on diamond. Diamond and graphite are both forms of carbon; graphite is the thermodynamically stable phase at low pressures, while diamond is the thermodynamically stable phase at high pressures. If diamond thus forms only at very high pressures, and such high pressures exist deep inside the earth, at what depth does the pressure become high enough for diamonds to form?

We develop an abstract conceptual model to determine the thermodynamic stability of diamond as a function of depth inside the earth. Diamond is thermodynamically stable with respect to graphite at the depth where the Gibbs free energy of diamond relative to graphite is negative, $\Delta G(h) < 0$. While ΔG depends directly on pressure (P) and temperature (T), P and T depend on h—P increases with depth due to the gravitational force from the material above, and temperature increases with depth due to the presence of radioactive material in the earth. The relevant equations are

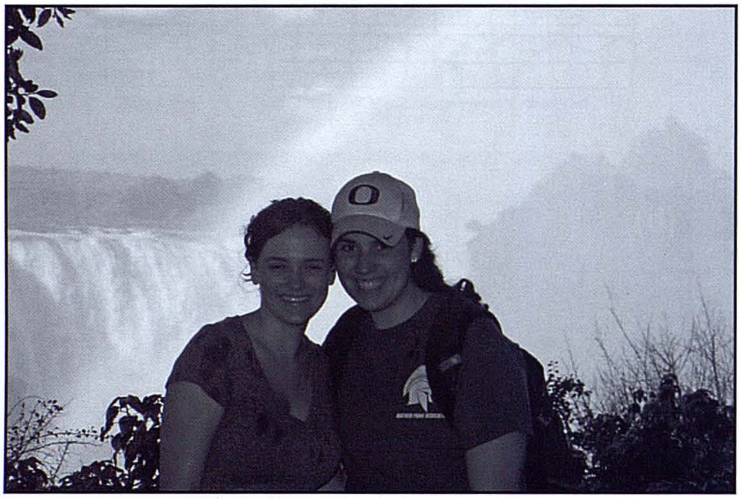


Figure 4. *Two of our students at Victoria Falls, with its permanent rainbow. A calculation carried out in class showed that the energy of the falling water at Victoria Falls could power 10 million 100 W lightbulbs.*

$$\Delta G(h) = \Delta G^0 + \left[P(h) - P^0\right]\Delta V^0 - \left[T(h) - T^0\right]\Delta S^0 \tag{4}$$

$$P(h) = P^0 + \rho g h \tag{5}$$

$$T(h) = T^0 + bh + ch^2 \tag{6}$$

where ΔV and ΔS are the differences in molar volume and molar entropy of diamond relative to graphite, the designation '0' implies evaluation at P=1 atm and T= 25 °C, ρ is the density, g is the gravitational constant, and b and c are empirical constants. These equations include approximations: Eq. (4) neglects changes of ΔV and

ΔS with P and T, Eq. (5) assumes constant ρ, and Eq. (6) is the polynomial fit of experimental results for the temperature profile under South Africa.[17]

Active experimentation with this model is used to estimate the depths at which diamond becomes stable, using Eqs. (4)-(6). A comparison of the pressure as a function of depth with the diamond-graphite stability range, shown in Figure 5, leads to the estimate that diamond is more stable than graphite for h>110 km (a more rigorous treatment would use more accurate pressure and temperature distributions in earth, and account for changes of ΔV, ΔS with P and T).

The students see that the diamond mine is only 300 m deep, far less than the >110 km depths at which diamonds are formed. In fact, diamonds are brought to near the surface by volcanic activity, whereby magma from deep in the earth ("Kimberlite") carries the diamonds from deep inside the earth to near the surface, where they can be collected and purified by mining operations.

ii. Energy from cow dung

Most African villages are not connected to national electrical and telephone grids. Portable devices such as cell phones are useful, but electricity is needed to charge the batteries (about 5 W-h per battery). A sustainable and essentially free source of energy in Botswana villages is cow dung—Botswana has more cows than people![18] Our trips outside Gaborone give students concrete experience with villages having no electricity but plenty of cattle (Figure 6).

Reflective observation is stimulated by a seminar describing research at UB using a calorimeter to determine the energy content of cow dung under various conditions. The abstract conceptual model underlying calorimeter involves the equation

$$\Delta E = MC\Delta T \tag{7}$$

where M and C are the mass and heat capacity of the water, and ΔE and ΔT are the changes in the internal energy and temperature of the water. As active experimentation, students are asked (on an exam) to determine how many cell phone batteries could be charged with 1 kg of cow dung, using the experimental result that the combustion of 206 g of cow dung increases the temperature of 2226 g of water from 16.8 ˚C to 52.1 ˚C. The calculation shows that 89 cell phone batteries could potentially be charged from the energy in 1 kg of cow dung.

ASSESSMENT

Our assessment of the 2011 implementation of our course aimed to evaluate the effectiveness of two "nontraditional" aspects of our course—the one-course-at-a-time format and the relationship of technical course content to societal issues in a foreign culture. A questionnaire was given to the students after they returned to the United States (and after grades had

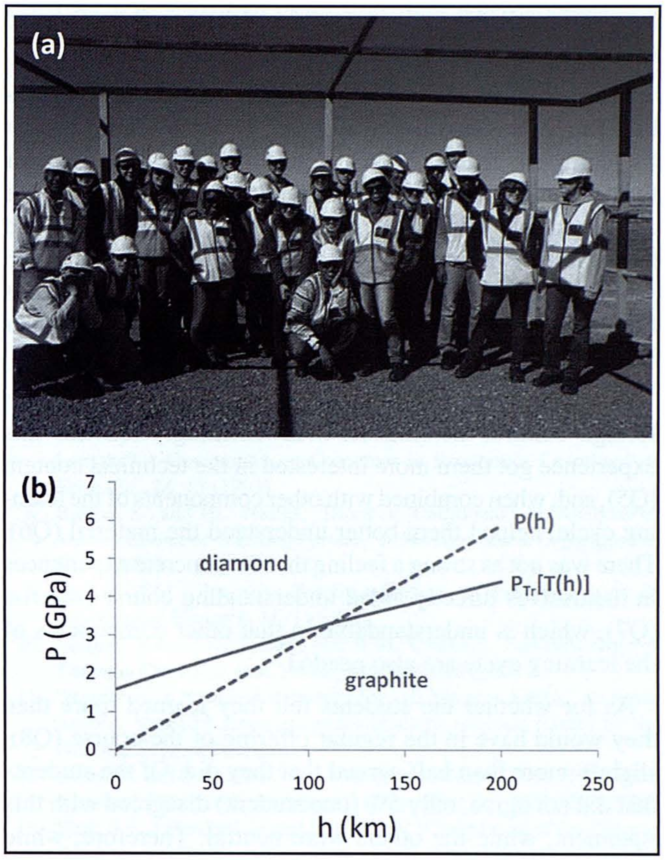


Figure 5. *(**a.**) Our students at the richest diamond mine in the world in Jwaneng, Botswana. (**b.**)Graphite-diamond stability curves as a function of depth inside of the earth. Results of our analysis show that diamond is thermodynamically more stable than graphite at depths below ~110 km in the earth. The model was evaluated with the parameters* $\Delta G^0 = 2900$ *J/mol,* $\Delta V^0 = -1.88$ *cm*^{3}*/mol,* $\Delta S^0 = -3.36$ *J/mol. K,*ρ *= 3000 kg/m*^{3}*, b= 11 ℃/km and c = −0.023 C/km*^{2}*.*

Figure 6. *The students saw that there are many cattle in Botswana, and villages without electricity. Calculations carried out in class, using data from University of Botswana research labs, showed that 1 kg of cow dung can provide the energy to recharge 89 cell phone batteries.*

been assigned). All students completed the questionnaire, and results are shown in Table 1.

The students overwhelmingly felt that the one-course-at-a-time format was effective in allowing for activities throughout the complete learning cycle (question Q1). The modular format had additional favorable features, in that the absence of other classes allowed the students to focus better (Q2), and that problem-solving activities during the class time catalyzed group work that helped learning (Q3). Only 10% of the class felt that the short duration of the course detracted from their learning (Q4).

In regard to the use of concrete experiences related to a foreign culture, the students overwhelmingly felt that this experience got them more interested in the technical content (Q5), and, when combined with other components of the learning cycle, helped them better understand the material (Q6). There was not as strong a feeling that the concrete experiences in themselves directly aided understanding course material (Q7), which is understandable in that other components of the learning cycle are also needed.

As for whether the students felt they learned more than they would have in the regular offering of the course (Q8), slightly more than half agreed that they did. Of the students that did not agree, only 5% (one student) disagreed with this statement, while the others were neutral. Therefore, while the students as a whole may not have felt they learned more in our course compared to the regular offering, they did not feel that they learned less.

Finally, all students felt that the course in Botswana gave them a global perspective that many people in the United States do not have the opportunity to obtain (Q9).

DISCUSSION AND CONCLUSIONS

Our goal is to create a course that overcomes the dry and often ineffective learning environment in traditional engineering courses. The approach follows the ideas of experiential learning, where students actively participate in a cycle of learning processes that tackle the problem in different ways (the Learning Cycle). The novelty of our approach is to intertwine the technical content with societal issues in a foreign culture to initiate the experiential learning. The course is taught at a university in a foreign country, in an intensive three-week format, to facilitate the experiential learning activities.

Based on the results of our assessment of our initial implementation of the course, we believe the approach met its intended goals. In particular, the students felt that experiential learning approach was successful—the connection of technical content to societal issues in a foreign culture generated interest in the technical content, and the use of activities throughout the Learning Cycle helped them better understand the material. Further, the students felt that the one-course-at-a-time format facilitated the experiential learning approach, and allowed them to focus better on the course.

Surprisingly, the cost for students to take our course is comparable to the cost for taking the same course on the CWRU campus during the regular (eight-week) summer session.

TABLE 1
Results of Assessment Survey

Assessment Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The intermixing of lecture with problem solving in a single (long) class period helped me learn the material better	75	20	5	0	0
2. The course format allowed me to work with others in the course more effectively, which in turn helped me learn the material better	50	45	5	0	0
3. I was able to focus better on this course because I didn't have to devote time to other courses	85	15	0	0	0
4. The course was too condensed in time and this prevented me from learning the material as well as I could have	0	10	25	40	25
5. The connection of course content to African life made me more interested in the course material	50	40	5	5	0
6. The opportunity to, within a day or two, actually see instances of a phenomenon (*e.g.*, water well, water fall, diamond mine, African hut), derive the relevant equations, and apply these equations helped me understand the material better	40	50	5	5	0
7. The connection of course content to African life clarified technical content and helped me learn the material better	25	45	25	5	0
8. I learned more than if I took the regular ENGR 225 course	35	25	35	5	0
9. The program in Africa gave me a global perspective that most people in the United States don't have	70	30	0	0	0

The costs for students in our course consists of three parts: (a) $3,100 for tuition, which is the standard tuition rate for a 4-credit summer course on the CWRU campus; (b) $650 for room and board (single room and all meals); (c) ~$1,500 for the flight to and from Botswana (the flights are booked directly by the students, and most students travel from their hometowns to Botswana). Thus the total cost for a student is approximately $5,250. In comparison to taking the same course on the CWRU campus during the eight-week summer session, the cost of the flight to Botswana is largely offset by the much-higher room and board costs at CWRU (over eight weeks). The tuition income from the course generated a surplus of funds after covering all course expenses (salaries and travel for two instructors and a teaching assistant from CWRU, all activities including a three-day safari excursion, and local costs at UB).

We realize that this type of approach cannot become the general solution to the inadequacies in engineering education due to "scale-up" issues. At CWRU, approximately 400 students take this core course every year, and it would not be possible to teach them all with the approach we describe here. We believe this is the only real shortcoming of the approach. Nevertheless, our approach can provide a great (and memorable) impact on a smaller scale.

ACKNOWLEDGMENT

This material is based upon work initiated with travel grants from the National Science Foundation (DMR-0912335), and the University Center for Innovation in Teaching and Education at Case Western Reserve University.

REFERENCES

1. Rugarcia, A., R.M. Felder, D.R. Woods, and J.E. Stice, "The Future of Engineering Education I. A Vision for a New Century," *Chem. Eng. Ed.*, **34**(1), 16 (2000)
2. Hake, R.R., "Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses," *Am. J. Phys.*, **66**, 64 (1998)
3. Felder, R.M., G.N. Felder, and E.J. Dietz, "A Longitudinal Study of Engineering Student Performance and RetentionV. Comparisons with Traditionally Taught Students," *J. Eng. Ed.*, **87**, 469 (1998)
4. Kolb, D.A., *Experiential Learning: Experience as the Source of Learning and Development*, Englewood Cliffs, NJ, Prentice-Hall (1984)
5. Kolb, D.A., R.E. Boyatzis, and C. Mainemelis, "Experiential Learning Theory: Previous Research and New Directions," in R.J. Sternberg and L.F. Zhang (Eds.), *Perspectives on Cognitive, Learning, and Thinking Styles*, Lawrence Erlbaum, Prentice-Hall, NJ (2000)
6. Kolb, D.A., I.M. Rubin, and J.M. McIntyre, *Instructors Manual, Organizational Psychology: An Experiential Approach to Organizational Behavior*, Prentice-Hall, NJ (1984)
7. van Scyoc, L.J., and J. Gleason, "Traditional or Intensive Course Lengths? A Comparison of Outcomes in Economics Learning," *J. Econ. Ed.*, **24**, 15 (1993)
8. Burton, S., and P.L. Nesbit, "Block or Traditional? An Analysis of Student Choice of Teaching Format," *J. Management & Organization*, **14**, 4 (2008)
9. Davies, W.M., "Intensive Teaching Formats: A Review," *Issues In Educational Research,* **16**, 1 (2006)
10. Cengel, Y.A., J.H. Turner, and R.M. Cimbala, *Fundamentals of Thermal-Fluid Sciences*, 3rd ed., McGraw Hill (2008)
11. "Research on Sustainable Energy for sub-Saharan Africa," an International Research Experiences for Students program funded by the National Science Foundation
12. Rives, C., and D.J. Lacks, "Teaching Process Control With a Numerical Approach Based on Spreadsheets," *Chem. Eng. Ed.*, **36**(4), 242 (2002)
13. Etuk, S.E., I.O. Akpabio, and E.M. Udoh, "Comparison of the Thermal Properties of Clay Samples as Potential Walling Material for Naturally Cooled Building Design," *J. Environ. Sci.*, **15**, 65 (2003)
14. <http://www.bpc.bw/doc/power_tariff_leaflet_eng.pdf>
15. Stark, A., J.M. Peralta, and L. Arendse, "Botswana: The World's Largest Diamond Producer By Value," *Eng. Mining J.*, May 2007, 70 (2007)
16. "Jwaneng—the de Beers Group," <http://www.debeersgroup.com/Exploration-and-mining/Mining-operations/Jwaneng/>
17. Rudnick, R.L., W.F. McDonough, and R.J. O'Connell, "Thermal Structure, Thickness and Composition of Continental Lithosphere," *Chem. Geol.*, **145**, 395 (1998)
18. "Botswana," U.S. Department of State, 4/18/2011, <http://www.state.gov/r/pa/ei/bgn/1830.htm> ❐