Int. J. Engng Ed. Vol. 10, No. 3, pp. 244–248, 1994
Printed in Great Britain.

0742-0269/91 $3.00+0.00

Engineering Students' and Science Educators' Rankings of Science and Technology Related Global Problems*

C. B. NDODANA†
K. ROCHFORD‡
D. FRASER§

†*School of Education*, ‡Student Learning Research Group and §Faculty of Engineering, University of Cape Town, Rondebosch, 7700, *Republic of South Africa*

Using 262 acknowledged science educators from 41 countries, Bybee developed a scale for measuring the ranked priorities of scientists, and others, with respect to 12 major global problems related to science and technology in 1984. In 1993 this scale was readministered to samples of 129 undergraduate chemical engineering students at the University of Cape Town and to 76 Cape Town science educators. High intercorrelations were obtained among the three samples' mean ranked priorities on the scale as a whole, over the 10-year period. Among the top six global problems in 1984, five received consistently high overall prioritization in 1993, namely population growth; world hunger and food resources; human health and disease; air quality and atmosphere; and water resources. The mean ranking of war technology as a priority declined by seven places. Important goals and issues singled out by individuals in a follow-up sample of 20 lecturers in engineering at the University of Cape Town in 1993 included the provision of mass housing and infrastructure, sanitation, urbanization, job creation, the abuse of high technology in communications, technological illiteracy among decision-makers, abuse and reduction of oceanic resources, photochemical smog, the prediction and possible control of droughts and floods, demands on the human race of the information explosion, electromagnetic wave hazards and pollution, resource depletion, education and the dissemination of knowledge, the emergence and separation of C. P. Snow's 'Two Cultures' and the myth of the peace dividend.

INTRODUCTION

RECENTLY, a new program has been developed at the undergraduate level at the New Jersey Institute of Technology (NJIT) for chemical engineering students through the collaborative efforts of three faculties, namely Chemical Engineering; Humanities; and Science, Technology, and Society (STS) [1]. One of the goals of this program is to foster independent thought, a sense of cultural and intellectual breadth, and an awareness of ethical issues. In the senior courses, emphasis is on the importance of applying scientific principles to *identifying and solving problems* such as conservation and environmental control [1].

Many engineering problems are global in concept but local in solution [2, 3]. Regional environmental problems provide good illustrations. Specific examples are: actions involving rainforests in Brazil affecting global warming; power plant emissions; US automobile emissions; and mitigating hazardous waste at a planned industrial park [1, 3].

Modern engineers have a multidimensional task in society. Their work involves meeting major human needs, including sustainable development and environmental protection; designing and solving problems in real situations; anticipating health effects; and many others [1, 4, 5].

It is in this context that the Bybee scale is a useful, convenient and appropriate instrument for measuring ranked priorities of engineers and other groups of scientists with respect to 12 of the most important recognized major global problems related to science and technology [6].

BACKGROUND

This study is an enlargement and corroboration of the consistency of the findings with a sample of 262 surveyed international science educators reported by Bybee and Mau [6], and by Bybee and Najafi [7] with a sample of 317 surveyed college science students. No similar studies, however, appear to have been carried out with samples of undergraduate engineering students.

* Paper accepted 16 January 1994.

OBJECTIVES

The aim of the research is to determine:

1. which global STS problems remain highly prioritized in 1993 compared with earlier prioritizations made in 1984; and
2. the significance of high rank-order correlations occurring among samples of engineering undergraduates, international science educators and Cape Town science educators on the Bybee scale.

CLARIFICATION OF TERMS

- *Chemical engineering* is that professional field which applies chemical and physical understanding to the manufacture of materials, fuels, pharmaceuticals, chemicals, fertilizers and foods that together enhance the quality of life [8].
- *Science–technology–society* (STS) is the term applied to the latest effort to provide a real-world context for the study of science, and for the pursuit of science itself. It focuses upon current issues and attempts at their resolution as the best way of preparing people for current and future citizenship roles [9].
- *Global problems* related to science and technology, as determined in 1984 by acknowledged science educators from 41 countries, are defined in the instrument used for the data collection [6], presented in Table 1.

PROCEDURE

Selection of the instrument

A 12-item instrument developed by Bybee for use with scientists [10], citizens [11], college students [7] and science teachers [12] was used for data collection. A Cape Town pilot study was conducted with a sample of 18 undergraduates in order to determine the test/retest reliability of the instrument. This yielded a reliability coefficient of $r = 0.80$ when the intact sample was retested with the same instrument after an interval of one hour. Bybee's instrument was originally developed and refined using 262 acknowledged science educators from 41 countries [6]. For the purpose of this study that original group in 1984 will be designated as sample 1.

Data collection in 1993

Sample 2 comprised 76 Cape Town science educators surveyed as an intact group in August 1993. Sample 3 consisted of 129 undergraduate chemical engineering students of the University of Cape Town, with the data collected in October 1993 from classes of students in years 2–4 being combined into a whole. Sample 4 comprised 20 lecturers in engineering at the University of Cape Town who responded to an open-ended follow-up questionnaire in December 1993.

Table 1. Ranking of science and technology related global problems

What do you see as the most important global problems related to science and technology? Rank the following from 1 to 12 (with 1 indicating your top priority). Insert your numbers in the appropriate brackets.

GLOBAL PROBLEM

[ ] HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals, lead paints)

[ ] HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress, noise, diet and nutrition, exercise, mental health)

[ ] MINERAL RESOURCES (non fuel minerals, metallic and non-metallic minerals, mining, technology, low-grade deposits, recycling, refuse)

[ ] WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertilizer contamination)

[ ] POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability)

[ ] EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity, widlife protection)

[ ] ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production)

[ ] WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear arms threat)

[ ] AIR QUALITY AND ATMOSPHERE (acid rain, CO_2, depletion of ozone, global warming)

[ ] WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation)

[ ] LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, salinization)

[ ] NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, terrorism)

RESULTS AND FINDINGS (see Table 2)

It was found that the rank-order correlation between the 1993 engineering undergraduates' priorities and the 1984 international science educators' priorities was 0.65. Between the 1993 engineering undergraduates' ratings and the 1993 Cape Town science educators' ratings, the correlation is 0.85. These are significantly high correlations reflecting a large degree of consistency over a 10-year period on the same set of issues.

Prioritization of the first six global problems in 1993 indicates a close match with the same global problems prioritized in 1984. However, individual changes in rank-order occur. There is, however, one exceptional item in each sample's ranking, namely *war technology* in the case of the international science educators; *hazardous substances* in the case of engineering undergraduates; and *land use* in the case of Cape Town science educators.

Priorities singled out by individuals in the follow-up sample of 20 lecturers in the Faculty of Engineering at the University of Cape Town in 1993 included the provision of mass housing and infrastructure, sanitation, urbanization, job creation, the abuse of high technology in communications, technological illiteracy among decision-makers, abuse and reduction of oceanic resources, photochemical smog, the prediction and possible control of droughts and floods, the demands on the human race of the information explosion, electromagnetic wave hazards and pollution, resource depletion, education and the dissemination of knowledge, the emergence and separation of C. P. Snow's 'Two Cultures' and the myth of the peace dividend.

Urbanization was described as a many-faceted problem encompassing sociology, systems engineering, water supply, waste water treatment and land use.

The abuse of high technology in communications was mentioned as encompassing global indoctrination of the masses by television; the creation of hybrid bioelectric systems; genetic engineering devoid of an understanding of the role that chaos plays in ensuring the survival of life; and the proliferation of doubtful information by satellite.

The depletion of oceanic resources was said to be manifested in overfishing, pollution, rising sea levels, and the effects of the ability of the oceans to absorb more carbon dioxide.

The effects of microwaves on humans and animals were also singled out as causes of concern.

The myth of the peace dividend was that even though less money is now being spent on armaments, the savings are *not* going into new technology to solve the problem. This concern is to be addressed in evolving engineering curricula.

DISCUSSION AND CONCLUSIONS

This study has shown that among the top-ranked items, over a 10-year period, the most important global problems remain population growth; world hunger and food resources; human health and disease; air quality and atmosphere; and water resources. These top-ranked items clearly relate to basic human needs for long-term survival (health, air, food and water) and provide evidence to support the importance, stability and relevance of modern curricula in chemical engineering. Population growth, with first and second rankings, suggests a common concern which links the above-mentioned problems directly or indirectly.

The higher ranking of the hazardous substances by the chemical engineering students indicates their awareness of the importance of this problem to human health. Currently, at the University of Cape Town, more than half of the third-year

Table 2. The mean priority scores, and ranks of relative importance, of 12 global problems in science and technology rated by three samples of science educators/engineers over a 10-year period

	1984 international science educators $n = 262$		1993 Cape Town science educators $n = 76$		1993 University of Cape Town chemical engineers $n = 129$	
Global problem	Mean priority score	Rank of relative importance	Mean priority score	Rank of relative importance	Mean priority score	Rank of relative importance
World hunger	3.92	1	3.98	3	4.96	2
Population growth	4.35	2	3.58	2	4.95	1
Air quality	5.43	3	6.49	6	5.26	4
Water resources	5.53	4	4.62	4	5.38	5
War technology	5.80	5	8.84	11	9.20	12
Human health	5.82	6	3.36	1	4.98	3
Energy shortages	6.30	7	7.15	7	6.80	8
Land use	6.52	8	6.01	5	6.47	7
Hazardous substances	7.49	9	7.96	9	5.83	6
Extinction of plants/animals	8.37	10	7.94	8	7.15	9
Nuclear reactors	8.38	11	9.82	12	8.98	11
Mineral resources	9.40	12	8.03	10	8.15	10

chemical engineering students take an optional course on environmental process engineering.

War technology, over a 10-year period, has been re-ranked from the fifth position initially designated by international science educators to the 11th and 12th positions assigned respectively by Cape Town science educators and undergraduate chemical engineers of the University of Cape Town. This change in position might be attributed to the agreed strategic arms limitations of the former USSR and the USA which, at this point in time, do not seem to threaten the Republic of South Africa.

The change in position of *human health*, during the last 10 years, from the sixth to the first and third positions, might be attributed to a more widespread awareness of diseases such as AIDS and an increase in the incidence of skin cancers associated with depletion of the ozone layer [13–15].

High-quality education, geared towards finding creative solutions to pertinent and pervasive problems such as these, remains crucial for the practice and development of relevant engineering for the wider benefit of humanity.

Acknowledgements—The authors acknowledge, with thanks, the critical comments and insights of Professor J. H. F. Meyer, and the assistance of the 1993 classes of chemical engineering students of the University of Cape Town; and the Cape Town science educators' in-service group which participated in the study. The financial assistance of the Centre for Science Development towards this research is hereby acknowledged. Opinions expressed in this paper, and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the Centre for Science Development.

REFERENCES

1. S. Fenster, New directions in engineering education at New Jersey Institute of Technology, *Int. J. Engng Ed.*, **9**, 56–59 (1993).
2. Z. P. Pudlowski, A brief review on engineering education on the Australasian and international scene. *Int. J. Appl. Engng Ed.*, **6**, 3–7 (1990).
3. H. Decker, Global and local aspects of engineering from a corporate perspective , *Int. J. Engng Ed.*, **9**, 90–92 (1993).
4. J. Bordogna, Systemic change for engineering education: integrated trends in the United States, *Int. J. Engng Ed.*, **9**, 51–55 (1993).
5. R. C. Jones, Results of the second international symposium for engineering deans and industry leaders, *Int. J. Engng Ed.*, **8**, 11–15 (1992).
6. R. Bybee and T. Mau, Science and technology related global problems: an international survey of science educators. *J. Res. Sci. Teach.*, **23**, 599–618 (1986).
7. R. Bybee and K. Najafi, Global problems and college education: a survey of students. *J. Coll. Sci. Teach.*, **XV**, 443–447 (1986).
8. H. A. McGee, Chemical engineering education in Japan, Germany and America. *Int. J. Engng Ed.*, **9**, 99–103 (1993).
9. D. H. Ost and R. E. Yager, Biology, STS and the new steps in program design and curriculum development. *Am. Biol. Teach.*, **55**, 282 (1993).
10. R. Bybee, Global problems and science education policy. In R. Bybee, J. Carlson and A. McCormack (eds), *Redesigned Science and Technology Education*, 1984 NSTA Yearbook, National Science Teachers' Association, Washington DC, pp. 60–75 (1984).
11. R. Bybee, Human ecology. In *A Perspective for Biology Education*, National Association of Biology Teachers, Reston, VA (1984).
12. R. Bybee and R. Bonnstetter, Science–technology–society: What do science teachers think? In R. Bybee (ed.), *Science–Technology–Society*, 1985 NSTA Yearbook, National Science Teachers' Association, Washington DC (1986).
13. W. H. R. Tseng, Environment and engineering: the society call for humane engineer. *Proc. World Conference on Engineering Education for Advancing Technology*, University of Sydney, Australia, pp. 923–926 (1989).
14. I. Ramalho de Almeida, Continuing education for the environment: an industrial perspective. International Cooperation between Industry and Academia, *Proc. Second European Forum for Continuing Engineering Education*, Technical University of Lisbon, Portugal, pp. 41–43 (1992).
15. P. B. Sloep, M. C. E. Van Dam-Mieras and W. H. De Jeu, International environmental issues at a distance. International Cooperation between Industry and Academia, *Proc. Second European Forum for Continuing Engineering Education*, Technical University of Lisbon, Portugal, pp. 35–40 (1992).

Cynthia Ndodana is currently a lecturer at Clarkebury College of Education in the Department of Sciences. She obtained her B.Sc. degree from the University of Fort Hare, PDE (Diploma) from the University of Transkei and B.Ed. from Rhodes University. She is currently registered for an M.Ed. (Sciences Education) at the University of Cape Town. Her research interests are in environmental science with particular reference to the global priorities of science and engineering educators.

Kevin Rochford is an Associate Professor of Science Education at the University of Cape Town. He gained his B.Sc. at Melbourne University, and B.Ed., M.Ed. and Ph.D. at the University of Cape Town. His chief research interest is in the diagnosis and remediation of specific cognitive learning disabilities among underachieving science and engineering students.

Duncan Fraser is a Senior Lecturer in Chemical Engineering at the University of Cape Town. He holds the degree of B.Sc. (Chem. Eng.) and Ph.D., both from the University of Cape Town. After obtaining his Ph.D. he worked in the oil industry for three years before returning to academia. He is a member of the South African Institute of Chemical Engineers. His research interests are in engineering education, particularly of disadvantaged students, modelling of chemical engineering systems and heat exchanger network synthesis.