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Diversifying Engineering Education: a Seminar Course on the Ethics and Philosophy of Appropriate Technology*

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Student awareness of cultural diversity issues, social and ethical concerns, and the practice of proactive environmental stewardship are all important components of an accredited engineering education today, as per the Accreditation Board of Engineering and Technology (ABET). This education is focused on outcomes that demonstrate student competence in technology, communication skills and multidisciplinary teamwork. Appropriate technology (AT) addresses all of these concerns. AT can be broadly defined as technology relevant to real social needs that is accessible, affordable and empowering to the communities it serves and that use it. This seminar course on the ethics and philosophy of AT was developed and offered to help fill a student-expressed need for education and enlightenment on this broad issue. The course begins with introductions to AT, followed by specialist-delivered seminars and discussions that expand on pertinent topics. These presentations included the history of engineering and technology development, the philosophy and ethics of technology, and the responsibilities of scientists and engineers. The seminars also cover particular case studies, including technology education and development in Cuba and Zimbabwe, and the global development and implementation of appropriate technology in urban and rural settings. Readings are assigned prior to each seminar and students are expected to participate in discussion and research and submit one short paper, as well as present and submit one major AT research or design project.

INTRODUCTION

A seminar course has been developed that provides students with a broad overview and an in-depth study of appropriate technology (AT), grounding the study in an understanding of, and appreciation for, the ethics and philosophy of technology and its uses. During the course, the faculty team facilitates discussions about the philosophy of technology including debates about the assumed neutrality of technology and ways to guide and control the direction of technology development. In addition to readings and seminars in ethics and philosophy of technology, the course introduces students to, and familiarises them with, case studies from around the world, focusing particular attention on alternative socio-technological and politico-economical models of development, with extensive presentation and discussion of the case studies of AT in Cuba and Zimbabwe.

The course is offered by the Department of Philosophy at Howard University, Washington, DC, USA. Participants in the course included those from science and engineering departments, as well as those from philosophy. This diversity led to interdisciplinary discussions of crosscutting themes and ethical issues.

Appropriate technology is a very broad term that

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has been applied to a diverse set of technologies that have generally been developed and implemented to facilitate development. The criteria for a technology to be deemed appropriate are broad and subject to extensive debate, and hence AT is difficult to define [1]. However, there is general agreement on what characterises such a technology. Appropriate technology has following characteristics:

- Requires only small amounts of capital;
- Emphasises the use of locally available materials;
- Is relatively labour intensive;
- Is small scale;
- Is affordable to individual families.

Appropriate technology should also be able to:

- Be understood, controlled and maintained without high levels of education and training;
- Be able to be produced in small shops and villages;
- Be adaptable and flexible;
- Include local communities in the innovation and implementation stages.

Ultimately, AT should not have any adverse environmental impact [2].

The rationale of AT resides in its empowerment of people at the grass roots level. Developmental professionals agree that local needs can be met more effectively with the community working to address their own needs. Tools that are developed should extend, not replace, human labour.

AT also emphasises controllable scales of activity. The rationale is also grounded in the minimisation of financial, transportation, education, advertising, management and energy services and costs with the goal of engendering self-sustaining and expanding reservoirs of skills within a community. The result is a lowering of economic, social and political dependency, and a move towards sustainable development that is focused on people's needs, which are grounded in empowerment through education, technology transfer, capacity building and local control.

COURSE OUTLINE

The course was configured as a 3-credit seminar course where students, faculty and other interested attendees meet for two hours each week. The seminar presentation outline is shown in Table 1. Beginning with an introduction to AT, its rationale and characteristics, students are led in a seminar-type lecture-discussion structured learning environment through various examples of AT. In the second seminar, various case studies of successful and unsuccessful developments and implementations of appropriate technology are presented and discussed. Potential topics for papers and major projects are detailed for students.

Table 1: Course seminar outline.

Week	Seminar Discussion Topic
One	What is Appropriate Technology?
Two	AT Paper Topics and Potential Projects
Three	Ethics as an Experimental Science
Four	Case Study 1: AT in Zimbabwe
Five	Engineering Ethics and AT
Six	AT, Anthropology and the Environment
Seven	Case Study 2: AT in Cuba
Eight	AT: Local and Global Issues
Nine	Case Study 3: Automobile Technology and Transportation: an Integral Approach
Ten	Student Major Project Presentations

The various lectures are presented by professors who have research interests, experience and scholarship in that particular area. Faculty seminar presenters and primary discussants come from a broad array of disciplines, including philosophy, chemical, civil, and electrical and computer engineering, systems and computer science, biology, anthropology and sociology, and science and technology studies.

The assessment and evaluation of student performance in the course focused on three components, namely:

- Students were evaluated on their class attendance and participation (20%);
- Students were required to research, write and submit one short paper (20%);
- Students were required to research, write and submit one major AT design project, while also making a seminar presentation of their major project (60%).

In the major project, two-thirds of the grade was based on the written report and a third on the students' presentation.

Students are provided readings prior to the seminar. The readings, course syllabus and other Internet resources are accessible from the course Web site: (http://www.geocities.com/howard_upat/PhEtApTe.htm). At the end of each seminar presentation, the material is placed on the course Web site, giving students continuous access to the seminar presentations. This was useful as students conducted their own research and investigation into AT.

The following provides some of the critical issues presented and discussed during the course.

APPROPRIATE TECHNOLOGY

Students were provided the syllabus and Web site, as well as several readings at the outset of the course. The introductory seminar set out to define and characterise AT and illustrative examples of technologies that are considered *appropriate*, as well as examples of technologies that were initially considered appropriate, but were later demonstrated to be unworkable.

For example, a project to develop, construct and deploy windmills made of local resources was implemented, unfortunately, in a region with little wind. Another example of a failed appropriate technology is the development of soap making skills and resources in a rural setting. Here, the community was actually too poor to purchase soap, while those that did have the monetary resources preferred the commercially available and popular versions of soap, especially for the social cachet such consumption provided the purchaser.

An excellent and early example of appropriate technology that underscores the importance of context in deciding whether a technology is appropriate or not is that of M.K. Gandhi urging his fellow Indians to use the spinning wheel to produce homespun cotton while eschewing British-produced clothing. The context is the Indian struggle for independence from Colonial Britain and the role this technology played. It initiated the development of indigenous textile industries and provided a focal and rallying point for the independence struggle.

It is often held that AT is *low-tech*, a notion embedded in the historical view of appropriate technology as being *intermediate* and bridging the gap between *low* and *high* technologies with the goal of accelerating development. This received notion is challenged as students are shown efforts in developing nations that have focused on *high-tech* applications, including solar energy and energy consumption analysis, biomass energy sources, dry land farming and other new agricultural techniques, food preservation, and information and communications technology [3]. This includes, more recently, the rural wireless Internet, and the impact of these technology projects on development and rural empowerment.

These discussions help students to understand that AT is highly context and situation-specific, where geography, culture, location and economics (to name a few variables) all play a role in determining the success or failure of a particular technology.

APPROPRIATE TECHNOLOGY PAPER AND PROJECT TOPICS

In the second week of the course, students are introduced to possible AT project and research topics. The discussion is stimulated by examples of successful appropriate technology projects, including the deep-well hand pumps in India, oral re-hydration therapy to combat dysentery, bamboo reinforced rainwater storage tanks in Thailand, rural access roads and the indigenously produced toolbar plough and cart in Kenya.

AT project areas include agriculture, water, energy, transportation, health care, education, small business, communications and small workshops. Examples of potential AT projects in each of these areas are shared. Students then submit a project proposal for approval by the faculty. In the area of water, for instance, water supply, hand pumps, water treatment and water storage are some of the specific project focus areas. In energy technology, suggested AT research topics can focus on renewable energy sources, biomass and bio-diesel, solar energy, bicycle and human power, hydroelectric and micro-hydroelectric energy, cooking stoves and wind energy, among others. In the healthcare area, projects can focus on the provision of primary health care, control of communicable diseases, developing, distributing and fostering alternative medicines, dental care and physiotherapy.

ETHICS AND PHILOSOPHY

The philosophy of technology is introduced in the second and third weeks to set the analytical tone for the course. The great majority of the undergraduate engineering students graduate without a critically informed view of technology and its effects on society. As a consequence, students engage in understanding technology development while turning a blind eye to philosophical analyses. One goal of this course was to provide the critical tools necessary for understanding technology development in the societal context.

If more engineering students enter the technology research and development workforce with a broader vision of the social implications of technology, critical and necessary discussions on the directions, scope and implications of technological advances can take place at various levels in society, including the political, financial, academic, cultural and human levels. These discussions should lead to socially relevant decisions that should reveal a more appropriate path to follow that address higher and more noble goals.

AT emerges as the outcome of broad and comprehensive theoretical study of specific technologies applied in a given context. In the course, the main focus was not to decide *a priori,* which technologies would be beneficial and which would be destructive but, more importantly, to develop and generalise a critical approach to technology evaluation and assessment that asks the questions necessary to reveal new directions to find better answers.

Ethics, together with the philosophy of science and technology, is an integral component of the course material. Ethics is introduced early (week three) with a faculty team member from Philosophy presenting the seminar and leading the discussion.

Ethics is introduced as an experimental science that is focused on the critical study of *morals* [4]. The course considers how transformations in society change what is considered ethical at given periods in history. Students are asked to question themselves and look inwards for the core source of their beliefs and their morality. They discover that ethical dilemmas confronting a science or engineering professional are viewed differently by those in the humanities, public policy and business.

The seminar focuses on ethical conflicts, particularly those posed by moral relativism and legitimate professional disputes over ethical judgements. Case studies illustrate useful techniques to help engineers and community members make group decisions about the ethics of appropriate technology applications.

Students are encouraged to approach ethical conflict as an opportunity and stimulus to create new approaches to ethical dilemmas, rather than view them as a hurdle to be overcome. The most effective case studies illustrate how the aim of ethics is to minimise the damage in a situation where no compelling arguments dictate a judgement issuing from *best ethical practices*.

Students are asked to consider the place of ethics in the larger discipline of philosophy, defined in the course as a set of beliefs and practices. As a set of beliefs, philosophy consists of the ungrounded, highly speculative assumptions people use to guide their lives under conditions of insufficient knowledge. As a set of practices, philosophy is the incessant activity of re-examining those assumptions in order to improve them.

Exemplary philosophers are those thinkers who challenge people's assumptions in order to give powerful new visions of how to solve intractable problems. In this course, Newton and Einstein are counted as philosophers, along with Plato and Socrates. The primary objective of philosophy as a *pursuit of wisdom* or total knowledge is to facilitate the discovery of new knowledge – the reason why PhDs, or *doctorates of philosophy*, are awarded to those who create new knowledge in any field whatsoever.

A primary theme of the seminar is the structure of ethical revolutions. Collective human ethics evolves from the realisation that a genetic bond need not be the glue of a chiefdom, to the claim that all humans constitute a single group, to the insight that human bonding should be based on people's fundamental differences, rather than people's homogeneity, to the controversial contemporary claim that ethical rights must be accorded to non-human living beings, even to inanimate nature itself.

Ethics is an experimental science precisely in the sense that cultures are experiments in living, as John Stuart Mill suggested. Those experiments are most successful that promote the survival and flourishing of life on Earth in a sustainable way. Ethics, science and engineering are all grounded in highly abstract assumptions. The aim in all three disciplines is to convert the grand philosophical gesture into a working theory that can be used to anticipate experience. Each discipline must rely on the other so as to achieve their collective aim: a sustainable life that is worth living.

APPROPRIATE TECHNOLOGY CASE STUDIES

The course format utilised case studies to expand understanding and discussion in the classroom. Two important cases on a country-specific basis are Cuba and Zimbabwe. These two countries present excellent opportunities for students to examine and investigate economic and social development, as well as the progress and evolution of technology, in a socialist environment that eschews private capital. The results are illustrative of the differences that can accrue in terms of development because of the socio-economic and political context of the location that these changes occur in.

Transportation technology is used as a technology case study of the unforeseen and unanticipated consequences of particular technology choices. It may be considered an example of what not to do with technology. Transportation technology development has shown a lack of focus on improving society, while directing excessive attention on profiting at any cost.

COUNTRY CASE STUDY 1: ZIMBABWE

After independence from Great Britain in 1980, the new Zimbabwean government chose a socialist, state controlled economic path of development. However, the reality of minority private ownership and control of the economic sector required the maintenance of private enterprise in most sectors. Additionally, concessions agreed upon at independence in the Lancaster House Agreement restricted the new government's options of economic reform.

One sector the government could control was education, and over the past 25 years, all levels of the educational system have been expanded. A strong emphasis has been placed on technical capacity building with the creation of a major science and technology university, the National University of Science and Technology (NUST) in Bulawayo, Zimbabwe, as well as several regional technical universities and colleges. In many instances, a curriculum was developed to reflect the national and regional technical skills critically needed for the development and alleviation of poverty. These curricula encouraged self-sufficiency and stressed empowerment through technology education.

In the late 1990s, political and social changes set the climate for an aggressive plan for agricultural land transfer. Land ownership and land reforms were implemented to correct the many inequities of past racially segregated regimes. Over one hundred thousand indigenous small family farms were provided fertile land for the first time. Making this transition as productive as possible proved a challenge to the young government. It required extensive training and the selection and deployment of appropriate technologies to match the skills and resources of the new farmers, as well as the geographic and agricultural particularities of the new farms.

The Minister of State for Science and Technology Development, Dr Olivia Muchena, pointed out: *unless appropriate science and technology policies are put in place, it would be difficult to address national needs and priorities* [5]. The manner of land reclamation and the fact that many displaced large landowners had close ties with Great Britain, resulted in condemnation from the Western powers. As land transfer was instituted on a broader and broader scale, the country was isolated more from the world capitalist system, as economic and financial blockades were initiated against Zimbabwe.

This isolation from the capitalist world economy forced Zimbabwe to rely more on its own resources for development. Here, AT is linked to the control of a nation's resources, with specific attention in Zimbabwe to the reclamation and redistribution of land through land-reform programmes, and to how AT can impact this. The focus is also to decrease the dependence of domestic technology developers on outside resources that consume scarce foreign exchange reserves (dollars or euros) and enhance the poor and small farmer's capacity to survive and prevail in the face of these tough conditions. This technology-based drive toward self-sufficiency goes beyond the agricultural sector.

The Scientific and Industrial Research and Development Centre (SIRDC) had been given a mandate to assist with the industrialisation of the country. SIRDC recently organised the production of a quality low-cost roofing material, called micro-concrete roofing or MCR [6]. In the context of technology transfer, it is critical to discuss the impact of politics and the power of external multilateral financial institutions on internal development. A conference recently held in Zimbabwe focused attention on AT for sustainable land management and rural development, and papers at the Conference highlighted strategies for indigenous and appropriate technology development [7].

COUNTRY CASE STUDY 2: CUBA

In Cuba, with its long history of being embargoed by its giant neighbour to the north, the USA, there has been a longer tradition of developing self-reliance on internal resources. This became especially important after the collapse of the Soviet Union and the loss of the oil subsidy it provided, as well as the loss of the markets for Cuban products in the Soviet bloc, which had by then ceased to exist. The early 1990s saw this as a *special period* where Cubans had to rely on internal resources and expend more efforts to harness and develop these resources. For Cuba, with its intense emphasis on education as the true mechanism for empowerment, this transition was difficult but made easier with the large pool of technically and scientifically skilled citizens that had been created as part of the early and heavy emphasis on educating people to move them out of poverty.

After the collapse of the Soviet Union and the loss of this superpower patronage, Cuba continued to invest in educating its children, in making itself self-sufficient in food production, in developing and providing adequate housing and in preparing each of its citizens with adequate job-training. Cuba's economic priorities have shifted, from mainly sugar and tobacco – which are still a good third or more of economic activity – to biotechnology, tourism and historic preservation, and higher education. Cuba's achievements are impressive: despite a Gross Domestic

Product (GDP) per capita of only $5,200 – the USA is $34,320 by comparison – Cuba's quality of life indicators, including life expectancy index (0.86 compared to the world highest of 0.94), education index (0.90 compared to the world highest of 0.99), and human development index (0.806 compared to the world highest of 0.944) are all at the high end of the scale. This suggests there is something to be learned from the social and economic development models and emphases that Cuba has adopted through its history, and is a necessary part of any discussion of technologies that are appropriate.

It is useful to provide some indicators of appropriate and *green* technology development. For instance, international indicators estimate that a city needs 12 m^2 of green space, per inhabitant, to be sustainable. Havana has met this requirement, even after Hurricane Charley wreaked its havoc on the island nation. Cuba has achieved this by many mechanisms, including *My Green Program*, which promotes citizen participation in urban reforestation efforts, and commits the citizens of Havana to plant two trees for every one that was torn down in the hurricane. Havana-based agricultural companies are joining with citizens in a unique urban agricultural movement to expand reforestation efforts that include gardens and house patios, as well as green areas around health, education and employment centres.

In terms of education, it has been reported that Cuba has developed over 200 computer programs for teaching in various disciplines and that the country has the largest number of teachers, per capita, at an astonishing rate of one for every 37 inhabitants, a rate not matched anywhere in the western industrialised world. Attendance of 100% in elementary schools is also higher than that in the developed industrialised nations [8].

In health care, Cuba has been hailed as an example of how to successfully combat the HIV/AIDS pandemic. Although the situation in an island nation economically isolated from much of the western industrialised is unique, the efforts of Cuban health authorities have resulted in an HIV infection rate of less than 0.1%, which is especially remarkable given that Cuba is in a geographic region with the fastest-growing HIV infection rates in the world [9].

Cuba's success in the critical metrics of human development is directly associated with its integration of AT with a national development agenda. As a case study, it offers numerous lessons on AT and challenges the capitalist notion of competition rather than cooperation as the most effective route to sustainable development.

TECHNOLOGY CASE SUDY: AT AND TRANSPORTATION

Transportation technology is examined in the course in order to illustrate the social and political forces that shape technology development. It also demonstrates the unforeseen consequences of technological advances. The story of technology development in the transportation sector exemplifies how the lack of focus on societal improvement with a concomitant excess of attention on profiting at any cost is antithetical to sustainable development. The outcome can be observed, from the streets of Honolulu to the avenues in Washington DC, from the smog in Los Angeles to the financial debacle of the US airline business, and from the uncomfortable urbanisation in Puerto Rico to the over-populated and crowded streets of Calcutta.

Kwinty documents and explains the deviant and skilful manipulation of the legal system by various corporations to dismantle and replace an existing and working transportation system in order to handsomely and selfishly profit from this massive, society-wide technological transformation [10]. In the 1920s, US transportation relied mainly on centrally generated electricity as the energy source for urban transportation. The transportation system was clean and energy efficient, especially when compared to the car-centred system in place today. The common perception and received understanding of the development of the car industry is that it was possible primarily because it outperformed any other alternatives, in fair competition. The story that ended with eight companies and seven individuals convicted on charges of criminal antitrust violations suggests a completely different rationale for the automobile's current success.

During the 1930s, a group of corporate executives from General Motors, Greyhound, Firestone, Standard Oil of California, Mack, Philips 66 and Bank of America, got together to plan the fastest and most profitable way to make the automobile central to the American way of life. It happened innocuously enough. These companies financed E. Roy Fitzgerald who was able, with this backing, to expand his tiny Minnesota-based bus company into a multi-city, multi-state bus company called National City Lines (NCL). The companies financed NCL with the objective of shifting electric-based public transport to gasoline-based bus transportation, not with any particular objective of making NCL profitable.

In fact, NCL's financing companies were not particularly concerned if NCL went bankrupt: they wanted this technology to debilitate electric-based transportation, and this is exactly what happened. In fact, General Motors was so eager to add new investors that even GM's competitor, Mack, was approached to join the group, even though this meant less profit for GM in bus sales.

In the trial that eventually took place, GM executives tried to claim that NCL was a profitable business, but they failed to explain why GM encouraged Mack's inclusion. It suggests that Mack's inclusion and the concomitant decrease in GM's profit was only a temporary financial burden incurred to achieve the greater long-term goal.

From what can be seen around us today, the goal was achieved, but at a high public and social cost. The electric rail systems were methodically dismantled and replaced with less efficient buses. After the trial, the companies and executives paid fines of $5,000 each and the individuals had to pay $1 each. What followed was now inevitable: government-funded development of US roadways and massive expansion of automobile use. Financial prosperity and long-term spots to feed at the public trough were secured for the oil industry, car manufacturers and the tire industry, among others.

It is impossible to know for sure what kind of transportation system would have prevailed and how urban and sub-urban development would have proceeded without the automobile as the central mode of mobility [11]. However, it is likely that a more energy efficient transportation system that would be more focused on mass transport and the minimisation of environmental damage would have been on the table, if not for the manipulations of these few executives and corporations.

The focus on transportation technology development provides students with a technology case-study experience relevant to the examination of technology and society. There are other interesting rapidly developing technologies that could be the focus of investigation. A case in point is the cellular telephone. Huyke poses a number of interesting questions, the answers to which have broad and deep consequences for society [12][13]. How are cell phones manufactured, produced, used, replaced and disposed of? How does the convenience of a cell phone affect a person's capacity to have meaningful interpersonal communications? The cell phone has become an extension of a person's body, an extra hand, extra memory, an extra ear, to the point where the modern citizen feels handicapped without it. The consequences of this modern technological social appendage are far-reaching and worthy of investigation.

There are a number of other technologies whose integration into modern society has made dramatic changes in social organisation. These include the Internet and its attendant promises of more democratic information access and distribution, including distance learning. Web-based learning provides education access to many non-traditional students, but if applied to replace existing educational spaces, the potential effects of this replacement must be evaluated and assessed.

For technology development to proceed with a minimum of social and environmental cost, there is a clear need for an impact assessment. Critical analysis of the impacts of technologies on society will only serve to improve the way that technology is designed, developed and implemented. This speaks to the need for the development of social policies that will require a *Technology Impact Assessment Statement* from technology developers, similar to the Environmental Impact Assessment Studies required by state and federal authorities for major technological projects.

CONCLUSION

This seminar course has only been offered once to students across the Howard University campus. Interest in the course was high, as demonstrated by the proportion of students who audited the various seminars. However, actual enrolment was low, partly due to a delayed listing of the course, but mostly because of a lack of awareness by academic advisors that this course could be used by students to satisfy humanities or social science requirements in the various university degree programmes.

Nevertheless, the feedback to the faculty suggested that this was a well-received course, with students valuing the structure of the course, the information received, and the discussions that took place. Feedback indicated that students felt that this course was particularly relevant to their engineering and general education, and provided a *real-world* perspective on technology development.

The mix of faculty disciplines involved was one of the major strengths of the course. Faculty were from a diversity of disciplines, including chemical and civil engineering, systems and computer science, philosophy, biology, and anthropology and sociology. For all faculty participants, the intersection of interests around technology development and education was particularly strong. Faculty were also individually engaged in some aspect of appropriate technology development and education. This experiential knowledge facilitated and energised the discussion of various aspects of the course and highlighted individual research and education efforts. This strengthened the material and underscored the need for multidisciplinary approaches to technology education.

The case study approach to appropriate technology education was particularly well-suited for the course and the diversity of issues that it encompassed. The case studies utilised represented countries that have been regularly painted by the mainstream media as *rogue* nations that will pay a price in development and poverty reduction for their particular choices in social and economic policy. This course offers students the perspective from the ground level, and particularly on technology education and transfer, and its impact on development.

This course has the potential of having a large impact on the implementation of AT within the context of the developed world as well, especially since a great deal of that development is not environmentally sustainable and will lead to the rapid depletion of resources.

Global demand for raw materials and technology will only increase as the less-developed world seeks to catch up to the developed world. Unfortunately, that goal may well be self-defeating as the environmental impact of current economic and technology trends become more apparent and their imprint becomes more severe.

In conclusion, it is important to note that the faculty participating both as presenters and audience in the course were energised and motivated by the interactions and discussions this course fostered and enabled. The seminars were well-attended by faculty who had an interest in the intersecting issues of science, technology, philosophy and development.

The faculty team has plans to offer this course again and the expectation is that student interest and enrolment will be higher with increased publicity within the university community, and as awareness among faculty academic advisors increases.

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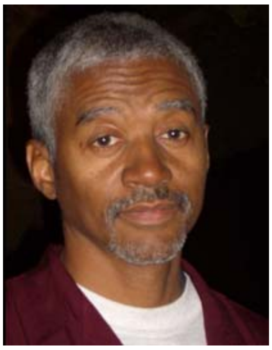

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