THE PROSPECT OF VIRTUAL LABORATORY IN SOLVING PROBLEMS OF LEARNING AND TEACHING ARCHITECTURAL SCIENCE IN INDONESIA

Prasasto Satwiko
Architecture Study Program
Atma Jaya Yogyakarta University
Indonesia

ABSTRACT

The lack of appropriate architectural science laboratories to support good learning-teaching methods has long been a problem in Indonesia and has been suspected result in the poor building environmental design quality. Anticipating the global free trade era, the methods should be improved if the students are to compete with their counterparts from countries with well-established education system. The current poor condition of almost all of Indonesian life sectors has forced people to use the limited resources more efficiently and effectively. Miraculously, those crises, instead of affecting the availability of computer technology significantly; they enlighten the positive potentials of the computer technology. Computer based virtual laboratories have become a realistic option; they offer a comprehensive solution for technical and non-technical problems of learning and teaching architectural sciences.

INTRODUCTION

A virtual laboratory is a computer laboratory with an ability to digitally imitate conventional equipment or reproduce real world phenomena. The term *virtual* is not only used to describe the virtual nature of the laboratory but also cunningly utilised the new trend, *the virtual technology*. An observation conducted in Yogyakarta showed students' high enthusiasm to virtual reality technologies.

The positive prospect of virtual laboratory in solving problems in learning and teaching architectural sciences has naturally emerged from Indonesia's current conditions. Those very pessimistic conditions (very poor economy, education, etc.) contain positive potentials, which should be responded creatively. This paper begins with a review on the present discouraging economic situation of Indonesia, which affects the education sector. It is followed by the discussions on the architecture education, the architectural science learning-teaching method, and the promising development of computer technology. The bright sides of the crises are explored and concluded with the relevance of developing architectural science virtual laboratories. Partial results of the research on the architectural students' knowledge of computer hardware and software, conducted in Yogyakarta Special Region, are presented.

ECONOMIC AND EDUCATION

Indonesia, with its more than 212 million people, is still considered as one of the poorest countries in the world. Average Regional Minimum Personal Income is around US$20.00 per month, but a daily wage of less than US$0.50 is not uncommon. Meanwhile, there are few people who can earn more than US$100,000.00 per month.

The wide gap between the wealthy and the poor is reflected on extreme differences of lifestyles, from a modern (even futuristic) lifestyle in metropolitan, such as in Jakarta to the Stone Age lifestyle in remote areas such as in West Papua. The gap also obviously presents in the education society, teaching and learning facilities offered by poor and rich universities; also between the poor and the wealthy students.

For the year 2000, the government can only allocate 6.8 % of its national budget for the education sector, which is considered very low by the education society for around 7.2 million students are predicted to drop out from their schools. Table 1 shows a relatively low state education expenditure per capita of three Indonesia's biggest cities (Jakarta, Surabaya, Bandung) compared to some cities in Asia, in 1999, according to Asiaweek. With such a low budget, it is easy to understand the low quality education results. Scholars openly state that the quality of Indonesian education system is steadily declining.

City	Population	Average Income per year (US$)	State Education Expend. per Capita (US$)
Hongkong	6,843,060	13,780.65	892.80
Taipe	2,639,169	19,080.02	802.06
Singapore	3,893,600	24,337.59	674.40
B.S.Begawan	45,900	15,207.39	649.06
Tokyo	11,937,433	44,921.58	559.43
Hanoi	2,356,000	3,270.00	468.00
Metro Manila	10,208,290	13,549.65	452.68
Seoul	10,147,101	12,714.53	387.74
Kualalumpur	1,420,000	23,198.90	329.96
Jakarta	9,489,024	3,468.57	173.12
Beijing	12,234,000	6,097.99	168.36
Islamabad	810,000	7,605.11	93.94
Kathmandu	657,341	3,254.90	92.67
Surabaya	2,824,838	3,389.74	89.35
Delhi	13,418,000	2,128.08	84.73
Bangkok	9,114,852	22,140.09	84.09
Bandung	1,839,755	2,680.26	75.39
Karachi	9,300,000	6,961.73	38.70
Colombo	935,000	2,608.91	6.56

Table 1: Comparison of the State Education Expenditure per Capita of Cities in Asia

ARCHITECTURE EDUCATION

Indonesia has 1718 higher education institutions (76 state and 1642 private). Ninety of them have an Architecture Study Program (14 state and 76 private), under the Faculty of Engineering, with various numbers of student bodies. Every year, universities welcome various numbers of new architectural students, from less than 50 students to more than 400 students.

In assumption, more than 3000 architectural students graduate every year and start working in various fields, from agribusiness (e.g. farmers) to education (e.g. lecturers). Limited job vacancies prevent them from freely choosing suitable jobs. Meanwhile, without an international standard of architectural skills (plus sufficient language proficiency), they are not internationally competitive. Presently, no license is required for a fresh graduate to work as a professional architect. A certificate is commonly sufficient to apply for a job.

Basically, every university can independently develop its curriculum based on local potentials and uniqueness. However, before obtaining an equalised level status, an Architecture Study Program of a private university needs to follow the architecture national curriculum, which is based on a nine-semester program and contains around 150 credits with 100 credits for the core curriculum (applied nationally) and the rest are for the local curriculum.

ARCHITECTURAL STUDENTS, LECTURES AND COMPUTERS

Computers have become popular instruments among architectural students. Despite the poor economic condition reported by printed and electronic media, a research project conducted among 450 students of five Architecture Study Programs in the Yogyakarta Special Region found that most of them are computer literate. (See Figure 2.) Only 7.0% of them have never used any computers. About 32.9% of the students have used computers for more than four years, 72.6% use them at home, and 22.7% use them everyday. Among the students who never use a computer, about 47.1% plan to have it soon, whereas 40.0% do not know.

In terms of hardware, most students have a standard configuration computer, which is considered sufficient for most current popular applications. Around 67.9% of them have Pentium processors with RAM of 32 MB are installed in 42.6% of students' computers and a 14" monitor is usually chosen (73.5%). Some students just do not care with the internal parts of their computers. They do not know their computer' processor (14.8%), whether they have a modem (12.8%), etc.; but they almost precisely know whether they have a printer (82.3%) or not (17.0%).

In terms of applications, students mainly use their computers for word-processing, with MS Word being the popularly used, though the use of old programs such as Wordstar can still be detected. However, with a soundcard installed at 66.1% of the computers, it is suspected that games and other entertainment software are also extensively used. Disappointingly, only a few architectural students use graphic software such as AutoCAD and ArchiCAD. MS Excell is the most commonly used spreadsheet. No student uses any architectural science related software, even though some of them, such as Lightscape (for lighting design), Fluent (for HVAC design) and STAAD (for construction design), are widely available.

Surfing in the Internet is a new trend. But, about 20.9% of the students honestly say that they never use the Internet.

With 21.42% of the students never and rarely use any computer, the gap between computer literate and illiterate students can be a problem. An observation at Atma Jaya Yogyakarta University found that those less literate students still have problems with basic computer operations, such as turning on the computer and using mouse buttons. They are potentially disturbing the class.

Informal interviews found that most lecturers are reluctant to explore the potential of computer technology to support their teaching methods. Some of the reasons are as follows:

- A computer presentation--even though it is much more excellent--is wasting time; a chalk does the job faster! The fee is the same anyway!
- Learning a computer program takes time; lecturers have an insufficient self-confidence to teach the students how to use the program, since many students know better about it.
- The local area network and classrooms' designs are not ready to support the computerised teaching method; installing the computer and the view projector before the class begins is very energy-consumptive. Moreover, experience shows that without a standby backup from a software and hardware assistant, even a small problem can ruin the class's mood.

ARCHITECTURAL SCIENCE

In general, the architecture national curriculum is divided into three groups of subjects: General Basic Subjects (10 credits; e.g., Religion, Civic, English), Skill Basic Subjects (40 credits; e.g., Mathematics, Materials, Building Physics, Architectural Theory) and Skill Subjects (50 credits; e.g., Architecture Design Studio, Structure and Construction). Architectural science related subjects take about 32 credits.

Subjects	Examples of topics which need virtual laboratory backup
Engineering Mathematics 1, 2	SFD and BMD calculation
Building Physics 1, 2	Aerodynamics simulation
	Natural/artificial ventilation simulation
	Natural/artificial lighting simulation
	Acoustics simulation
	Data processing
Ecology	Pollution tracing
Building Utility	Smoke hazard
Landscape	Wind pattern
Building Structure and Construction 1, 2, 3, 4	Structure analysing
Urban Design	Wind simulation
Energy Conscious Architecture	Heat transfer

Table 2 An example of virtual laboratory utilisation in some subjects.

The growing criticism on the poor building environmental designs reflects problems in the architectural science learning-teaching method. The present method does not give students a clear understanding to building physics phenomena and does not train their sensitivity to those phenomena. When doing assignments students mostly rely on their intuitions, daily experiences and references (which are very limited, mostly in English and developed for non-tropical climates).

The problem is understandable since the provision of appropriate laboratories is expensive. Even a very simple architectural science laboratory with very basic instruments is unaffordable for most universities. Building special purpose facilities, such as an un-echoic chamber and a wind tunnel, is very expensive that makes them the least priority for most universities. As a result, the architectural science related subjects have to be taught conventionally using chalks and blackboards, with a more numerical approach. Being bored and unmotivated, transcendentally, students develop opinions that architectural science related subjects are subordinate. They tend to pay less attention to them.

A more realistic way to improve the teaching-learning method is to find general-purpose equipment such as computers. The development of computer hardware and software has made it possible to develop virtual architecture laboratories. The employment of virtual wind tunnel using computational fluid dynamic software, for example, has more advantages than using conventional laboratories. Figure 1 shows a result of a virtual wind tunnel constructed using a CFD program. It is more cost effective (initial, operational, labour), more flexible in modelling (no scale required, easy to adjust the material properties), no risk (from smoke hazard), etc. The same arguments emerge for lighting, acoustics, ventilation, structure, construction, and other laboratory. The same computers can be used for writing papers, preparing presentation, analysing data, etc. Thus, the limited amount of money can be spent more effectively and efficiently.

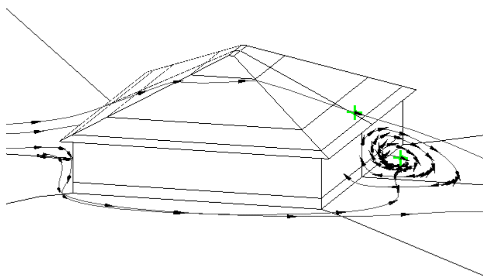

Figure 1 Airstream around a building as simulated by a virtual wind tunnel constructed using CFD-ACE program**.**

HARDWARE AND SOFTWARE

Computers are available in a wide range of option. The price of a standard branded computer (with Intel Pentium® III Pro 500 MHz, 64 MB SDRAM, 6.4 GB

HD, 15" SVGA Monitor, 512 KB L2 Cache, multimedia facilities) starts from US$900.00. That price is relatively inexpensive, considering its versatility. The configuration is sufficient to run various popular programs. Non-branded computers (cloned computers) are usually 20 % cheaper than the branded ones and sometimes more powerful (and possibly come with more accessories).

Unlike that of computer hardware, the provision of computer software is a dilemma. On one side, Indonesia has signed an intellectual copyright agreement, which forces its people to buy legal software. On other side, the legal software is very expensive and unaffordable for most people, especially with the rupiahs depreciation to dollars (US$1.0 ~ Rp.9, 500.00). This has encouraged people to buy illegal software, which can be easily found anywhere from malls to pedestrians. With US$2.50, one can buy a CD contains various programs valued thousands dollars. Or, when he/she buys a computer he/she can ask for any programs to be installed in his/her new computer for free. Freeware and shareware can become an answer to copyright problems. Many of them are offered in the Internet, even though in general they are not as attractive as the commercial ones (such as in terms of user-friendliness and powerfulness).

SIMULATION TECHNOLOGY

The current development of simulation technology becomes a positive point for virtual laboratory development. The reliability of the programs' results has long been a crucial issue introduced by some sceptical lecturers. It is hard for them to believe that the computers can closely reproduce real word phenomena.

One of the most interesting cases to justify the programs' reliability is the utilisation of CFD programs to simulate building aerodynamic and thermal performances. Even though the CFD theory has long been described, its non-linearity nature has made it practical only a few years ago, thanks to the more powerful computer technology. The reliability of the programs is improving from time to time. Studies conducted to compare CFD programs' simulation results with field data, for example, have found very close agreements (Satwiko, 1997; Selvam, 1992; Williams, 1996). In Indonesia, some architects have started using CFD programs confidently to simulate building aerodynamics and thermal performance (Kindangen, 1996; Kindangen, 1997; Satwiko, 1994; Satwiko, 1999). The advantages and disadvantages of using CFD compared to other methods can be seen from Table 3.

THE PROSPECT OF VIRTUAL LABORATORY IN ARCHITECTURAL SCIENCE EDUCATION

The computer utilisation in architecture education can be divided into three categories: (1) word processing and general presentation, (2) building architectural design and animation, and (3) building environmental and structural performance simulation. Ideally, the teaching-learning methods at the third category should be backup by reasonable laboratories, which as has been mentioned, are very expensive. Thus, virtual laboratories can better replace those conventional laboratories.

An example of SWOT (Strength, Weaknesses, Opportunities, and Threats) analysis to show relevance of virtual laboratory conducted at Universitas Atma Jaya Yogyakarta is shown at Table 4. The SWOT analysis indicates that the prospect of virtual laboratories to fast improving the teaching-learning method of architectural science subjects is very good. It is better than that of conventional laboratories. Being based on the world latest technology, the virtual laboratories can be used as a shortcut to enhance the students' capabilities in solving numerical problems, so that they can compete with those from countries with better-established education. However, this analysis method is not the best one, since it is merely based on the contemporary condition. A more thorough study (involving education history, culture, trend, etc.) is needed to obtain a more accurate strategy.

The positive prospects of virtual laboratory in Indonesian architecture education can be seen from many aspects as follows:

- *Academic*

In general, the Indonesian higher education has three objectives: education, research and social works. Reasonable laboratories are required to support those objectives.

- *Architectural science education*

The low environmental design capabilities of students graduated from the ninety Architecture Study Programs every year throughout Indonesia might result in the poor quality designs. Virtual laboratories are useful to improve those capabilities.

- *Computer simulation technology*

Computer simulation technology has come to a level to be able to accurately reproduce real world phenomena. Studies confirm that the reliability of the simulation results is improving everyday, thanks to better computer software and hardware technology.

- *Financial resources*

Developing computer based virtual laboratories are financially more effective and efficient than conventional laboratories.

- *Psychology*

New architectural science related programs are written with user-friendly approaches in mind. This makes learning architectural sciences--which is usually considered as boring--becomes more enjoyable; students will be more motivated.

- *Culture*

Indonesia is experiencing a shocking culture transition from traditional to modern lifestyle, from an agriculture to an industrial society. A computer is not just an electronic good, but also a symbol of modernisation. Introducing a computer based virtual laboratory is culturally more interesting than a manual instrument based conventional laboratory.

- *Computer technology*

The world computer technology development is accessible from Indonesia; even the latest technology is quickly available and sometimes in less expensive version. Building a computer based virtual laboratory anticipates the future of technology.

- *Economic*

Virtual laboratory buildings offer income opportunities from the hardware (computers, networks, etc.) and software (system, curricula, syllabi, programs, manuals, tutorials, etc.) provision. Anyone with sufficient skills can take those opportunities.

- *Global strategy*

Mastering information technology is a prerequisite to enter the global competition. A computer based virtual laboratory will be an excellent means for students to learn the future technology.

CONCLUSION

Computer based virtual laboratories are relevant to be developed to improve the learning and teaching method of architectural science related subjects. Their prospect is very good. They can comprehensively solve the non-technical and technical problems.

REFERENCES

Atma Jaya Yogyakarta University (2000). *Master Plan 2000-2004*, confidential report for limited circulation, Yogyakarta: University Development Centre.

Etheridge, D., Sandberg, M. (1996). *Building Ventilation: Theory and Measurement*. Chichester: John Wiley and Sons.

Kindangen, J. and Krauss, G. (1996). Investigation of Natural Ventilation with Computational Fluid Dynamics, a Comparison Study with Wind Tunnel Results, *Architectural Science Review*, vol.39, no.1, p.113-120.

Kindangen, J., Krausss, G., and Depecker, P. (1997). Effects of Roof Shapes on Wind-Induced Air Motion Inside Buildings, *Building and Environment*, Vol.32, No.1, pp.1-11.

Satwiko, P. (1994). *The Development and Modelling of a Natural Ventilation System for Indonesian Condition- case study of a roof chimney*, unpublished Master of Building Science thesis, School of Architecture, Victoria University of Wellington.

Satwiko, P. (1999). Traditional Javanese Residential Architecture Designs And Thermal Comfort-*A Study Using a Computational Fluid Dynamics Program to Explore, Analyse, and Learn from the Traditional Designs for Thermal Comfort.* Unpublished Doctor of Philosophy thesis, School of Architecture, Victoria University of Wellington.

Selvam, R.P. (1992). Computation of Pressure on Texas Tech Building, *Journal of Wind Engineering and Industrial Aerodynamics*, 41-44, pp. 1619-1627.

Williams, P.T., Baker, A.J., Kelso, R.M. (1996). Numerical Calculation of Room Air Motion - Part 2: The Continuity Constraint Finite Element Method for Three-Dimensional Incompressible Thermal Flows, *ASHRAE Transactions*, vol.100, part 1.

Property	CFD	Full scale	Model scale	Simple methods
Continuum	No	Yes	Yes	No
Geometric similarity	Approx.	Yes	Approx.	Approx.
Size limitations	No	Yes	Some	No
Scale effects	Some	Moderate	Yes	Yes
Instantane-ous turbulence	Indirectly	Yes	Yes	No
Hazardous events	Yes	Limited	Limited	Yes
Modelling of moving people	Limited	Yes	Limited	Limited
Empirical content	Some	None	Little	High
Potential accuracy	High	High	Moderate	Low
Tuning required for highest accuracy	Yes	No	No	No
Capital cost	Moderate	High	Moderate	Low
Running cost	High	High	High	Low
Experienced user desirable	Yes	No	No	Yes
Useable at design stage	Yes	No	Yes	Yes

Table 3: Strength and weaknesses of CFD (Etheridge, D., 1996).

	Opportunities: • Free trade agreement encourages graduates to seek international careers • Inexpensive latest computer technologies are available; non-branded computers can be 20% cheaper than branded ones. • Software vendors offer academic licenses with less expensive prices • Free- or shareware with reasonable quality are available throughout the Internet • Virtual laboratory is still a new developed concept	**Threats:** • Opened competition with architects from countries with well-established education system • Computer technology is developed very fast, which can result in a rapid obsolescent for the high invested computer system • Rupiahs depreciation to dollars that makes imported laboratory instruments very expensive
Strengths: • Under the new high education accreditation system, the Architecture Study Program has a B+ grade, which allows it to be more independent (autonomous) and develop its own uniqueness • University's high enthusiasm to computerisation • Simple bureaucracy • Students' eagerness to have a sophisticated and interesting laboratory • Sufficient students' computer-literacy	**S-O:** • Develop a specially designed curriculum which helps the graduates to be more competitive • Develop a computer-based virtual laboratory to improve the learning-teaching methods • Optimising the use of latest hardware and software technology	**S-T:** • Develop a curriculum that takes international trends into consideration • Develop a virtual laboratory which is flexible to the computer technology development
Weaknesses: • Very poor teaching-learning activities in architectural science subjects using a very conventional chalks and blackboards method • Students high reluctance to learn numerical related subjects (*allergic to mathematics*) • Gap between computer illiterate and literate students • Computer illiterate lecturers are still the majority • Limited financial resources force the university's authority to seek for an effective and efficient laboratory • Lack of experiences and references to develop computer based laboratory for architectural sciences	**W-O:** • Develop a specially designed curriculum to revolutionise the current poor teaching-learning methods • Develop an interactive and user-friendly laboratory to encourage students to learn architectural science subjects • Develop a syllabus that can accommodate the various students' abilities on the computers • Develop a learning-teaching method that can minimise (or eliminate) constraints caused by computer illiterate lecturers (who are still the majority in number).	**W-T:** • Develop an especially-designed syllabus and manuals to help computer illiterate students learn the computer effectively and efficiently • Optimise the use of inexpensive hard- and software • Develop a flexible computer system, which can be upgraded easily at low cost. • Use the effect of computer technology development to the price of the computers, which tend to drop significantly each time new technology being introduced; buying a one step older technology gives an insignificant capability difference, while it gives a significant lower price.

Table 4: SWOT analysis for Atma Jaya Yogyakarta University (Atma Jaya Yogyakarta University, 2000).

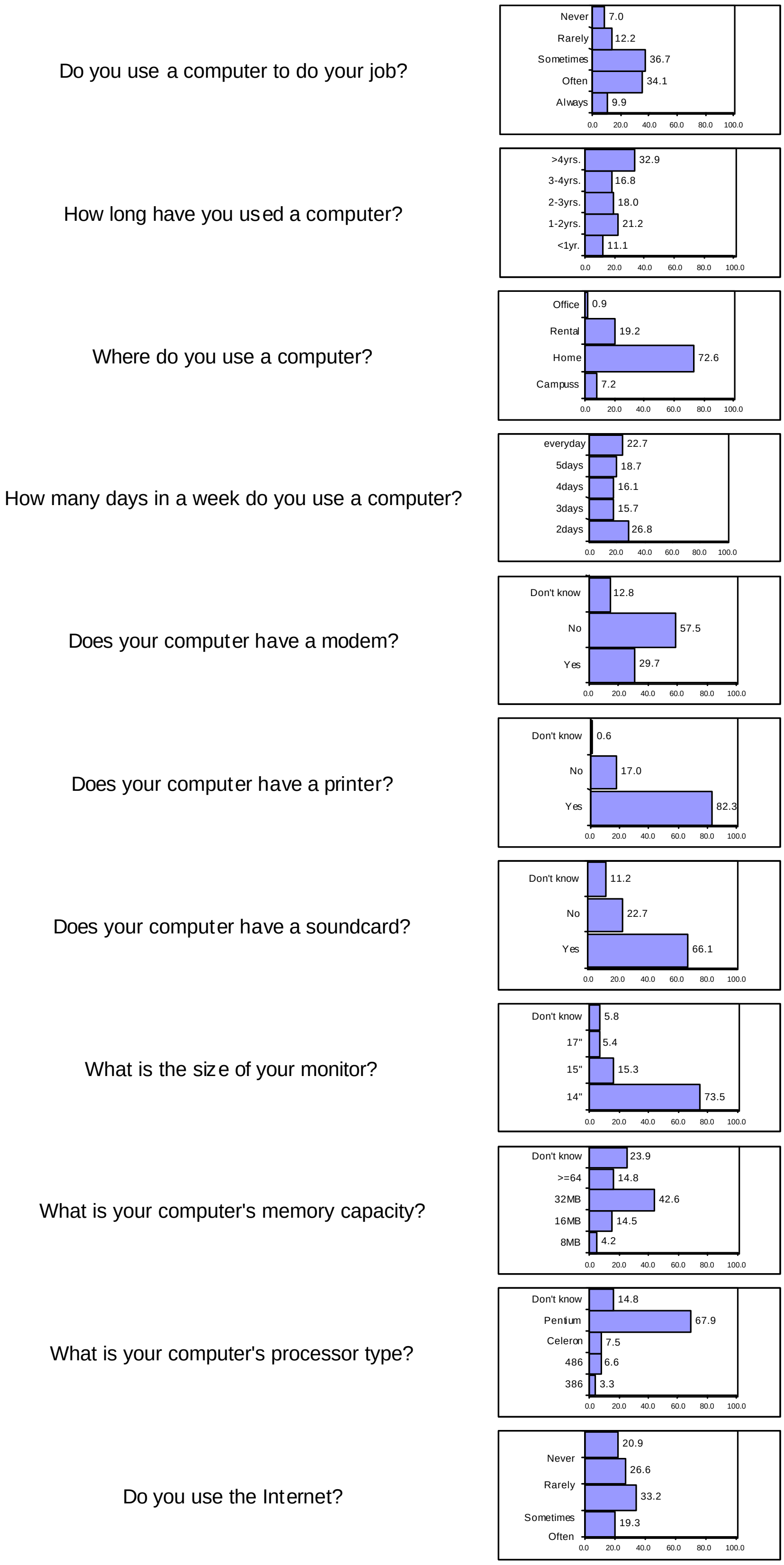

Figure 2: Students' responses to questions (abridged from the tentative report of research conducted by the author in Yogyakarta Special Region, from January to March 2000).