

Design & Test Education in Asia

At the Asian Test Symposium roundtable, *D&T* was pleased to have very senior people from the Asian test community participating in a discussion of design and test education. Recently, there have been significant increases in design and test activities in Asia, not only in Japan, Taiwan, and Korea—as is traditionally the case—but a lot is happening in India, China, and many South Asian countries as well. So all these new movements, together with the increase in semiconductor design and manufacturing activities, prompted *D&T* to hold this roundtable and share with its readers new views of where the industry is today and where it is going.

IEEE Design & Test thanks the roundtable participants: moderator Yervant Zorian (Virage Logic), Debesh K. Das (Jadavpur University, India), Hideo Fujiwara (Nara Institute of Science and Technology, Japan), Yungang Li (Beijing Huahong IC Design, China), Yinghua Min (Institute of Computing Technology, Chinese Academy of Sciences, China), and Shiyi Xu (Shanghai University, China). *D&T* gratefully acknowledges the help of Roundtables Editor Kaushik Roy (Purdue University), who organized the event. Special thanks go to the IEEE Computer Society for sponsoring the roundtable.

Zorian: What is Asia's undergraduate and graduate education for design and test like? How do students continue their education, and what are their activities in the industry? You may want to use your organizations as examples.

Fujiwara: The Nara Institute of Science and Technology (NAIST) is a special university in Japan begun 10 years ago as a national university to promote education and research at the graduate level only. We have only three graduate schools: Information Science, Biological Science, and Materials Science. Information Science has three departments: Information Processing, Information Systems, and Bioinformatics. In these departments, we have a tier system with 24 full professors, 24 associate professors, and 48 assistant professors. We offer more than 30 graduate courses. So each professor teaches one or two courses a year, and we focus on research. We have three courses in design and test—Hardware Design I and II, and Computer Architecture. We have another very special course called Project Practice—hands-on design and test practice—in which we teach the latest subjects related to the theory and application of information science. Students take the project course either on campus or in industry laboratories doing private research.

Li: Huahong Co. Group is the largest national ASIC design and manufacture group in China. Huahong Group incorporated specifically to undertake the “909” project, the most important microelectronic project of China's ninth 5-year plan. As the demand for IC industry grows, so does the demand for IC design groups. As of now, more than 400 ASIC design companies in mainland China employ about 20,000 people. In 2002, for example, mainland China produced 9.6 billion chips and imported 32 billion chips. The ICs produced account for only about one-fourth of the total demand; three-fourths must be imported. This situation is what has promoted development of China's industry. However, most of the produced chips are still low end. The key problem faced by Chinese IC companies is the high demand for ICs, coupled with a lack of experienced engineers; as a result, there is keen competition for engineers.

Zorian: Can you elaborate a little more on this?

Li: One reason for the lack of engineers is that IC industry develops so quickly; another reason is that education is not adapted promptly. First, let's look at college education: Many universities have an EE or ECE department but with insufficient workstations,

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EDA tools, and testing equipment, for instance. Most university faculty has rarely had occasion to participate in actual IC design; therefore students learn only book knowledge. Because so few top-level universities have ideal conditions, few encourage students to concentrate on design.

As for testing, at present there aren't enough engineers; there aren't enough students in that field. The reason is that, because doctoral and master's students are required to write a certain number of papers, the institutes and universities focus on teaching theory instead of practice.

Das: Jadavpur University, where I teach, offers two courses: Electronics and Telecommunication, and Computer Science and Engineering. In our province in India, we are attracting the best students of our province. Their mathematical skills are excellent, and many plan to pursue research. Many Jadavpur students travel to the US for their MS or PhD studies.

Previously, Indian universities were not very active in design and test, but the past 15 years has seen many changes. One important event in India was initiated by Dr. Vishwani Agrawal: the International Conference on VLSI Design. One reason this conference has drawn so much interest is that in 1994 the conference committee started a fellowship program for students, researchers, and faculty to attend the conference free. That situation motivated many people to become interested in VLSI.

In 1997, as a result of this conference, the Indian Institute of Technology, Delhi, followed by others, began offering VLSI courses. In 1998, the Indian government initiated the Special Manpower Development Project on VLSI and Related Software, for developing

manpower for VLSI design and test. The project, which has cost about \$3.5 million since 1998, included the installation of hardware and software tools for 19 institutes so they could design and offer appropriate courses. In this project now, there are roughly 70 faculties in VLSI, 250 to 300 MTech students, about 1,500 undergraduate students, and 8 to 12 PhDs per year.

India plans to spread this activity to as many as 60 institutes to train students on VLSI software tools; it also has a plan to produce about 300 faculties for these institutions. Some of the present faculties have international experience. India's immediate requirement is about \$15 million for VLSI lab setup (tools and hardware), and it needs about \$2 million for books and journals. Overall, India sees a good future for VLSI education.

Xu: Shanghai University, the largest in area in Shanghai, merged in 1994 with four institutions of learning. We now have about 30,000 undergraduates, plus 5,000 graduate students, spread across three different campuses. Shanghai University is one of the few universities in China that introduced design and test to the undergraduate and graduate curriculum. The School of Computers, one of Shanghai University's largest institutes, has both a solid curriculum and some important design-and-test government projects. In addition, there are some plans for D&T education at Fudan and Jiaotong universities in Shanghai.

Education in the design and test area is quickly expanding in China. Ten years ago, few people in China understood what fault tolerance was—even three years ago, an expert in computer science asked me what it meant.

I have been a supervisor of about 60 graduate students, including those from Asia, Africa, and Latin America, since 1985. Now most of them have earned a master's degree, and some have PhDs. But during the 1980s, students majoring in testing had almost nothing to do with D&T of LSI and VLSI after graduation. Few factory or research organizations asked graduate students to do testing because most digital components, such as chips, were simply imported at that time. Therefore, almost no D&T work was needed. Manufacturing still had low standards and depended on the imported chip, which they didn't have to design. All that manufacturers would do then was just test the whole system, such as a microcomputer, when it was assembled and completed.

For instance, I visited some manufacturers in

Shanghai about 20 years ago and observed their test conditions and what they measured. It was basic—high temperature, using high vibrations and voltage, changing from high to low. They never tested or verified the logic. In the past 10 years, however, these manufacturers have grown and begun using some high-tech methods to test and verify the logic design before shipping products.

About one-third of my graduate students go abroad after graduation, mostly to the US. Several years ago, going abroad was one of the best approaches for graduate students in China if they wanted a good job in design and test, especially within their specialty. Some of my students now work at some well-known US companies in California, such as Actel in Mountain View and Applied Materials in San Jose. Others work at Microsoft in Seattle and IBM in Poughkeepsie, New York. The other two-thirds of my students stay in the Shanghai area but change their area of specialization—they work in other jobs, and only a few work in the test area, which is a problem.

However, D&T research has recently blossomed in China, both in industry and academia. Due to the lack of test engineers, employers in communications, IT, and aerospace, for example, have sought test experts. Now people understand the importance of a reliable system, in the age of information and knowledge, so are realizing the critical significance of D&T research. Students majoring in testing now are invited to work everywhere in different areas, including state-owned, private, and joint-venture companies in China. Strangely enough, most students in this area now are reluctant to go abroad to find work. This is likely because the students see a promising future in their own country for developing their knowledge and skills, or they might have found that they could get excellent payment in this area in China.

Min: At the Institute of Computing Technology, Chinese Academy of Sciences (CAS), a research as well as an educational institution where I teach, we have only graduate students, no undergraduates. We've offered test courses since 1984, when I first gave the course at the CAS graduate school—Yungang Li was in the first class.

I wrote a textbook, *Logical Circuit Testing*, published by the China Railway Publishing House in 1986, based on what I learned in a course given by Edward McCluskey at Stanford University. Since then, many universities in China, such as Tsing Hua

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University, have offered that kind of course. Some professors later modified my textbook to fit their teaching requirements.

I'm also a professor at Hunan University, which has more than 17,000 students. There is an undergraduate course on circuit design, with an emphasis on testing, but no separate course on testing. We do offer a test course at the graduate level—last year, for instance, I gave a test course in English for foreign students.

The challenges of design and test education in China include problems. First, China's IC design industry is growing fast. As Li said, there are hundreds of design companies; most of their employees, however, aren't design-and-test students.

Zorian: What is the students' background and how can they contribute to the industry? Are they coming from a computer science or an engineering background?

Min: They can use design and test tools after they come to the company. On the other hand, students majoring in design and test might not find employment in that field but in computer networking, doing systems analysis or technical support instead.

Zorian: How would you collaborate with industry to learn its needs so you can prepare your students accordingly? On one hand, China has a shortage of experts in design and test. On the other hand, as you indicated, India is exporting experts to other countries. So there seems to be a mismatch between what

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industry needs and what educational institutions are producing.

Min: A second, related problem is the culture to accommodate the advanced technology. I've found that Chinese people are interested in doing something that's regarded as guaranteeing product quality, but testing may be unknown to the public. Another difficulty is that most universities lack design and test tools for students; maybe there isn't enough money to buy CAD tools. In Taiwan, and other countries, universities have all those tools for students—in China, we don't have this type of free software for students. However, I've heard recently that the situation is improving.

Since 1985 and 1989, when the ISCAS85 and ISCAS89 benchmarks became available—I appreciate Professor Fujiwara's providing all those benchmarks to us—we have been able to conduct research with these benchmarks, although they're limited. For RTL and high-level testing, we have a number of benchmarks, but we need more, even though the test community has already worked so much on them.

The third problem is textbooks. Recently, I used V.D. Agrawal and M.L. Bushnell's textbook. It's a good book but with too much information for students to read. We have limited hours to teach the testing course, so we have to concentrate on basic principles. We can't use a textbook that's like a dictionary, with everything defined in it.

Zorian: How best can we match the design and test industry's needs by preparing students in their educational institutions?

Fujiwara: With respect to undergraduate programs related to design and test, first you need to understand that, essentially, many universities attach con-

siderable importance to the basics. We have a number of undergraduate courses (some of which are very popular) on, for example, computer design, computer architecture, logic design, system design, IC design, semiconductor device design, VLSI design, and computer-aided design. A typical course in the postgraduate master's program for design and test is on the basic process flow, on where the design test application is, and so on. Another course teaches design and test algorithms. But undergraduate courses focus mostly on basic education.

As far as participation with industry is concerned, we have collaborative laboratories with industry. Our Graduate School of Information Science features 24 regular laboratories and eight collaborative laboratories. Each regular laboratory consists of one full professor, one associate professor, and two assistant professors—all full-time government employees. Professors of collaborative laboratories, on the other hand, are industry researchers, serving concurrently as part-time professors. The collaborative laboratories accept a small number of students for collaborative research; unfortunately, we have no such laboratory in VLSI design and test.

Zorian: How do universities learn what industry needs are, for example, in the area of testing? If there is no collaborative laboratory, do you have a way to find out from industry what kind of experts they need so you can prepare in your courses accordingly?

Fujiwara: In our hands-on, Project Practice course we offer many themes. Three themes relate to design and test; one theme is LSI design and its implementation. Students first learn how to design LSI by means of VHDL and how to use CAD tools. Then they design a small processor and implement it with FPGAs, or they make a chip experimentally with the help of the VLSI Design Education Center (VDEC), which is an intellectual education center on VLSI technology.

Zorian: Would anyone else like to address the industrial influence on education?

Das: I spent six months in Hideo Fujiwara's lab, so I can compare Japan and India. The collaboration between industry and institutes in India differs from that in Japan. In Japan, the collaboration is significant; collaboration in India is negligible. Although

recently there's been a change: Some of India's leading institutes are collaborating with multinational companies, like Intel, Fujitsu, and Texas Instruments.

One problem, which we have in common with China, is that we don't have enough students trained properly in design and test. Our universities don't have enough money to buy the CAD tools. Although some schools have obtained tools, up to now there haven't been enough properly trained people and few with experience on these tools—their knowledge is not enough. There are also problems in installation, commissioning, maintenance, and technical support for these tools.

Zorian: Where do you get the tools?

Das: Clearly, we are missing some tools. Industry has these tools but few universities do. At my university, we do have Cadence and Synopsys tools, but because we lack enough properly trained people, we couldn't utilize them fully. Another problem is that in India—in comparison to Japan—few companies conduct VLSI design and test. Students who find jobs here do have the required basic background in VLSI, but they are not getting the jobs in VLSI companies. Some companies have started a special diploma/certificate in design and test, which takes four to six months to complete.

Zorian: Is the diploma provided by the universities?

Das: No, by the companies. The companies provide training.

Zorian: So the companies are acting as an educational institute?

Das: Yes, exactly.

Zorian: Mr. Li, do you want to comment on the industrial needs and the supply of appropriately trained students?

Li: What the industry needs is engineers who can apply knowledge to practice.

Testing can be divided into theoretical research and practical research. The former research is relatively clear; it includes all kinds of new means for testing algorithms, while the latter research concerns industry problems and focuses on specific testing, for

example, how to conduct functional tests, parameter tests, and so forth—this doesn't require a doctoral or master's degree.

Zorian: Are you receiving these kinds of people from the university? And if not, how can you communicate with the university?

Li: At the beginning, we received some students straight from universities. When we found they were unable to perform the required work, we had to train them.

Xu: There is a big gap between education and industry in the testing area. For instance, now we have some courses in fault diagnosis and fault-tolerant computing, both at the undergraduate and the graduate level. But we don't have any practice conditions in most schools in China, so all we can do, beyond learning and doing research, is just to write and publish papers. Obtaining national funding is probably the only way to get support of our research work. It's very hard for us to get industry investment or funding; I'm not quite sure why. Apparently, industry doesn't believe that teachers and students can provide useful services in terms of practical application, because the graduate students are available only for two years before they graduate. So industry doesn't want to give them a large project, and the result is that all we can do is concentrate on theoretical research. And then we can cover the costs with funding from the national science foundation.

Zorian: Where do you see advanced research work being done? Does the government channel funds for you to do research? Do you collaborate with other international universities, perhaps, in the US or in Europe? Do you collaborate and partner with your local industry, or with international industry? I'm not referring to the educational aspect now but to advanced research.

Fujiwara: We are benefiting greatly from many community organizations, such as VDEC. It aims at improving instruction on VLSI design and supports VLSI chip fabrication for universities in Japan. Another example is the collaboration between universities and industries supported by the Semiconductor Technology Academic Research Center. STARC, funded by Japan's 11 semiconductor manufacturers, aims to strengthen the country's technological foundation

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concerning silicon semiconductors and to enhance international competitiveness by commissioning universities for basic research and promoting joint projects with universities.

Zorian: So STARC is an intermediate organization between the manufacturers and the universities?

Fujiwara: Yes. Another organization is a government agency called JSPS, the Japan Society for Promotion of Science. This is an independent institution, established by national law, for contributing to the advancement of science in all the natural and social sciences fields and the humanities. Thanks to JSPS, in my case, I'm getting several benefits from various JSPS programs—postdoctoral fellowship, visiting research fellowship, grants-in-aid for research, center of excellence (COE) program, and so on. So far, I've hosted postdoctoral fellows from France, Sweden, Bulgaria, India, and China with JSPS support, and, similarly, I've also hosted visiting researchers from the US, China, and India. Thanks to JSPS, we can promote international scientific cooperation, which will benefit the research education of our postgraduate students.

Zorian: So you have a combination of industrial and government participation.

Fujiwara: Yes. I'd like to make another point about VDEC, which is very important because it supports chip fabrication as well as education. For example, more than 450 research groups from 158 universities in Japan are utilizing the services and support from VDEC. In 2000, 335 chips were fabricated at various chip foundries through VDEC for academic research purposes.

Das: How much did it cost to fabricate those chips for those faculty members? Were they free?

Fujiwara: No. We paid for it—I don't know the exact figure, but it was fairly inexpensive.

Zorian: Dr. Min, would you like to comment on university–industry relations in China?

Min: The situation—the gap between industry and academic communities—is better now in the universities. Some IT design groups have established cooperation with Cadence, Synopsys, and other western companies. And Fudan University introduced a US expert into its national laboratory.

However, we can consider the problem in two other respects. From industry's point of view, design and test is not the number-one issue in China, especially test, because for the small volume of IC products or for old IC chip series, testing is generally not a big problem. But that's not the case in the US and other countries with major IC producers, who have to manufacture a large volume of advanced ICs, make the production line work, and produce the ICs with high yield to make money. Therefore, those countries are anxious to pursue new design-and-test technologies.

Design is a priority, but now most designs can be implemented by design tools, which companies can buy. Design unavoidably requires some labor, so training is then necessary to satisfy the requirements. This is one reason for industry to need academic research from industry's point of view.

From the academic community point of view, on the other hand, funds come from the government, not from industry, so universities try to contribute with papers to provide new ideas. In fact, they may not have a real chip to work on. So in this case it seems difficult for them to serve the industry directly.

Das: In India, companies involved in design and test are involved chiefly to solve the problems of others. That is, they're getting the orders from companies in other countries to design chips, they're doing the designs, and the fabrication is done elsewhere. Thus, the Indian companies involved in this area are trying to get the contacts from the outside companies producing the chips. So the problems these Indian companies are working on are not India's problems. In that sense, the companies are more interested in getting those contacts from outside companies, rather than to produce a chip that is needed for India. So the collaboration between industries and universities is not there to solve the problems of Indian industry.

In a nutshell, collaboration is being conducted at a very high level, with some institutes establishing collaborations with multinational companies, primarily at the research level. The government is funding most research projects in institutes. Obviously, the problem in India is that faculties have more interest in writing a research paper than in solving a given problem.

Zorian: Do international forums, like this one, help the advancement of your research, education, and industrial practices in Asia? How do you view the help of collaborative forums, such as ATS or other IEEE activities, for universities and industries in Asia? Are they useful in certain ways but not others?

Fujiwara: With respect to the ATS, it needs to be followed up by encouraging research activities in the Asian test community, not only for industry researchers but also for PhD students. PhD students in Asia can get many benefits by attending the symposium. They can network with other researchers and students from all over the world.

Min: Fujiwara and I established the IEEE Workshop on RTL and High-Level Testing in 2000. I think this is beneficial, because it provides a solid foundation for computer science students to act on. From the computer science point of view, students can learn high-level descriptions, algorithms, and so on, with a focus on circuit testing. This workshop isn't very big, but it will grow as more people become involved.

Zorian: How about industry? Does the industry see benefits from these professional forums?

Xu: In my opinion, industry pays much attention to the practical achievements of academic research but not much to theoretical research. This is understandable because practical achievements might enhance the profit industry might attain, while theoretical research may be far from being put into production.

But there's a paradox: If we don't have a sound theory, how can we direct our practical work correctly and obtain a practical result? From the school's perspective, we should insist on teaching students in a way that is compatible with the practical work in industry. Meanwhile, from industry's perspective, industry must understand that most academic work is theoretical but might have practical applications. Therefore, the problem is how the two parties, acad-

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emia and industry, can gain a mutual understanding. If they do, then the benefit is mutual.

From a long-term point of view, industry must reap what it has sown as long as the cooperation between academia and industry is ripe enough. Therefore, it is my sincere hope to see more investment made in academia from industries. As a matter of fact, I know a number of big US enterprises have done something like this, such as IBM, Microsoft, and Applied Materials.

Das: Industries are getting benefits from the professional forums. I understand that the International Conference on VLSI Design, held every year in India, has a lot of attendees, and it's created some research groups. So definitely symposiums like ATS and the VLSI conference encouraged research in India. We need this international assistance. In 2005, we're going to host the Asian Test Symposium in India at Kolkata, which will encourage some students and faculties to do research in this area of testing.

One problem is that we don't have adequate labs. Because of the VLSI industry's recent growth in India, we need more people to provide this education. We need international cooperation and strong collaboration between Asian countries.

In my experience, when we do research in India, we're mostly thinking about a few critical problems. But when I went to the Fujiwara Lab, I learned what were the problems of industries, what were the current research problems in that area. International collaboration is needed to solve industrial problems.

Texas Instruments had collaboration with some institutes in India. Motorola, Intel, and Fujitsu did also. The universities don't have chip fabrication programs. That can be another problem. Even when they do, it's old technology, so that's not very useful. That's a problem.

Zorian: My final question relates to expertise. We discussed developing expertise in India, China, Japan, and so on, but today we see that expertise is a global resource. Where do you see the trends in each of your countries in terms of the movement of this expertise? Do you see more experts moving from your countries toward the outside, or are you seeing the opposite now—do you see that expertise returning back to your countries?

Das: In India, most experts still go abroad, typically to the US. In one way, this is good, in one way this is a problem. The number of experts from a country who go abroad depends on how much the industries have been developed in that country, and of course it's different for different countries. In India, the VLSI industries are still solving the problems of outside companies. The time has to come when they solve India's internal problems. At the same time, since India has undergone so much development in the last few years, many students in India are now staying home. In terms of the number of people going abroad, the total number is decreasing.

About the participants

Debesh K. Das is a professor of computer science in the Computer Science and Engineering Department, Jadavpur University, Kolkata, India.

Hideo Fujiwara is a professor of computer design and test in the Department of Information Processing, Graduate School of Information Science, Nara Institute of Science and Technology, Nara, Japan.

Yungang Li is a professor of VLSI design at the Chinese Academy of Science and is also CTO at the Beijing Huahong IC Design Co., Beijing, China.

Yinghua Min is a professor of computer science working on fault-tolerant computing and microelectronic testing at the Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China.

Shiyi Xu is a professor of computer science at Shanghai University, Shanghai, China, and is also a vice president of the Shanghai College of Science and Technology, Shanghai.

Yervant Zorian, our moderator, is vice president and chief scientist at Virage Logic, Fremont, California.

Zorian: How about in China? Where do you see the movement of expertise—going abroad or returning to China?

Min: Many people are returning to the mainland of China, including PhDs and math students. I read that, for one position in Zhongguancun, three individuals who'd earned their MS degrees in the US were competing for it. There are also some designers, very successful, from the Silicon Valley moving to the mainland. But no testing people return. [laughter]

Min: That's because testing isn't a hot topic in mainland China, and not many testing positions are available. But if enough students were to come back from abroad, that could change the test situation for the better.

Zorian: Students are studying in China, then earning the PhD abroad?

Min: Right. Some of those who earn a PhD or MS degree abroad return to China because China is such a hotbed for development right now, so they think they'll have no trouble making money, although that's not necessarily true. They may want to start a company, but they might find it not as simple or straightforward as they thought.

Zorian: In the industry, do you see a return of experts from abroad?

Min: Yes.

Li: I see lots of people from Silicon Valley coming to China, maybe after obtaining a PhD from the US or from another country. Just as Professor Min says, this happens whenever one industry position is advertised.

Zorian: It's interesting to see that the design and test activities are so heterogeneous; each country has a different situation, with a different maturity of industry and academia.

Thank you all for your participation. This was very enlightening.