
The Tiny, Elite California Institute of Technology

by Yuk Ling Yung*

California Institute of Technology is an institute of science and engineering, and it has ranked No. 1 for three years in the online publication *Times Higher Education*¹. It has just 978 undergraduate students and 1,253 graduate students. Most people are surprised that it is so small, because that is unimaginable when compared with its renown and achievements.

A Brief History of Caltech

Caltech originated as a technical school called Throop Polytechnic Institute, which was founded in 1891 by Amos G. Throop, a businessman and politician, in a suburb of Los Angeles called Pasadena. It later changed into a polytechnic college, and was renamed California Institute of Technology (Caltech, in short).

In 1904, while scientific research in America was still in its infancy, George Ellery Hale, an astronomer from Chicago, built an observatory on the top of Mount Wilson, which is near the city of Pasadena. He joined the board of trustees of the polytechnic college in 1907, and according to his plan, he gradually turned Pasadena into an important science and culture center. In 1908, he hired a very capable humanist, James A. B. Scherer, who also knew how to raise funds, to take over as president of Throop. President Scherer persuaded a local businessman Mr. Charles Gates to donate \$25,000 to build the first on-campus laboratory, named Gates Laboratory. In 1910,

the polytechnic college received a donation of land for a permanent campus site, and it moved to the present location.

After that, under the support of the board, the polytechnic college turned into an institute that specialized in scientific research. The research areas of Throop attracted Arthur Amos, a physical chemistry expert who came from MIT. With his support, Throop became a science and engineering research center.

After the beginning of the First World War, Professor Hale created the National Research Council, and planned to use science to deal with the difficult problems in the military. He suggested that the government offer capital to support science research, but instead worked to raise a privately financed research fund of 1 million dollars. This fund was used to support the national defense research.

As the president of the National Research Council, Hale made speeches everywhere, and emphasized the importance of scientific research. He believed that Throop should take a place in national research. Before long, Throop received a sum of money to do physics research, and built the Norman Bridge Laboratory. Robert Andrew Millikan, the famous experimental physicist of from the University of Chicago, joined Throop in 1917, drawn by the new physics laboratory.

In 1920, Throop became Caltech. Hale, Noyes and Millikan decided to build Caltech during the First World War. Under the great leadership of these three masters, Caltech finally became a renowned scientific research institute in the country in the 1920s.

Millikan was the Chairman of the Executive Council from 1921 to 1945. He made great contributions

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¹ <http://www.timeshighereducation.co.uk/world-university-rankings/2013-14/world-ranking>.

to Caltech,² and he was the soul of it; we could tell his importance from the fact that Caltech was once called “Millikan’s School”.³ When Millikan was the Chairman of Caltech (he never held the title of President, though he effectively served as such), he founded a visiting-scholar program that invited famous scholars to visit Caltech. Many famous scholars came from Europe, including Einstein.

Millikan’s Efforts at Caltech

First, emphasize research. Millikan created a revolutionary new concept at that time. He believed that professors would soon fall behind the fast development of science. So, professors should use most of their time to maintain their advanced research level. At that time, most people regarded this idea as a crazy thought. He suggested that the teaching time for each professor should be no more than one course (no more than four hours a week). To do this, there is only one way – that is, to have a small population of students. Caltech has about 300 professors, and about 1,000 undergraduate students, so the ratio of professors to students is 1 to 3. This means that one professor has only three students on average. It is said to be the highest ratio in America. Because professors have so much time to do their own research, and pass on their most advanced knowledge to their students, Caltech has become an institute full of high achievers. Since Millikan became the Chairman in 1921, Caltech has nurtured 32 Nobel laureates during the last 92 years.

Second, foster an academic atmosphere. Many people feel that Caltech has a strong academic atmosphere that can be seen nowhere else. This atmosphere is like an invisible hand that can impel everyone to be positive and active. First, there is an honor system between students and professors, which says that exams are not necessarily taken in class. Students can get their exam paper from the secretary of the professor, and complete it in his/her bedroom in the allowed time, and put the paper in an envelope and hand it back to the secretary. Stu-

² An alumnus recalled that: Professor Jesse Dumond told me that there was rarely research grant from the Government. If he had an experiment configuration, he would tell Millikan, and if Millikan thought it practicable, he would took \$50 out of his pocket, letting him buy the instruments. In the ‘30s, Caltech is very poor; Professor Dumond got no salary. Stanford University hired him as paid professor, but he chose to stay at Caltech. President Millikan was not only an excellent scientist, but also good at raising funds. He solicited money from the rich with perseverance, at last they all agreed to donate.

³ J. I. Goodstein: *Millikan’s School: A History of the California Institute of Technology*. Norton, 2006.

dents can discuss assignments together, but copying from each other is not allowed. There is only one principle about the honor system, and that is: one should never take unfair advantage of another person. More importantly, if anyone is found cheating, this case is handled by a council managed by the president of the Student Union. He or she lets the Student Union decide whether this student has broken the rule or not, and then hands the student over to the school for punishment. Professors have no right to interfere. Thus, it can foster self-respect, self-awareness and independent thinking in students. I think that this atmosphere is very valuable. In this environment, everyone will strive for scientific excellence. This is very different from other places where presidents and directors have to use some compulsory targets to urge students to gain success, publish papers and earn recognition. I always emphasizes to others that if leaders wrongly take indicators as goals, they will never realize their expected goals.

Third, tiny but elite. Caltech has about 300 million dollars for research each year, so every professor has one million dollars on average. This is relatively high in America. Professors obtain most of the money competitively from national research programs, so every professor has total academic freedom. Professors can choose their own research direction; he or she is the boss of his or her own research group, and he or she can freely use the money and adjust his or her personnel. Even the President and the Provost have no right to interfere. Graduate students and professors can choose each other by their common interest in scientific research. This has some advantages: first, everyone is doing a project for his or her own interest; second, the result can soon be carried forward and developed when a breakthrough occurs; third, a professor can immediately dismiss people who are not productive or not qualified. According to this, we know that the professor is the one who stands on the front line in a group. He or she is the one who chooses the best research strategy based on the trend of the group’s research area, and leads his or her students to move forward in the best direction. Whether in resources or morale, students of Caltech enjoy exceptional advantages, and they can soon achieve something significant. This is the benefit of being tiny but elite.

I have been a professor for Caltech for more than 30 years, and in each decade, there has been a new proposal for expanding the school. However, this proposal has been vetoed every time. Our philosophy is very simple: if we are determined to train scientific leaders for the next generation, we do not need many people, just high quality. There is an old Chinese saying: “should be few but good.”

My Own Experience

First, teaching is learning. In martial arts novels, we can often read that there is a bible that is the ultimate scripture in the martial arts. The bible was written by a master, and no one can surpass this master. So, if someone obtains this book, and then practices according to its instructions, he/she will become the Kung Fu Master. It will be wrong if we use this idea to treat scientific research. Firstly, there is no such bible in the world. If there is, it will be obsolete soon; the true book is not handed down from the ancients, it is created by the concerted effort of the masters and apprentices.

After many years, I truly realize the meaning of teaching is learning. Generally speaking, the research topics are figured out by me, and the research grant is also obtained by me, but as for the actual research work, it is the achievement of the concerted effort of my students and me, which is a synthesis of my students' energy and my experience. In this respect, the school provides two kinds of vitally important resources. For one thing, it recruits the most talented students all over the world; for the other, every year it has internal funds for our professors to carry out high-risk-high-reward researches. Usually, for such high-risk subjects, it will be difficult to get research grants from the national agencies, but if there is any breakthrough, the yield will be enormous. It indeed provides a very effective greenhouse for the invention and development of new ideas and new technology.

Second, army of the United Nations. Half of the graduate students in our school are from different countries; they belong to different races, cultures and religions. I think of my research group. I have people from China, England, France, Canada, the Middle East, Eastern Europe, India and Jamaica. They came from different fields such as astronomy, physics, chemistry, mathematics, engineering, and biology. They sincerely cooperate with one another, and use their expertise to overcome their shortcomings. For many years, they are like a family. In light of this, real pluralistic unity only exists in the USA.

Third, an academic atmosphere. I often tell my students, that our research group is like a basketball team; every player is equal, and you must sincerely cooperate with each other. The model of fighting alone, such as tennis and table tennis, does not work for us. Our research group has group meetings twice a week, and there are also three group meetings that are focused on some particular topics. In addition, if some students cannot find me by day, they can call me at home so that we can burn the midnight oil. So many significant breakthroughs appear during our group discussion. Some ideas, including some of

mine, are not mature at first, or are even wrong. After several discussions, the wrong ideas get corrected, and the good one are carried forward.

Recently, the director of a European institute visited our school to learn from our experience. He asked me to tell him the secret of our school's success. He said: As director, I have tried so hard for years to create the freely creative spirit, the lively communication, as well as the sincere cooperation like yours. How could I create such an atmosphere?

I looked at him for a long time, and then said: My dear Herr, Doctor, Professor, Direktor, the problem of your institute is your title. As far as I know, in your country, people have to call you with four titles; the lack of any one will be regarded as disrespectful. Imagine, in such a pyramidal power structure, how could the people in the forefront of the researching staff dare to challenge the head of the institute with four titles? In addition, this kind of pyramidal power structure not only prevents the ideas from the bottom up, but also holds the communication back among different groups, because every team leader will think of the staff of his team as his personal property. If the subordinates cannot communicate with each other, it will be hard to take in ideas from other teams. At last, I told him that if he really wanted to change his research institute into something like Caltech, he must first modify the vertical management structure.

Fourth, serving the society. There are two major aspects in which our school contributes to the society. First, it nurtures scientific talents; there are 32 Nobel Prize winners from our school. Second, it cultivates industrial leaders for the society. For example, Prof. von Kármán studied rockets; many rocket and satellite companies in the USA were started by his students. Another example is that Millikan's outstanding students in those days not only had great achievements in academia, but also started companies in industry, leading to the invention of the semiconductor and the birth of the electronic age.⁴ With such success, the alumni donate to the alma mater generously, realizing the positive feedback between school and society.

There are three words engraved in metal, representing the spirit of our school, which you can see on the ground of Avery House. They are: *Creativity, Tenacity, and Integrity.*

All three are indispensable.

A Discussion with Chinese Students

I once discussed the factors of Caltech's success with several Chinese students. The following is a transcript of our discussion.

⁴ J. Gertner: *The Idea Factory: Bell Labs and the Great Age of American Innovation*. Penguin Press, 2012.

Student: How many students are there in your class?

Yung: Often only a few, seldom more than 10.

Student: Isn't that quite a waste?

Yung: My students always have to write term papers. If they do a good job, I will make them publish papers. If I have dozens of students in my class, it will be difficult to have such outcome.

Student: Why do students have motivation?

Yung: In addition to talent, motivation is very important. Why do you do it? For whose benefit do you do it? In the USA, the indigenous postgraduates all have good reasons. They give up the very good jobs to do scientific research for its freedom, and they can do almost anything they want.

Student: In China, the elite does not have such ideas. They think the higher the degree the better it is without knowing what they really want, so that they don't have motivation for doctorates. Usually after 6 or 7 years, they have not published. Otherwise in America, most of the graduates will head for the industry, few for the academia.

Yung: The feature of Caltech is that quite a lot of students head for the academia. There was a report pointing out that the number of graduating Ph.Ds in China is larger than that in America. But quite a proportion of the Ph.Ds choose jobs for which their majors are almost irrelevant. They do their doctorates only for the sake of qualification. But in America most doctoral students want to make a career in their specialty. According to such calculation, only half of the Ph.Ds in China practice what they study; the other half contributes nothing to the advancement of their profession.

Student: This is not just a problem between schools of the United States and China. The difference is determined by the social atmosphere of the two countries. China does not protect intellectual property effectively, so that the overall technology level is low. Even if Ph.Ds are willing to, it is difficult to find the positions to develop their expertise.

Yung: Prof. Zhou Pei Yuan got his doctorate at Caltech in 1928; he was the first Chinese Ph.D. of this school, and later he became the president of Peking University. Prof. Qian Xuesen was the first Chinese professor of Caltech, and he said that his lifetime regret was that while he could bring science and technology back to China, he could not bring back the spirit of Caltech.

Other student: Why does our school have a lot of money, including research funding?

Yung: When David Baltimore was the president, he raised \$1 billion, of which 600 million came from Gordon Moore, who was one of the founders of Intel. He is an alumnus of Caltech. The rich in America donate their money to society and charity organization, so that their children will not become parasites. Bill Gates leaves his child \$1 million, and puts billions into a charity fund. Wealth needs to be recycled, only with circulation can it contribute to society. Schools are set up by society aiming to cultivate talents, and society will give back to schools, thus forming a positive feedback cycle. To the Chinese, the concept of the family is deeply rooted, and the tradition of donation has not yet been established.

Student: Why is it difficult for the many students to have success after they returned home?

Yung: Only when the students leave Caltech, will they know how good the school is. I know some classmates. When at school, they were very outstanding and remarkable in research, but after their returning home, they became managers and lacked the opportunity to engage in scientific research. In China the status of officials is higher than scholars, so a smart man chooses to be an official, but then he is unable to continue to develop his own professional skills. On the contrary, at Caltech the best do what they are good at. For example, the physicist Feynman in our school did whatever he wanted, and the school left him alone. The American system protects the brightest and allows talents to bloom.

Student: What is the difference between Caltech and Cambridge?

Yung: Cambridge also has world-class research, and the DNA breakthrough occurred at Cambridge in 1953. Crick is English, Watson an American. But the USA built a great industry based on genetic science. The commercialization is better here; they turn a scientific discovery into wealth. One of my old schoolmates in physics was of average ability when he finished his doctorate. If he had stayed in the field of physics, there would be no future. So after he graduated, he went to a company to be in charge of the manufacture of MRI scanners. He really did well there. From most of Europe, class distinction is strong, and the scientists are all intellectual aristocrats, belonging to the upper class; the skilled labor belongs to the underclass.⁵ There is little connection between theory and technology. At Caltech, the students have startups as well as the professors, and the technology can cross over smoothly to industry from campus.⁶

⁵ Except for Germany, which has strong vocational schools.

⁶ Other elite schools, such as MIT, Stanford, also have startups.

Student: How can we promote China's scientific development?

Yung: Your generation has opportunities. In our generation, few could return to China because of lack of money for research. But nowadays the circumstance is different; there are opportunities in China, like Taiwan starting about 20 years ago. Social stability is important for scientific research, now the economy in China is changing, so is the progress is constantly towards the better. In Taiwan nowadays, many of its leaders have studied in U.S., getting the advanced ideas. I believe that so many Chinese students studying in U.S. that some will bring the new ideas back to China soon.

Student: This year the Caltech will have a new president, which challenge do you think the new president will face?

Yung: Since Millikan established Caltech more than 90 years ago, Caltech has generally combined science and engineering together. The challenge in the future is the combination of science, engineering and humanities, because now the human society is facing complex problems, for example, global warming and nuclear energy. Scientists and engineers must not only solve technical problems, but also accurately estimate their social impact, then explain to the people in very simple language. It is extremely irresponsible and dangerous if we do not deal with it in this way, but take these difficult problems to the people for a referendum. Actually we really need a man like Millikan. Few people know that he was well versed in humanities. During his college days, his major was classics not science. The new president should also be a master unifying humanities, science and technology like Millikan.