STEM Student Learning across Countries

Prashant Loyalka, Ou Lydia Liu, and Igor Chirikov

Abstract
Universities contribute to economic growth and national competitiveness by equipping students with higher-order thinking and academic skills. Despite large investments in university STEM education, little is known about how the skills of STEM undergraduates compare across countries and by institutional selectivity. The authors have provided direct evidence on these issues by collecting and analyzing longitudinal data on tens of thousands of computer science and electrical engineering students in China, India, Russia, and the United States.

We collected internationally standardized assessment data on the critical thinking and academic (math and physics) skills of more than 30,000 STEM undergraduates in China, India, and Russia.

A major goal of undergraduate science, technology, engineering, and math (STEM) education is to help students gain higher levels of academic skills and higher-order thinking skills. Such skills contribute toward the productivity of higher value-added industries and innovation. Despite tens of billions of dollars invested globally each year to help engineering and computer science students develop academic and higher-order thinking skills, we still know very little about the degree to which students actually acquire these skills during their undergraduate studies.

To address this gap, we collected internationally standardized assessment data on the critical thinking and academic (math and physics) skills of more than 30,000 STEM undergraduates in China, India, and Russia. These three countries produce approximately half of the world's STEM graduates. We further expanded this dataset by including information on the critical thinking skill levels and gains of STEM students in the United States. We found substantial differences in skill levels and gains among countries and between elite vs. nonelite institutions.

Divergent Paths in Skill Levels and Gains across Countries

At the start of their studies, students in China and the United States have similar levels of critical thinking skills, which are much higher than skill levels of freshmen in India and Russia. Freshmen in China have the highest levels of math and physics skills, compared to freshmen in Russia and India. Freshmen in Russia have significantly higher levels of critical thinking and math skills, but not physics skills, compared with freshmen in India.

To what extent do students in these four countries improve their skills during college? With regard to critical thinking, whereas students in China, India, and Russia make no gains (or even worsen) during university, students in the United States make significant gains. China's advantage in math and physics skills narrows considerably after two years due to cross-country differences in skill gains. Skill gains from the start of the first to the end of the second year in China are negligible or negative in math and physics. By contrast, skill gain estimates are positive and significant in India and Russia for math and in India for physics.

Do Students at Elite Universities Learn Better?

In the past two decades, policy makers in China, India, and Russia have actively pushed elite institutions to become world-class, which has led to a growing differentiation of higher education systems into elite and nonelite institutions. Elite institutions are characterized by higher levels of investment and prestige. They are generally thought to be of higher quality compared with nonelite institutions, which train the vast majority of university students in most countries.

We observe large differences in critical thinking and academic skill gains among students in elite and nonelite institutions, both within and across countries. For example, students in elite institutions in China have higher levels of critical thinking and math and physics skills than students in elite institutions in India and Russia. Notably, freshmen in nonelite institutions in China exhibit substantially higher levels of critical thinking skills compared with freshmen in elite institutions in India (this gap closes by year 4), and higher levels of math and physics skills compared with freshmen in elite institutions in Russia (the gap in math but not physics skills closes by year 2). Overall, elite universities in all three countries admit students with higher skill levels but do not contribute to heightening their skill gains, when compared to nonelite universities.

Closing Gender Gaps in Skill Acquisition

Finally, there are small differences in skill levels and gains by gender. At the start of their university studies, female students exhibit similar levels of critical thinking skills to male students in China, India, and Russia. Female freshmen in China and India have slightly lower math and physics scores compared with male freshmen. Female freshmen in Russia score at the same level as male freshmen in math and physics.

During the first two years of university, female and male students in all three countries make similar gains in critical thinking. By the end of their studies, female students in India and Russia have similar scores in critical thinking while female students in China score lower compared with male students. Female students in China, India, and Russia make higher gains in math compared with male students, closing the gender gap in China and India and outperforming male students in Russia by the end of their second year.

Universities seem to be closing gender gaps in math (in China, India, and Russia) and critical thinking (in India and Russia), which can have implications for increasing the equal representation of women in the STEM workforce. However, the initial gender gaps in math and physics at the start of university indicate that countries need to invest more in improving student achievement in math and science at the secondary level, or that STEM programs in these countries have room to attract higher achieving female students.

A Call to Improve the Quality of STEM Education Worldwide

To summarize, the study provides important insights into the global competitiveness of STEM university students across nations and institutional types. The large variation in skill gains across countries and institutions underscores the need for more research on skill development in university. The fact that students in different countries and types of institutions experience significant variations in skill development indicates that higher education systems, including elite and nonelite institutions, often do not prepare students for skill-based technological change. In their efforts to improve STEM education, universities and policy makers should look beyond mere increases in the number of STEM graduates and consider the quality of their learning outcomes. ◢

Prashant Loyalka is associate professor at the Graduate School of Education and senior fellow at the Freeman Spogli Institute for International Studies at Stanford University, US. Email: loyalka@stanford.edu.

Ou Lydia Liu is a principal research director at ETS. Email: LLiu@ets.org.

Igor Chirikov is SERU Consortium director and senior researcher at the Center for Studies in Higher Education, University of California, Berkeley, US. Email: chirikov@berkeley.edu.

This article is an edited version of a study published in Nature Human Behaviour *and coauthored by Prashant Loyalka et al.*