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COMPUTER SCIENCE EDUCATION BUILDS SKILLS FOR LIFE

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DEWS: Welcome to the Brookings Cafeteria, the podcast about ideas and the experts who have them. I'm Fred Dews.

My guests today argue that computer science education in K through 12 schools matters, not because it's about training the next generation of computer programmers, but because computer science education builds skills for life. Emiliana Vegas, senior fellow and co-director of the Center for Universal Education at Brookings, and Michael Hansen, senior fellow in the Brown Center for Education Policy at Brookings, are co-authors, along with Brian Fowler, of a new report, "Building Skills for Life: How to expand and improve computer science education around the world," and they join me on the Brookings Cafeteria today.

Also on this episode, Adie Tomer, senior fellow in Brookings Metro, reflects on the enactment of the new federal infrastructure program, which he calls the largest single investment in the country's built environment in at least half a century.

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JOHN MCARTHUR: Hi, I'm John McArthur with the Center for Sustainable Development at Brookings.

ZIA KHAN: And I'm Zia Khan with The Rockefeller Foundation. We're the co-hosts of "17 Rooms," a podcast about actions, insights, and community for the Sustainable Development Goals and the people driving them.

MCARTHUR: 17 Rooms is a new way of getting people together to take action on the 17 Sustainable Development Goals. In this podcast, you'll hear our conversations with dynamic leaders shaping actions towards the Goals.

KHAN: “17 Rooms” is produced by The Brookings Podcast Network. You can download and listen to it on Apple, Spotify, or wherever you like to get your podcasts.

DEWS: You can find “17 Rooms” and ways to subscribe to it on our website, brookings.edu/17RoomsPodcast.

And now, here’s my interview with Emiliana Vegas and Michael Hansen on computer science education’s importance in building life skills. And stay tuned to hear from Adie Tomer on infrastructure.

DEWS: Emiliana, welcome back to the Brookings Cafeteria.

VEGAS: Thank you, Fred. It's a pleasure to be back.

DEWS: And Mike, welcome back to the Brookings Cafeteria as well.

HANSEN: Thank you, Fred. It's great to be here.

DEWS: So, the report's main title isn't about computer of science education at all. It's titled "Building Skills for Life." Why that emphasis?

VEGAS: When we started off with this project, a lot of our research agenda at Brookings has to do with what are the skills that individuals need to succeed in life and to succeed at work and to be active citizens. And given how technology permeates every aspect of our life, we came to the conclusion, and kind of the research also suggests, that having a functional knowledge of computer science is today as important as being able to read, write, and do basic math. And so, we conclude that it's a foundational skill, it's a basic skill that everyone needs to have to be successful and thrive in this century and in the future. And we believe that not everybody needs to be a computer scientist or an engineer, but that having this basic skill also builds other skills that are very important for life.

HANSEN: Often in computer science, education initiatives are seen as an effort to simply create more programmers. And while employment certainly is a key outcome that often motivates these kinds of policies, computer science fundamentals offer many benefits to students, even if they don't become programmers, just as Emiliana has described.

DEWS: So, what is computer science education? And, Mike, you just said one of the things that it is not, it's not about training computer programmers, but what are some other things that it is not?

HANSEN: Well, it is not just simply computer literacy. Computer literacy would be basic skills like typing or using word processing or spreadsheet applications, or perhaps how to use mobile app technology or those kinds of things. Rather, computer science, it's the study of computers and computing processes and how computers are used in society broadly and how they impact the society and the world at large.

DEWS: So, should we think of it or not think of it as a subset of STEM--science, technology, engineering, and math?

HANSEN: Many, many places would consider computer science part of the T, the technology part of STEM. And so, skills that one might typically encounter in a computer science class would be fundamental skills along the lines of things like abstraction, that is, creating a model to solve a problem. Generalizing a problem so that we remix or reuse sources that were previously created in different solutions and applying them to a new solution. Decomposition where you break a complex tasks into smaller subtasks. Algorithmic thinking, programming, debugging.

Now, I just mentioned a moment ago that it's not about creating computer programmers. Of course, many computer programmers they learn many different languages within computer science. Now, for the purposes of K-12 education, the purpose is not to teach kids C++, or HTML, or any other computer program per se, but it is providing the experience and the opportunity to start seeing how a computer language does operate and what the program looks like and would be introducing some very basic functions.

But it's not just about becoming a programmer, but it's rather understanding the process, and deconstructing that process, and understanding how it can be used to operate in the world, and how through the use of these programs, we can manipulate many things. So, robots, for example, things in the real world, or things in the digital space through thoughtful use of programs in the creation of designs and of course, we can debug them as any problems arise.

VEGAS: And just to add to that, what I find really interesting about expanding computer science education in K through 12 education is that by teaching kids, and by building these skills like what Mike was referring to—how to solve and parse out problems, how to debug, which means basically when something's not working, what was the problem that created that in programing—you're also learning a lot of problem solving, critical thinking skills. You're collaborating with others. You're in fact learning a new language. And all these skills are so important for any job and not just STEM jobs. They're important for social science jobs. They're important for any job in, sort of, the knowledge economy.

DEWS: So, again, back to that building skills for life emphasis in the title. And you start the report, which can be found on the Brookings website, Brookings dot edu, within the context of COVID-19's impact on educational investment and student learning. Why is that context so relevant when it comes, in particular, to computer science education?

HANSEN: Well, first and foremost, many schools across the globe were shuttered *en mass* in the face of the pandemic last spring. And those that maintained instruction and connection with their students over computers are generally viewed as having served their students better than situations where computers were not used, and connections were much more tenuous or infrequent.

But beyond schools, COVID impacted many industries worldwide. Industries and companies that could shift to computers and into a virtual space were therefore much more resilient in the pandemic than those that couldn't make that pivot.

And so therefore, beyond basic computer literacy, having some knowledge of computer science among employees to be able to have the insights and the ability to quickly make a transition into more of a digital space in these business operations, it speaks to the value of being able to employ those skills and how COVID-19 was sort of a great sifter of places that had those abilities within different sectors.

VEGAS: Yeah. I mean, that's absolutely right, and I think that even beyond COVID, we will see an even greater uptake in the use of technology now that we've kind of shifted. And I think having that deeper understanding of what it means for our privacy and for our lives in general is ever more necessary.

DEWS: So, you've explained how computer science education build skills for life, but there's also an economic component and you document a relationship in the report between economic growth in countries that have more workers with so-called ICT, or information, communications, and technology skills. Can you expand on that?

HANSEN: So, we look at the relationship between technology skills and employment and outcomes, of economic outcomes, on sort of two different levels. First is at the macroeconomic level, and we do find an association across countries that high levels of employment within technology sectors is associated with greater GDP per capita growth, for example. And not only that, but also it is associated with benefits on the more micro economic level, if you will.

So, having computer science skills, they are much more likely to have higher earnings in the labor market. And those with these skills also find themselves unemployed much less and for shorter durations as well.

And beyond that, even for those people who aren't directly in computer science occupations, even those with computer science skills, they find themselves actually quite highly employable even in other occupations. So, whether they're going into retail or into, for example, into various other science areas in the STEM fields, so social sciences. And even other places beyond social sciences or engineering or even other places beyond those more typical applications, many places are beginning to bring those skills into the workforce.

VEGAS: It's also a way of reducing inequality. We know that technology has been a key driver of social and economic inequality within countries. So those who have access to technology, those who have access to connectivity have advantages both in education as well as in the workforce. And so, having these skills and having the ability to generate applications of technology in disadvantaged communities also will help, in our view, reduce economic inequality across the world. And so as Mike said, it has benefits for countries as a whole, has benefits for an individual, but it also can help produce more equal societies.

DEWS: Well, the report has some great data and charts that show that relationship between ICT and economic growth. It also has some great charts on the extent of computer science education worldwide. How would you characterize the state of computer science education around the world? Are certain countries and regions lagging, or other places leading?

VEGAS: We took a scan of the extent to which computer science education has been made available to students from K through 12 across the world. And I think it's the first scan of that nature that really took into account all parts of the world to the extent that we could access information. And not surprisingly, you know, we found that students who live in higher income countries tend to have higher access to technology and computer science education. So, for example, you know, in many parts of Europe and several parts of North America and Australia, computer science is mandatory in both primary and secondary schools or in one or the other. Then you have a group of countries, both of upper- and sort of middle-income countries where computer science education is available, but as an elective course, so students are not required to take it at any place. And one of the things we also found is that even when it's available as an elective course, there's issues of take-up, of students actually taking it and understanding how it may benefit them.

Then there's a group of countries where—a majority of U.S. states, for examples, are here, several countries in Latin America and in Asia are in this category—where it is being expanded, but in some districts or in some school systems, but not across the board. And then a few countries where the government has announced a pilot with the intention of expanding it.

But there are many countries in the world, particularly in sub-Saharan Africa and in other less developed regions of the world where there's no computer science education available yet to students in primary or secondary schools.

And so that was kind of like, our not surprising, but still very striking key takeaway that students have different access and particularly students who are, even in high income countries, of disadvantage populations who would most benefit from computer science education, so it's historically underserved populations, girls. They are often excluded.

DEWS: I'll be back in a moment with Emiliana and Mike, but now here's Adie Tomer with a look at what he calls a historic investment in the nation's infrastructure.

TOMER: My name is Adie Tomer, and I'm a senior fellow at Brookings Metro, focusing on infrastructure issues.

After years of calls to action and unfulfilled promises, federal Washington finally delivered a landmark infrastructure bill this November. The Infrastructure Investment and Jobs Act, or IIJA, is easily the largest single investment in the country's built environment in half a century or more.

Now, in any piece of legislation this big, two major questions come to mind. First, what's in it? And second, what will it do for me?

Let's start with the bill’s content. Clocking in at over 1,000 pages, IIJA is far from a light read. The law bundles capital grants, workforce development investments, R&D programming, and regulatory reforms across all the major infrastructure sectors—transportation, water resources, energy, and broadband. And it commits real money to rebuild the country. At least $550 billion in new funding, and potentially over $1 trillion in total spending over five years.

All that activity is about to set off a spending boom we haven't seen since at least the mid-20th century. In fact, our estimates project IIJA to push federal infrastructure spending to similar levels as seen during the New Deal. And if the reconciliation budget becomes law too, we will easily exceed that New Deal number.

The historic comparison works because this new law aims for durable impact. Remember, IIJA isn't a stimulus bill, it's not a singular response to a specific economic crisis. Instead, IIJA represents a longer-term, patient approach to rebuilding American competitiveness through the built environment.

Which leads to the second big question. What will this bill do for you? The short answer is this: It will undoubtedly touch your life, but it will take some time. Unlike income related programs like unemployment insurance or the child tax credit, infrastructure policies take years to ramp up. Inside Washington, agencies need to hire more staff and design new rules to guide all these investment dollars.

And then in state capitals, county offices, and city halls, the truly hard work takes place. All those government officials must hire their own management staff. Agencies and their private sector partners need folks like engineers and environmental scientists to help plan and evaluate projects. There must be enough skilled tradespeople to construct everything. Contractors will need input materials like sand and heavy equipment to execute all the work. It's a herculean lift.

Now, those implementation challenges are significant, but so is the payout. IIJA includes enough funding to make sure projects of some kind will happen in essentially every corner of the country. And even if a “construction underway” sign doesn't appear down your street, you'll still feel the effects of this bill within a few years—airport improvements when you travel; faster broadband in your communities; reduced wildfire and flood risk to keep us all safe; smoother access to goods through our ports.

Federal Washington has a problem with hyperbole. But that's not the case here. With IIJA, America really did just make a historic investment in itself, and before we know it, we'll all be reaping the rewards.

DEWS: Visit our website, brookings.edu, to find more research about infrastructure from Adie and his colleagues. And now, back to my interview with Emiliana Vegas and Michael Hansen.

DEWS: Yeah, that's a good segue way to a set of questions and issues about access to computer science education. It seems to me that CS education depends on a number of conditions that may be lacking in some regions or countries, like unequal access to reliable electricity, broadband, qualified teachers, and computer hardware itself. How can countries and school systems overcome those barriers?

HANSEN: Of course, many countries across the world don't have the infrastructure for computing technology already in place. So, this would be broadband or other internet connections. And they don't have maybe even reliable electricity, as you just mentioned, Fred. And then also qualified teachers or, you know, the devices themselves.

Some of our case studies do explore some of those scenarios in those settings and what computer science education looks like in those contexts. The short answer is that with some resourcefulness, some of the fundamental skills can still be taught. So, for an example, in South Africa they have a heavy reliance on mobile phones and mobile technologies rather than using desktop technologies because they don't have a dedicated land based, broadband internet. So, some of those technologies can help fill those gaps.

There's also resources like CS Unplugged, which offer a variety of lesson ideas and resources about how to approach and teach a fundamental computer science principles without the use of any technology. And so, for example, it teaches about the binary system, or it teaches about constructing a set of instructions, so that a robot could follow them, but even with separately from actually sitting down and programing.

Now these kinds of solutions are nice and very useful. However, getting to a full curriculum that really teaches computer science in a really rigorous way, you really do need access to broadband, to computing devices. And so that is a key lesson and one that really does make different countries' sort of preexisting investments into electricity, into broadband, those are pivotal and how quickly they can scale up and create more universal access to computer science education for their students.

VEGAS: And if I may add to this just last point, I think COVID, the pandemic, has really laid bare how important it is for those countries that are behind in getting access to connectivity, electricity, and to really speed up their progress. And there is, I think, a global effort led by the UN agencies, including UNICEF and others, to try, with some private corporations, to invest in accelerating, let's say, the access to connectivity and technology in rural parts of the world and in more disadvantaged areas of the developing world. So I'm hoping that one of the positive benefits of the pandemic with all the negative aspects of it will be a new awareness of the importance of really not leaving more children behind and investing in access and broadband for all.

DEWS: So, you end the report with six key lessons for governments that want to expand computer science education, it's detailed really well in the report. But can you summarize those?

VEGAS: Well, we identified sort of six key takeaways from looking at 11 systems around the world, jurisdictions—some of which are states or provinces in North America, or others which are countries around the world—that have expanded and integrated. And all of them have faced, you know, some challenges. So it hasn't been an easy ride, and no one has completely, I think, mastered having it accessible to everyone equally with high quality.

But among the kind of lessons that we kind of teased out from this case study research is that first, you know, countries or systems where there was an explicit economic strategy as a nation to expand technology-based jobs were more likely to then invest in introducing quality computer science education in primary and secondary. So, that's a powerful lever, if you're trying to insert yourself as a lower-, middle-income country in the knowledge economy, attracting tech-based jobs will be a priority and therefore building these skills will become also a priority.

The second, and you alluded to this, Fred, is that countries that had already invested in information, communication technology in schools, you know, installing broadband access, having obviously electricity, and having access to devices for students and teachers, had an easier time in expanding computer science education because they had to tackle mainly the challenge of human capacity. But the infrastructure aspect was kind of already had already been invested in.

And this leads me to kind of the third key lesson, which is a huge challenge for all countries regardless of their resources and their infrastructure investment, is that even in the most high income, highly committed countries, developing qualified teachers to deliver quality computer science education has been a challenge, because there are so many demands on teachers in general. There's already shortages in some of the STEM fields, including math and science, so that kind of retraining or diverting those resources for computer science may be an issue. And so one of our lessons is that it's really important for all teachers in their pre-service education to get exposed and get some foundational knowledge south so that that and then through professional development they can deepen those skills.

The fourth key lesson that we teased out is that exposing students to computer science education early, in their earlier grades in kindergarten, first, second, third grade, can help foster demand and interest among students, and especially among girls and other historically underserved populations, which then continue to be underrepresented in the STEM fields.

And then a fifth way in which countries can address these challenges is that, you know, there are stakeholders that that want to see this happen and who have been very helpful in some of the low- and middle-income countries and also in some of the higher income countries in addressing some of these bottlenecks, either in access to infrastructure or teacher capacity. And so, for example, some of the large corporations have programs themselves. Some non-governmental organizations or civil society organizations have been very impactful in generating interest, for example, among students and underserved populations. Programs like Girls Who Code, the Hour of

Code, all of these programs have been very effective in some settings to generate interest and then to build Canada to help support the rollout of these computer science education in primary and secondary schools.

And then the last key lesson is that when, and related again to our title, that when it starts in an interactive and hands-on way using not just computers, but also sometimes blocks, robots, and other engaging, let's say, tools and devices can really help build skills for life that go beyond kind of programing and computer science itself.

HANSEN: Let me hope in here briefly, Fred, I want to follow up on the fourth note that Emiliana highlighted, which is that by exposing students to computer science education, particularly exposing them early during their elementary years, it helps to foster demand and it helps to provide those learning opportunities, especially for underserved populations. These populations—for example, girls, students of color, these are historically underrepresented populations in STEM fields. And of course, economically, these groups often do lag behind as well. And so, providing opportunities for those exposures early is seen as a way to reduce inequalities as we spoke about in the beginning.

But beyond that, one thing that I do want to highlight is that STEM fields are often seen as a very efficient method of assimilating into society for immigrants, for example. It's also seen as a key way of upward social mobility. And these kinds of skills are very effective in reducing those gaps. And as we can make high quality computer science education more accessible, the hope there is that we can reduce and mitigate some of these gaps that have arisen historically, and quite frankly, that technology is part of creating some of these gaps. And with access to computer science education, we're hoping that some of those gaps can be mitigated and weakened.

DEWS: Emiliana, you are the co-director of the Center for Universal Education at Brookings, which I tend to associate with kind of a global education focus. Mike, you're a scholar in the Brown Center on Education Policy, which I tend to associate with a U.S. domestic focus. Can you talk about how computer science education sits at that kind of nexus between the two centers, with a global focus and with the U.S. focus?

VEGAS: I think what brought us together was our shared interest in improving opportunities for students, for Mike, obviously, most of his work in the U.S. And for me, most of my work in low- and middle-income countries. But when we started our conversation around this project, it was the idea that a lot of the progress in expanding quality computer science education has happened outside the U.S., although there are some states in the U.S. that are making really strong progress, including Arkansas, which we featured in our report. But that there's a lot that the U.S. itself can also learn from what's happening outside its borders. And so, I think that, from my perspective, was something interesting. And you know, on a personal side, we were looking for ways to collaborate. So, that was really nice to work with Mike on this.

HANSEN: Thanks, Emiliana. I wholeheartedly agree with everything you just said, especially the pleasant working collaboration here.

One thing I do want to add is that listeners in the audience will be well aware that we have longstanding social inequalities within the U.S. And as I mentioned just a moment ago, improving access to computer science is seen as a way to help improve social mobility, to help close some of these employment gaps and opportunity gaps that we see not only across countries, which is sort of what this global lens gives us, but also within countries, which is what the U.S. focus that I bring that I really want to, you know, zero in on.

And these inequalities have been growing within the U.S., of course, over the last several decades, and social mobility, you know, has appeared to be slowing. But by bringing a more inclusive approach to computer science education and to really help to change the way we teach it across the country so that, instead of just being an optional class that some kids take in high schools if they're technology inclined but something that becomes mandatory and becomes something that kids are exposed to from young ages, and that they can learn some of these fundamental skills.

And the hope is that they will be, some of them, of course, will be interested in becoming programmers, but also even beyond becoming programmers, that they can have the skills where they can, once they get into college, they can navigate college better because a lot of college happens online. Or when they get to the workplace-- there's many different aspects of many professional jobs that require a range of computing skills and being able to navigate those environments is an important part of helping students be college and career ready.

DEWS: Well, Emiliana and Mike, I want to thank you both for sharing your time and expertise today. It's been really interesting.

VEGAS: Thank you for having us.

HANSEN: Thank you, Fred. It's been a pleasure.

DEWS: Again, the report is "Building Skills for Life: How to expand and improve computer science education around the world," by Emiliana Vegas, Michael Hansen, and Brian Fowler. It's on our web site, brookings dot edu.

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Until next time, I'm Fred Dews.