Chapter 16
EdTech for Equity in China: Can Technology Improve Teaching for Millions of Rural Students?

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Abstract Despite major advancements in China's K-12 educational outcomes over the past several decades, large regional inequities in academic achievement still exist, a proximal cause of which are gaps in teaching quality. Although conventional approaches to improving teaching quality for disadvantaged populations have overall been unsuccessful in China (i.e., student relocation to better-resourced urban schools, attracting high-quality teachers to low-resource rural schools, and rural teacher training), technology-assisted instruction may play a role in bridging these gaps. This paper explores why conventional approaches to improving teaching have not been effective in rural China and then describes the potential applications of technology-assisted instruction based on the small but growing body of empirical literature evaluating such interventions in other low- and middle-income countries. The paper concludes that while other (non-tech) interventions have thus far been ineffective at raising teaching quality, China may be uniquely positioned to harness technology-assisted instruction due to a favorable ecosystem for the scaling of EdTech in rural areas, though much more experimental research is necessary to assess which approaches and technologies are most cost-effective and how to best scale them.

16.1 Introduction

Previous literature suggests subpar teaching is a primary reason why rural Chinese students lag behind academically. In this paper, we initiate an investigation into the potential of educational technology (EdTech) to increase teaching quality in rural China. First, we discuss why improvements in conventional teaching approaches in remote schools are infeasible in China's context, referring to past research. We

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then explore the capacity of technology-assisted instruction to improve academic performance by examining previous empirical analyses and discussing why China might have especially favorable conditions for implementing technology-assisted instruction at scale compared to most other low- and middle-income countries. This paper lays the foundation for a long-term research investigation into whether EdTech can narrow China's education gap.

16.2 Why Poor Teaching is Widening China's Education Gap

In recent decades, as China's economy has grown exponentially, China's education system has achieved a number of notable successes. The adult literacy rate increased from 66% in 1982 to 97% in 2019 (UNESCO 2019a). Students from large cities in China have performed among the best on international standardized evaluations, such as the Organisation for Economic Co-operation and Development's (OECD) Program for International Student Assessment (PISA). In fact, on the 2012 PISA, students from Shanghai, China, outperformed students from 64 other countries in all subject areas tested (OECD 2014). Overall school access has also increased dramatically over the past decades, as nearly all (99%) of China's children—both urban and rural—are finishing primary school, and all children are entitled to nine years of free schooling (which includes primary and lower secondary school in China) (Chung and Mason 2012). Since 2005, the share of youth attending upper secondary school (grades 10–12) has also increased rapidly (Bai et al. 2019).

Despite these accomplishments, large disparities in academic performance still exist between China's urban and rural youth. Gaps in school performance between China's urban and rural children emerge as early as primary school (Zhang et al. 2015) and have been shown to exist not only in the national aggregate but also at the provincial level (Xiang et al. 2019). Differences in achievement on international assessments make these gaps even more apparent. While Shanghai students have performed among the top in the world on standardized tests, students from lower-income, inland, and predominately rural provinces have performed among the lowest (Gao et al. 2017). This is worrisome as rural children make up approximately 70% of China's school-aged population (National Bureau of Statistics 2020).

As a result of academic performance disparities, there are significant differences in educational attainment between students across urban–rural and regional boundaries. For example, only 60% of students from poor counties in Ningxia Province take the high school entrance exam, while almost 100% of students from non-poor counties do (Loyalka et al. 2017). Without sufficient years of quality education, rural students may not be able to develop the human capital needed to succeed in the knowledge economy (Wang et al. 2018).

Research in recent years has shown many reasons why rural students in China struggle in school. For example, despite substantial improvements over the past few decades, schooling facilities in rural areas are still worse than in urban areas (Wang et al. 2017; Yang et al. 2013). Urban parents usually have attained a higher level of education and have more time and ability to help their children with their studies (Huang and Du 2007). Average incomes in urban areas are more than 2.5 times higher than those in rural areas, so urban families also have more resources to invest in their children's education (NBS 2020). Furthermore, health problems among rural students negatively impact their academic performance. Specifically, studies have shown that, at least over the past decade, conditions such as anemia (Li et al. 2018), intestinal worms (Liu et al. 2017), and uncorrected visual acuity (Ma et al. 2014; Nie et al. 2018) negatively affect the performance of students in rural schools.

Among the most important factors driving low student performance may be the poor quality of teaching received by rural children. The close relationship between teacher quality and student outcomes has been demonstrated in numerous studies in the international literature (Boyd et al. 2008; Kane et al. 2006; Sanders and Rivers 1996; Goe 2007; Rice 2003; Rockoff 2004; Hanushek 2011). In China, as well, research has demonstrated the importance of teacher quality for student learning (Chu et al. 2015; Park and Hannum 2001; Zhang et al. 2018) and the poor quality of teaching in rural areas (Niu 2009; Liu and Onwuegbuzie 2012; Zhang and Campbell 2015; Chung and Mason 2012).

While teacher quality is key in any effort to enhance student performance, the literature has shown that the teaching received by rural students in China lags far behind that received by urban students. This raises several questions: What are conventional ways—approaches tried in other contexts—to resolve a school system's teaching quality problem? Have these ways worked in rural China, and why or why not? If not, are there alternative ways of teaching rural students with the assistance of technology that has worked in other contexts, and would these be viable approaches in rural China?

The overall goal of this paper is to seek out answers to these questions. First, we will review common approaches to improving teaching quality for disadvantaged student populations and discuss why they may not work in China's context. Second, we will explore the existing international literature for the potential roles of EdTech in addressing this gap.

To meet these objectives, we will use the following strategy. First, we will examine the existing literature on three different strategies that educators in other nations (and China) have used to address the needs of rural students and provide evidence for why such approaches have not been universally effective in rural China. Second, we will explore analyses of the potential of the newly-emerging EdTech sector to improve student outcomes, hypothesizing why large-scale adoption in low-resource areas of developing countries is rare and why China may be uniquely advantaged to harness EdTech for improving instructional quality at scale.

16.3 Traditional Ways to Improve Teaching: Can They Work in Rural China?

How then can China improve the quality of teaching for rural students? In theory, three traditional solutions have been used internationally that China could implement, but due to structural and political barriers, they are either not feasible or have been tried and failed. These three traditional solutions are (1) to allow children to migrate to urban areas to access better schooling; (2) to attract well-trained, well-educated urban teachers to rural schools; and (3) to raise the quality of rural teachers through teacher training or professional development programs.

16.3.1 Rural–Urban Migration

In some countries, the easiest solution is for children in low-resource school districts to migrate to more developed areas to access higher-quality education (Echazarra and Radinger 2019; Crowley 2003; Deluca and Rosenblatt 2010). In China, however, moving rural students to city schools to access higher-quality teaching is not feasible for most rural families. Of course, as in other countries, those who wish to move to cities for their children's education often face financial barriers due to the huge urban–rural income gaps that exist in China. However, even for those who can afford urban housing and living costs, rural families face administrative restrictions in the household registration, or *hukou,* system. Under the hukou system, a person's access to social services—including public education—is tied to their hukou registration (which is inherited at birth). As a result, those children with rural hukous have historically been unable to legally enroll in urban primary schools (Chan and Buckingham 2008). Although policy shifts at the national level in recent years have mandated that local authorities provide free education to rural migrant students, schools in some—especially larger—cities continue to impose an array of difficult-to-fulfill administrative and academic requirements that can prevent migrant students from attending at all (UNESCO 2019b).

16.3.2 Teacher Relocation

With rural children unable to access the higher-quality educational resources of urban areas, another approach to reducing educational disparities between urban and rural areas could be to attract high-quality teachers from urban areas to rural schools (Roberts 2004; Harmon 2001; Hudson and Hudson 2008; McEwan 1999; Cobbold 2006). Starting in 2007, due to a perceived shortage of the supply of high-quality teachers in rural areas, China's Free Teacher Education (FTE) program offered qualified students at six of the top normal universities in different parts of China a package of financial benefits, which included tuition exemption for a degree in teaching, free accommodation, and a monthly stipend (MOE 2007, 2018). While ambitious, according to the literature, the FTE program has so far failed in its key goal of attracting teaching majors at high-quality universities to work in rural schools after graduation, partially due to negative attitudes of FTE students toward the subpar working conditions, remote locations, and lower pay compared to urban teacher positions (Fu and Fu 2012; Shang 2017; Zhou 2010; Li et al. 2011; Shang and Yu 2018; Wang and Gao 2013; MOE 2005, 2006; He and Wang 2016; Li 2010). Although recent adjustments to the policy have attempted to address some of these issues, such as by shortening the mandatory period of service (MOE 2018), so far, it is too early to tell whether such revisions will improve outcomes.

16.3.3 Teacher Training

Considering the restrictions barring the enrollment of students in urban schools and the reluctance of urban teachers to move to rural areas, a third approach to improving educational outcomes for rural students is teacher training programs. Initiatives to train teachers have been implemented elsewhere to varying degrees of success (Yoon et al. 2007; Gersten et al. 2014; McEwan 2015; Popova et al. 2018), while in China, the literature generally indicates null impacts on learning. In one study of Beijing migrant schools by Zhang et al. (2013), the researchers conducted a randomized controlled trial (RCT) that measured the impact of an intensive, short-term in-service teacher training program on teacher performance and student achievement. The results displayed no significant program impact on either teachers' pedagogical practices or students' test scores. In another province-wide study of rural schools in central China, Loyalka et al. (2019) evaluated the effectiveness of the National Teacher Training Program (NTTP), ultimately finding no impacts on student academic performance or teaching approaches. The results of Loyalka et al. (2019) were basically supported by Lu et al. (2019), who also evaluated the impacts of the NTTP and concluded that the program may have even negatively impacted the performance of students on a standardized math test—at least in the short-run. The overly theoretical content and rote delivery methods of the programs, the busy schedules, and poor baseline content knowledge among teachers were all reasons cited for the lack of impact.

In conclusion, the three traditional approaches to improve teaching quality have not been successful thus far in rural China. First, barriers with historical foundations in a discriminatory residence registration system have prevented children from rural areas from attending higher-quality public schools in cities. Second, policy initiatives to bring new graduates to rural areas have failed to do so despite employing a host of incentives and contractual obligations. Finally, small-scale, independently-run, and nationwide, government-run professional development programs have not been able to improve the pedagogy of rural teachers for a number of reasons, in particular, the lack of emphasis on content and techniques easily applied to the classroom and misalignment with teachers' baseline knowledge and schedules. In light of these challenges, we now turn attention to a fourth approach that has only become practical in recent years: using new technologies to enhance teaching quality in rural China and, in turn, systematically raise student academic performance.

16.4 The Potential of EdTech to Improve Teaching and Achieve Equity

With rural children unable to migrate to cities for better education, urban teachers unlikely to move to rural areas, and mediocre returns (if any) on the attempted teacher training programs, are there other options for improving teaching quality in rural China? In recent years, one opportunity that has arisen is using new internet- and mobile-based technologies to improve the educational experience. This section provides relevant background on EdTech in general and describes different types of EdTech that could be potentially used as alternative solutions to poor teaching in remote, rural schools, focusing specifically on technologies for improving classroom teaching.

16.4.1 Introduction to EdTech

EdTech can be broadly defined to include all technologies used in education. This comprises hardware, software, internet connectivity components, and the content delivered through these platforms (J-PAL 2019; Bulman and Fairlie 2016). While there are many goals and uses of EdTech, studies in the economics of education generally focus on how technology may or may not impact academic outcomes in major subject areas, such as math or language.

One unifying theme in the evaluation of EdTech effectiveness is that the use of technology is placed in the context of educational production functions commonly discussed in the economics literature. Investment in computer hardware, software, and connectivity may offset other inputs that affect student achievement in the context of the household and the school. Likewise, time spent using computers offsets other educational or recreational activities. Carefully considering how technology use complements or crowds out other investments is crucial to conducting a cost/benefit analysis of introducing new technologies in education and understanding whether EdTech will serve to narrow or exacerbate educational disparities.

Several past reviews of EdTech have categorized EdTech innovations into different modes or approaches, each of which attempts to intervene in a different part of the learning process (Bulman and Fairlie 2016; Escueta et al. 2017, 2020; Rodriguez-Segura 2020). The primary modes with some evidence of effectiveness include software packages that allow students to engage in self-led learning in specific subjects (computer-assisted learning); technology-enabled behavioral interventions, such as text-messaging campaigns that aim to provide teachers, parents, or students with information or incentives; and technologies that aim to directly support teacher pedagogy. In line with the scope of the current study, we will focus on this third category of EdTech interventions ('technology-assisted instruction'), particularly those that can enhance and transform classroom instruction in K-12 education.

16.4.2 Types of Technology-Assisted Instruction

Nowadays, in places that have achieved broad access to hardware and internet connectivity, there are a wide variety of digital resources available to teachers that can be used to improve classroom pedagogy. Because EdTech tools and approaches are so wide and varied, to identify those that can be helpful in specific settings to address specific problems, it is important to understand both the functions of different EdTech tools and carefully identify strategies for using them that can most effectively improve student performance.

Previous scholarship has sought to identify different frameworks to better understand the functions of these tools. One recent framework, the substitution augmentation modification redefinition (SAMR) model, developed by Dr. Ruben Puentedura, divides classroom technology integration into four different categories: (1) substitution, (2) augmentation, (3) modification, and (4) redefinition. These categories differ mainly in the degree to which they alter the educational process. For example, while those technological tools that 'substitute' or 'augment' merely enhance existing tasks (for example, by improving the efficiency of grading or the efficacy of feedback), technologies that 'modify' or 'redefine' can fundamentally transform existing tasks to create previously inconceivable ones (e.g., allowing students to learn a foreign language by communicating with native speakers over the internet) (Puentedura 2014).

Of the many forms of technology-assisted instruction, remote instruction (also often referred to as 'distance learning' or 'long-distance learning') has become one of the major foci of research since the 1980s. Remote instruction uses physical technology and educational processes to give access to students when they are removed from the source of instruction and resources by either space or time (Cavanaugh 2001). Beginning in the 1990s, it became increasingly common for distance learning to be conducted online instead of on radio or television (Means et al. 2009).

Remote instruction conducted online can be further split into two types: asynchronous and synchronous (Wicks 2010; Hrastinski 2008). Asynchronous online learning is separated by time. The teacher(s) and the student(s) are able to operate separately, as they do not need to be online at the same time. In this form of learning, students can watch pre-recorded videos of the distance teacher and communicate with the teacher via email and discussion boards. The obvious advantage of asynchronous online learning is removing the need to operate simultaneously. However, this also raises the concern that the student may lack direct or sustained communication with a teacher and fellow students, reducing their feeling of belonging to a learning community. Such communities are essential for collaboration and learning (Hrastinski 2008).

On the other hand, synchronous online learning requires the teacher(s) and the student(s) to be online simultaneously, interacting in real-time. It commonly utilizes media, such as live video and chat. While this ensures that teachers and students can engage in more direct communication closer to traditional face-to-face (F2F) instruction, an obvious practical drawback is the need to be online simultaneously (Chen et al. 2005).

Nowadays, different types of online learning are being blended together with F2F approaches to transform the teaching and learning process. One example of this is the flipped classroom. This model received its name for reversing the traditional educational process that required students to attend an F2F lecture in the classroom (the group setting) and then practice what they learned at home (the individual setting). Instead, the flipped classroom model requires students to view an asynchronous lecture video at home before attending class. Then, in the classroom, students work in groups to practice and master the material while the teacher is free to walk around the room and provide guidance (Delgado et al. 2015). In recent years, the flipped classroom model has received extensive attention in the media and scholarly communities (Tucker 2012; Gilboy et al. 2015; Strelan et al. 2020).

16.4.3 Evidence of Impacts on Academic Performance in High-Income Countries

Does EdTech work inside or outside the classroom to improve students' academic performance? Even more than a decade ago, there was already a large body of literature examining the relationship between technology-assisted instruction and student performance (Cavanaugh 2001; Bernard et al. 2004; Zhao et al. 2005; Means et al. 2009), though findings from the body of technology-assisted instruction research before the turn of the century appear to be largely inconclusive (Trucano 2005). Beginning in the '00 s, a more rigorous body of research gradually began to emerge with the goal of evaluating the effectiveness of EdTech, with some modest evidence of its benefits. Two of the meta-analyses that specifically looked at K-12 education in this period, Cheung and Slavin (2013), found some evidence of a small positive effect (+0.15–0.16 SD) on reading and math achievement in comparison to traditional instruction. Like Trucano (2005), however, they acknowledged that more rigorous studies often had smaller and less significant effect sizes. Escueta et al. (2020) reviewed the literature on online courses and found that while purely online instruction has resulted in worse learner outcomes than F2F instruction, blended instruction can potentially match the effectiveness of F2F instruction. However, an important caveat is that the literature they reviewed almost entirely focused on online courses for college students. Recent evidence of learning losses during school closures in the COVID-19 pandemic generally supports the view that purely online instruction delivered to students at home is not as effective as F2F or blended instruction in school for K-12 students (Engzell et al. 2020; Kuhfeld et al. 2020), though these were not rigorous evaluations of specific in-school interventions.

Overall, the body of literature that has formed on this topic in developed countries does not provide convincing evidence about whether technology integrated into the classroom impacts student performance. This is partially due to inadequacies in most previous studies' experimental and methodological designs, making it difficult to rely on their results. Another concern is that most research has focused on post-secondary education, which is not necessarily applicable to the K-12 environment. Even when looking past these limitations, there is no consistent trend among past meta-analyses regarding whether technology-assisted instruction is more effective than traditional classroom learning. At the very most, there may be some evidence that blended learning has more promise than pure online learning (Zhao et al. 2005; Means et al. 2009; Escueta et al. 2017). In addition, for those studies that do report positive impacts, it is often difficult to ascertain whether this was due to increased instructional time or the technology itself. In a rapidly developing sector such as EdTech, the existing body of literature will need to be frequently built upon to keep up-to-date with the most current technologies.

16.4.4 Previous Research in Low-Resource Contexts of Low- and Middle-Income Countries

Provided that there is an effective model available for implementing and scaling technology-assisted instruction, it might potentially improve educational outcomes for students in isolated, poorly-resourced areas. For instance, with remote instruction, neither the students nor the teachers are required to physically relocate while still matching skilled educators with the students who need them the most. Although these interventions may not have had consistent positive impacts in high-resource settings, it is possible that in poorly-resourced schools, the teaching and academic performance are low to such a degree that EdTech could make a significant difference in outcomes. Many studies in the international literature have raised the possibility of EdTech's potential in this regard (Hannum et al. 2009; Sattar 2007; Sundeen and Sundeen 2017; Barker and Hall 1994; Sharma 2003; World Bank 2021).

In recent years, the evidence base of technology-assisted instruction's effectiveness in low-resource contexts is growing, though still nascent. Rodriguez-Segura (2020) reviewed the literature on EdTech effectiveness in developing countries and found two studies that evaluated synchronous remote instruction delivered via satellite in rural areas, including one at-scale experiment in India involving over 2,000 schools (Naik et al. 2020) and another large-scale experiment in Ghana in 77 schools (Johnston and Ksoll 2017). Both RCTs found evidence of effectiveness for improving student learning outcomes compared to normal F2F instruction. Although the authors of the Ghana study noted that the program was quite costly, especially concerning upfront fixed costs (including installing the satellite dishes and equipment in the schools), Naik et al. (2020) reported that in India, when implemented at scale, the program was highly cost-effective (with an additional cost of USD 16.7 per year). There has also been some evidence of the effectiveness of using pre-recorded (asynchronous) lectures in the classrooms of low-resource areas in both Mexico (Borghesan and Vasey 2021) and Pakistan (Beg et al. 2019). The few large-scale evaluations of technology-assisted instruction in China have thus far employed primarily quasi-experimental designs (Bianchi et al. 2020; Clark et al. 2021), and randomized experiments will be necessary to understand which approaches are most cost-effective in China's rural areas.

16.4.5 Challenges to the Scaling of EdTech in Low-To-Middle-Income Countries (LMICs) and China's Unique Potential

Considering the positive effects of these past interventions and the need for higher-quality teaching in most low-resource areas, why have there been relatively few efforts to investigate and scale the use of technology-assisted instruction in low-resource areas of most LMICs? As alluded to in Johnston and Ksoll (2017), a major reason is that many developing countries still do not have the necessary information technology (IT) infrastructure. Although the required computer-to-student ratio for remote instruction is relatively low compared to other interventions like computer-assisted learning, the purchasing of the equipment and cost of installation (in addition to satellite technology or broadband internet, as well as software maintenance) may still be too high in some contexts (Sundeen and Sundeen 2017). Other factors that may hinder the implementation and scaling of EdTech include a lack of relevant education policy and vision set by the government, an insufficient supply of EdTech products and services in the market, and low levels of human capacity (e.g., educators, NGOs, and on-the-ground leadership that can implement the interventions and ensure that they are sustainable) (Omidyar 2019).

China, however, may be an exception to the limitations described above. Over the past several decades, the country has made substantial investments into the IT infrastructure of schools to equip the large majority of classrooms (including in rural areas) with computers, projectors, and internet access (CNNIC 2018; Bianchi et al. 2020). This is partially thanks to China's ambitious policy agenda, which has highlighted EdTech as an integral part of its strategy to improve learning for the millions of students in rural areas that receive poor teaching (Zhao and Gan 2017; MOE 2019) and which has become further emphasized following school closures during the COVID-19 pandemic (MOE 2021). China is also home to some of the largest EdTech companies in the world, and in 2019 private investment in the EdTech market surpassed USD 4.4 billion (Omidyar 2019). Many NGOs and corporate social responsibility departments of companies have experimented with the use of remote instruction in rural schools, and the government is now piloting the use of the dual-teacher model (in which a high-quality remote teacher cooperates with a local classroom teacher to deliver instruction) in provinces like Zhejiang (Xinhua News 2019). Finally, although China has had difficulty attracting high-quality teachers to rural areas, it does not generally face the barrier of teacher absenteeism like in India (Duflo et al. 2012) and South Africa (Bipath and Naidoo 2021), thus enabling it to have adequate levels of human capacity to implement EdTech in schools (as long as adequate training is provided).

For these reasons, it appears that China has a favorable ecosystem to facilitate the scaling of EdTech interventions, though rigorous experimental research will first be necessary to establish a roadmap for the future. Just as prior RCTs have pointed to the effectiveness of supplementary computer-assisted learning in rural China for remedial tutoring (Mo et al. 2015), there is a need for rigorous experimental research to evaluate the effectiveness of technology-assisted instruction. To understand how technology-assisted learning can be implemented most sustainably to improve learning, the goals of such a research agenda should include measuring which approaches are most cost-effective over time, exploring what levels of intervention intensity (i.e., minutes per day) lead to the greatest impacts and how these interventions should be integrated into classroom instruction (i.e., supplement or substitute existing learning inputs), how impacts may vary across different regions and student characteristics, and how the effects of these interventions on student outcomes (including outcomes related to both academic performance and social-emotional development) can best be monitored from year to year.

16.5 Conclusion

By drawing from the existing academic literature, reports from the public and private sectors, and independently acquired data from the field, we have explored the potential of using technology-assisted instruction to improve teaching in China's rural areas. Like in other contexts, teaching quality is a major determinant of children's schooling outcomes in China, and regional disparities in teaching quality are a proximal cause of the urban–rural educational achievement gap. As traditional methods to improve teaching—including student migration to the cities, attracting quality teachers to rural areas, and teacher training—appear to have fallen short in China, a significant role for technology may exist. Although a small but growing body of evidence indicates the effectiveness of technology-assisted remote instruction (particularly high-quality live-streamed or pre-recorded remote instruction delivered in class during the school day), most developing countries have yet to harness such technologies to provide quality education to disadvantaged learners at scale. There is reason to believe that China is uniquely positioned to successfully implement and scale up technology-assisted interventions due to its adequate infrastructure in rural areas, ambitious policy initiatives, and large EdTech market. Although China appears well-positioned to scale technology solutions to address problems of equity in education throughout the country, more rigorous experiments will first be necessary to understand which approaches are most effective for reaching the tens of millions of students in rural schools.

Recollections of Professor Keijiro Otsuka

I was first introduced to Keijiro Otsuka, who I know simply as Kei, by my Cornell Ph.D. advisor Randy Barker when Kei was at the International Rice Research Institute. He and his group at that time then introduced me to Jikun Huang, who was also a PhD student, and the foundation of my career was established. Over time, Kei and I met often … in Japan, in the US, and in meetings around the world. We have met and worked as collaborators, colleagues, and friends. The breadth of his work is amazing. He is one of those rare scholars who can work on many different areas of economic development during his career and make an impact in all of them. I am proud to be able to participate in Kei's Festschrift. Congratulations to you, Kei! – *Scott Rozelle.*

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