The Math Learning Gap:

Preparing STEM Technicians for the New Rural Economy

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The Rural Math Excel Partnership (RMEP) identified math competencies used by technicians in the workplace compared to standards of learning required in the public school curriculum. A modified DACUM process revealed 39 math competencies used by technicians in STEM-related occupations of the rural region. Group interviews with faculty in three community colleges helped substantiate math gaps. A project math specialist and team of teachers identified four types of learning gaps: (1) math competencies not included in state standards; (2) math competencies included in state standards taught prior to Algebra I, Algebra II, Geometry, and Algebra Functions and Data Analysis (AFDA) courses; (3) math competencies included in high school state standards that students struggle to learn; and (4) math competencies community college students struggle to learn. Implications include five lessons learned in the gap analysis process and six questions for guiding future innovation and research.

Keywords*:* math education, rural education, technician occupations, workforce development

Rural America is historically associated with a strong work ethic, a place where the farmer "works from daylight to dusk." Blue collar labor jobs dominant the economy. Hard work is a way of life, where cultural traditions guide most workers to give an "honest day's work for an honest day's pay." Getting a good "academic" education, particularly earning a Bachelor's degree, is the perceived pathway to a more prosperous career economically—if you are also willing to leave the countryside for an urban environment.

This cultural viewpoint may have found favor with past generations of rural residents, particularly those who labored in agriculture, manufacturing, mining or other natural resource-based jobs. Agricultural occupations required plenty of manual labor, but also may have required entrepreneurial and management skills if one owned a farm or ranch. But new demands of global competitiveness, advancements in technology, and requirements of a knowledge economy reward lifelong learning skills and the ability to continuously adapt to change. Mastering mathematics increasingly is essential for future success, especially in STEM related careers. Almost all of the 30 fastest-growing occupations in the next decade will require some background in STEM (Change the Equation, 2011). But what mathematics do high school students needs for STEM-related jobs that may help revitalize local and regional rural economies?

Traditional blue-collar, rural communities now need high school graduates capable of pursuing technical-level and higher career choices (Alliance for Excellent Education, 2010; Beaulieu & Gibbs, 2005; Gibbs, Kusmin, & Cromartie, 2005; President's Council of Economic Advisers, 2010; Thompson, 2007; Wuthnow, 2013), particularly technician-level occupations. Technical occupations are among the fastest growing job fields in America (Carnevale, Smith, & Strohl, 2010). Increasing student achievement and promoting economic and community development must become mutually beneficial goals for public education (Harmon & Schafft, 2009; Scafft & Harmon, 2010). A key premise of the RMEP project is to reinforce the need for public schools to address academic success needs of students in ways that also serve economic and workforce development needs of rural communities.

Although Drabenstott (2010) suggests "rural areas have highly unique contributions to make in critical new areas of the economy such as green growth and renewable energy" (p. 45), an educated workforce is essential to attract these types of jobs into rural communities. Carr and Kefalas (2009) note, however: "Any attempt to plug the rural brain-drain and rebuild small towns must first acknowledge the basic truths of the process. Small towns invest far too heavily in the young people who are most likely to leave…" (p. 52). Too often, the attitude of those who stay in the community after graduation is "just surviving high school feels like a major accomplishment" (Carr & Kefalas, 2009, p. 60). Carr and Kefalas (2009) conclude, consequently, that these students are unprepared for a future of enormous economic insecurity. This article reports on initial efforts of the Rural Math Excel Partnership (RMEP) that found four types of gaps exist in math learning compared to math competencies used by technicians in the regional workforce.

RMEP Concept and Context

On January 1, 2013 the Virginia Advanced Study Strategies, Inc. (VASS) and six rural school systems began the Rural Math Excel Partnership (RMEP) project. Funded by a U.S. Department of Education investing in innovation (i3) development grant and matching funds from a private foundation supported by the state Tobacco Indemnification and Community Revitalization Commission, RMEP seeks to develop a sense of *shared responsibility* among families, teachers, and communities in rural areas for student success in foundational math courses as preparation for advanced high school and postsecondary study. Foundational math courses include Algebra I, Algebra II, Algebra Functions and Data Analysis, and Geometry.

Located in a southeastern state, each of the six school districts is eligible for the federal Rural Low Income Schools Program, the USED i3 program's definition of a "rural" local education agency (LEA). Five of the six LEAs are public countywide school systems, with one district classified as an independent public school system within a county. It is considered a city school system and is located in a rural county (i.e., one of the five counties in the project). Seven high schools and seven middle schools are included in the project. One county school system has two high schools and two middle schools. Table 1 shows key characteristics of the 14 schools in the RMEP project.

Table 1. Key Characteristics of RMEP Project Schools

Public School System (LEA)	School Type (Grade Level)	Enrollment 2011-2012	Ethnicity % African American/ % White Students	% Free/Reduced Lunch Students in School 2010-11	% Children in District in Poverty	% Male/ Female Students in School
LEA 1	High School (9-12)	669	36/60	47.4	24.6	51/49
	Middle School (6-8)	477/139[a]	31/65	54.5	24.6	49/51
LEA 2	High School (9-12)	465	43/54	66.0	22.7	52/48
	Middle School (6-8, grade 5 added in 2012-13)	302/103[a]	39/56	49.0	22.7	49/51
LEA 3	High School (9-12)	1,716	49/49	52.1	22.6	49/51
	Middle School (6-8)	1,345/449[a]	47/50	63.0	22.6	51/49
LEA 4	High School 1 (9-12)	1,229	19/76	50.9	23.9	48/52
	High School 2 (9-12)	920	35/59	48.9	23.9	50/50
	Middle School (6-8)	764/238[a]	35/57	61.2	23.9	53/47
LEA 5	High School (9-12)	666	63/31	54.5	33.6	49/51
	Middle School (6-8)	535/171[a]	60/34	69.5	33.6	52/48
LEA 6	High School (9-12)	697	63/34	53.9	24.3	51/49
	Middle School (5-8)	747/187 [a]	56/40	63.1	24.3	54/46

[a] Enrollment is for all grades in school and for grade 8 only; for example 477/139.

The counties are like many rural areas in the U.S., seeking to grow a new economy consistent with changing realities of global competition and regional economic development opportunities. Loss of tobacco, textile, and manufacturing jobs has resulted in some of the highest unemployment and lowest income levels in the state. Table 2 reveals key characteristics of the five counties.

Table 2. Key Characteristics of Counties in RMEP Project

Characteristic	County 1	County 2	County 3	County 4	County 5	State
% Population Change (2010-12)	- 1.4	- 2.0	-1.1	-2.2	-0.5	2.3
% Total Population in Poverty (2011)	37.6	33.8	32.3	39.5	34.1	16.2
% Unemployment Rate (2012)	8.5	6.8	9.4	9.9	8.7	5.9
Median Household Income (2011)	$35,677	$40,080	$35,170	$32,596	$36,503	$61,877
Education: % Less than high school (2007-11 avg.)	27.0	23.4	25.4	25.6	21.1	13.4
Education: % High School (2007-11 avg.)	31.7	39.1	35.5	35.2	39.7	25.6
Education: % Some College (2007-11 avg.)	26.1	23.4	25.1	27.9	19.5	26.6
Education: % College (2007-11 avg.)	15.2	14.1	14.1	11.3	19.7	34.4

Note. Source of data is USDA Economic Research Service county-level data sets. See http://www.ers.usda.gov/data-products/county-level-data-sets/.aspx

All counties lost population from 2010 to 2012, compared to a 2.3% increase in the state's total population. The percentage of total population in poverty in each county is double the state percentage. Unemployment rates range from 6.8 to 9.9 percent, exceeding the state rate of 5.9%. The state median household income far exceeds the income in each county. A review of the five-year average (2007-2011) educational attainment shows a much higher percentage of the population in each county with less than a high school education compared to the state average. Three community colleges, a public university, and a regional higher education center give rural residents access to postsecondary education. The percentage of the population with some college approximates the state average. The gap in college attainment, meaning a Bachelor's degree or higher, is much lower in each country compared to the state average.

Math Learning Gap

A tradition of going to work instead of to postsecondary education is engrained into the mindset of the local rural culture as the right education path if one plans to live in the local area. Few jobs exist in the local economy for those who earn a college education (i.e., Bachelor's degree). Generally, students learn to prepare for work that they, their parents and the community perceive relevant and valuable. For the vast majority of students, pursuing academic subjects like mathematics as preparation for (STEM) occupations align with the need or desire to leave home for a more prosperous opportunity in an urban place.

Consequently, students need supports that enable them to understand the relevance of foundational math competencies to their future success after school. Hardré (2011, 2012) emphasizes the importance of relevance in teaching math to rural students, as do results of the rural systemic initiatives funded by the National Science Foundation (Harmon & Smith, 2011). In essence, the RMEP model of shared responsibility that is under development must address gaps in "what" math content students should learn, as well as the cultural gap of "why" students must learn the math competencies. A key activity of the RMEP project in year one was identifying the mathematics that technicians in the rural region used to perform their jobs.

Methods

A modified DACUM process was used to identify the math competencies performed by technicians working in STEM-related occupations important to the rural region. DACUM (**D**eveloping **A C**urricul**UM**) has been used worldwide for more than 40 years (DACUM, 2013). It is a quick, effective, and relatively low cost method of analyzing job duties and tasks. Results provide a foundation for developing curriculum and instructional materials. A RMEP staff member (lead author), certified as a facilitator of the DACUM process, modified the process to focus primarily on math competencies used by technicians to perform the job duty that required the most application of mathematics.

DACUM Participants

RMEP staff synthesized state workforce information to determine the technician-level occupations in the region labeled as "bright outlook" (see https://data.virginialmi.com/vosnet/Default.aspx). The National Center for O*NET Development defines "bright outlook" occupations as those in a national high growth industry. "Bright Outlook" occupations are expected to grow rapidly in the next several years, will have large numbers of job openings, or are new and emerging occupations (see http://www.onetcenter.org/bright.html). Additional technician occupations without the bright outlook designation were included if local and regional economic development initiatives targeted them as important to future workforce development of the region. More than 30 occupations were identified as related to careers requiring knowledge in STEM courses.

Two DACUM sessions were held in fall of 2013. For the first modified DACUM session, RMEP staff asked faculty members at the three community colleges in the region to nominate former graduates of certificate or Associate of Applied Science (AAS) degree programs who were believed to work in the region. Contact information of faculty in programs that prepared students for the pre-identified bright outlook or important occupations were identified by reviewing certificate and degree programs listed on the web site for each community college. Faculty members were contacted by e-mail and phone to solicit nominations and contact information of program graduates. RMEP staff contacted the nominated program graduates and solicited their participation in the DACUM session. A total of 17 persons, representing 19 technician occupations, participated in the first DACUM on September 13, 2013.

For the second DACUM session, RMEP staff solicited nominations of technicians by contacting human resource personnel or other employees of businesses in the region believed to employ persons in the pre-identified technician occupations. In some instances, RMEP staff contacted the employee directly if staff knew a technician who worked in a particular business (e.g., medical technician). Consequently, RMEP staff communications resulted in 19 technicians participating in the second DACUM session on November 2, 2013. Therefore, 36 persons, representing 35 different technician occupations, participated in the two DACUM sessions. Technicians received a stipend to participate in a one-day modified DACUM session. Table 3 shows the 35 technician occupations.

Table 3. Technician Occupations Represented in DACUM Sessions

Bright Outlook or Important Technician Occupation in Southside, VA Region		
1. Accounting & Administrative Coordinator	13. Information System Technologist	25. Process Control Programmer
2. Agriculture Technician	14. Information Technologist	26. Product Design Engineering Technician
3. Auto CAD Technician	15. Instrument and Controls Technician	27. Project Industrial Engineering Technician
4. Automobile Technician	16. Licensed Practical Nurse (LPN)	28. Quality Control Technician
5. Cardiology Technician	17. Machinist	29. Read Line Technician
6. Certified Para Optometric Assistant	18. Maintenance Technician	30. Respiratory Therapist
7. Dental Hygienist	19. Motorsports Technician	31. Simulation Technologist
8. Electrical Technician	20. Occupational Therapy Assistant	32. Soil Conservation Technician
9. Electronics Control Technician	21. Operations Technician	33. Surgical Technician
10. Electronics Technician	22. Paramedic	34. Veterinary Technician
11. Energy Consulting Technician	23. Pharmacy Technician	35. X-ray Technician
12. Forestry Technician	24. Physical Therapy Assistant	

Consistent with DACUM information collection protocol (DACUM, 2013), two RMEP staff (i.e., authors) conducted the DACUM sessions. One, a certified DACUM facilitator, guided the modified DACUM process to solicit technician responses to questions. The RMEP math specialist served as session recorder to interpret math terms mentioned by the technicians, write each math competency statements on a 5x7 card, and hand the card to the facilitator for placement on the wall under the appropriate technician occupation. This process allowed technicians to check accuracy of each statement for their respective occupation.

Research in mathematics education (Noss, Hoyles, & Pozzi, 2002) reveals it can be remarkably difficult to elicit the kinds of mathematics people actually use in the workplace, as often the workers do not know. Therefore, further facilitation allowed the technicians to provide example applications of how the math competency was used on the job. DACUM facilitation also enabled each technician to suggest the kind of math and STEM courses a student should complete in high school to be ready to succeed in the postsecondary education certificate or Associate of Applied Science degree program.

College Faculty Interviews

In addition, RMEP staff conducted faculty group interviews at the three community colleges. Group interview sessions enabled participants to reveal math competencies taught in courses required for completion of the technician programs that resulted in a certificate or Associate's degree. Community college faculty also were asked to share insights on which math competencies their students struggled with most, and what high school courses would best prepare the students for success in the STEM-related postsecondary technician programs. A 2-3 hour session was held at each college, conducted by the facilitator of the DACUM sessions, with the math specialist recording detailed written notes of responses to questions. In one college, both mathematics faculty and selected faculty of technical occupational programs participated in the group interview session. In two community colleges only mathematics faculty and key administrators participated. A total of 26 community college personnel employed by the three community colleges participated in the group interview sessions.

Findings

The math specialist and six teachers on the project development team, one per school district, refined an original list of 51 math competencies to 39 competencies. Several competencies in the list of 51 were duplicative or addressed by a single state standard. Using both the competencies from the modified DACUM sessions with technicians and the group interview sessions with community college personnel, the RMEP math specialist created a gap analysis matrix. The matrix, presented as Table 4, shows math competencies used by technicians in important STEM-related occupation careers in the rural region, compared to what students were expected to learn in the state Standards of Learning (SOLs) and the national Common Core State Standards. The matrix also reveals the math competencies students struggled to learn in public school and community college courses.

For purposes of the RMEP project, the math specialist and teacher development team determined four types of math learning gaps existed:
(1) math competencies not included in state standards;
(2) math competencies included in state standards prior to Algebra I, Algebra II, Geometry, and Algebra Functions and Data Analysis (AFDA) courses;
(3) math competencies included in high school state standards that students struggle to learn; and
(4) math competencies community college students struggle to learn.

Table 4 also shows how the 39 technician math competencies aligned with math competencies in the Common Core State Standards. The six RMEP school districts, however, are not located in a state that has adopted the national Common Core State Standards.

Table 4. Technician Math Competencies, Standards Alignment, and Learning Gaps

Math Competencies for Technicians in STEM Related Career Fields	Math Competency in State Standards	Math Competency in Common Core State Standards	Learning Gap Type
1. Translate verbal information into algebraic expressions and equations	Yes; A.1	Yes; A-CED 1,2,3	3-high school state standard but students struggle
2. Solving real world problems with equations	Yes; A.4a	Yes; A-CED 1,2,3, A-REI 3	3-high school state standard but students struggle 4-community college students struggle
3. Conversions among Metric Units	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
4. Determining and using proportions	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
5. Adding and subtracting fractions	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
6. Multiplying fractions	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
7. Dividing fractions	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
8. Decimal calculations	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle

9. Converting between fractions and decimals	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
10. Determine the area of irregular polygons	No; it is state standard taught prior to Algebra I	No; it is a standard prior to Algebra I	2-in state standards before high school
11. Calculating volume of three-dimensional geometric objects	Yes; G.13	Yes; G-GMD 1,3	3-high school state standard but students struggle
12. Calculating and examining slope in the real world	Yes; A.6a	Yes; F-IF 6	3-high school state standard but students struggle 4-community college students struggle
13. Direct and inverse variation	Yes; A.8, AII.10	No; it is a standard prior to Algebra I	3-high school state standard but students struggle
14. Arcs and tangents	Yes; G.11a,b,c	Yes; G-C 4,5	3-high school state standard but students struggle
15. Using right triangle trigonometry	Yes; G.8	Yes; G-SRT 6,7,8,9,10,11	3-high school state standard but students struggle
16. Calculating radius, diameter, and circumference of a circle	No; it is state standard taught prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school
17. Create/use prediction equations	Yes; A.11, AII.9	Yes; S-ID 6,7,8,9	3-high school state standard but students struggle
18. Calculating averages	Yes; A.9	No; it a standard prior to Algebra I	3-high school state standard but students struggle
19. Create and solve inequalities for real world problems	Yes; A.5a,b,c, AII.4a	Yes; A-CED 1,2, A-REI 3,12	3-high school state standard but students struggle 4-community college students struggle
20. Piecewise functions	No	Yes; F-IF 7b	1-not in state standards
21. Collecting and analyzing data	Yes; A.11,AII.9	Yes; S-ID 5,6,7	3-high school state standard but students struggle
22. Measuring using tools (ruler, protractor, micrometer, etc.)	No; taught in state standard prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
23. Determine angles	Yes; G.10, G.11a,b	Yes; G-CO 1, G-SRT 5, G-C 2	3-high school state standard but students struggle
24. Percent error	No	No	1-not in state standards

25. Comparing data graphically, verbally, and numerically	Yes; A.7f	Yes; F-IF 1,4,5,7,9, F-LE 2,5	3-high school state standard but students struggle 4-community college students struggle
26. Dimensional analysis	No	Yes; N-Q 1	1-not in state standards 4-community college students struggle
27. Use Pythagorean Theorem to determine sides of a triangle	Yes; G.8	No; it is a standard prior to Algebra I	3-high school state standard but students struggle
28. Calculating and using percentages	No; it is state standard taught prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
29. Domain and range	Yes; A.7b,e, A.II7a	Yes; F-IF 1,2,5,9, F-LE 2,5	3-high school state standard but students struggle 4-community college students struggle
30. Approximation and estimation	No; it is state standard taught prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school
31. Calculating surface area of three-dimensional geometric objects	Yes; G.13	No; it is a standard prior to Algebra I	3-high school state standard but students struggle
32. Analyzing graphs	Yes; A.7b,e,f, AII.7a,d,f	Yes;, F-IF 4,5,6,7a,c,d,e	3-high school state standard but students struggle 4-community college students struggle
33. Conversions between Metric and US Customary Units	No; taught in state standard prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school 4-community college students struggle
34. Calculating maximums and minimums	No	Yes; F-IF 4	1-not in state standards
35. Determine frequency	No; it is state standard taught prior to Algebra I	No; it a standard prior to Algebra I	2-in state standards before high school

36. Solving multi-step equations	Yes; A.2a,b, A.4d,e, AII.4c,d	Yes; A-CED 1,2,3, A-REI 2,3	3-high school state standard but students struggle
37. How dimensional changes affect perimeter, area, surface area, and volume	Yes; G.14a,b,c,d	Yes; G-SRT 1a,b,2, G-GMD 1,2, G-MG 3	3-high school state standard but students struggle
38. Solving equations for a specific variable	Yes; A.4a	Yes; A-CED 4	3-high school state standard but students struggle
39. Verifying solutions and confirming they make sense in the context of the problem	No	No	1-not in state standards

The team determined five of the 39 math competencies were not in the state standards (see Table 4). Surprisingly, the team of teachers learned that conversions between metric and U.S. customary units (competency item 33) and conversions between metric units (competency item 3) were emphasized by most of the technicians. Based on their experiences, the team decided that teachers of the four foundational math courses in their school systems seldom taught these conversion competencies. Numerous technicians explained many of the products, procedures or volume weights came from overseas where metric was the standard unit of measure, thus requiring them to convert the metric measure to U.S. customary units of measure. Medical technicians of various types pointed out that such conversion to or from U.S. customary units was required in their job, such as kilograms, centimeters, and milliliters. Community college faculty also noted students struggled with conversion calculations.

Development team teachers indicated many students came to their classes without a working understanding of how to make conversions. These specific competencies were included in state standards for classes students take before the four foundational courses. Of the 39 math competencies the team documented from comments of the technicians, 14 (about 36%) were listed in state standards to be taught before Algebra I. In arriving at the types of gaps noted in Table 4, the team also decided that 19 of the 39 math competencies were listed in high school state standards but students struggle to learn them.

Of the 14 competencies taught in public school standards before Algebra I, 10 were judged by the teacher development team as math competencies community college faculty also reported students struggle to learn in their college-level courses. Of the 39 math competencies, the RMEP teacher team also determined from review of notes from group interview session with community college faculty that community college students struggle to learn 17 of the math competencies.

Discussion

Because the RMEP project's shared responsibility model encourages the vast majority of high school students to pursue an educational pathway for attaining at least a postsecondary occupational credential, a credential usually earned in one of the three community colleges of the rural region, results of a National Center on Education and the Economy (2013) report are informing. Center researchers report most of the mathematics required for student success in community college courses is not high school mathematics, but middle school mathematics, "especially arithmetic, ratio, proportion, expressions and simple equations"(p. 2). The report also reveals that "many students, to be successful in our community colleges, need to be competent in some areas of mathematics that are rarely taught in our elementary or secondary schools, such as schematics, geometric visualization and complex applications of measurement" (p. 2).

Moreover, the national center report revealed that Algebra II is widely thought to be a prerequisite for success in college and careers, but their research shows this is not so. The researchers found the most demanding mathematics courses typically required of community college students are those required by the mathematics department, not the career major. Content of the first year mathematics courses offered by the community colleges' mathematics department is typically the content usually associated with Algebra I, some Algebra II and a few topics in Geometry. Based on their data, the authors (National Center, 2013) concluded that "one cannot make the case that high school graduates must be proficient in Algebra II to be ready for college and careers" (p. 3). Baker (2013) also concludes that requiring students to take Algebra II is the wrong answer as a solution to student success in life.

Further, the researchers (National Center, 2013) report the high school mathematics curriculum is now centered on the teaching of a sequence of courses (i.e., geometry, Algebra II, pre-calculus) leading to calculus. Yet, according to the researchers, fewer than five percent of American workers and an even smaller percentage of community college students will ever need to master the courses in this sequence during college or in the workplace. Authors of the report contend a major gap exists in the alignment between the mathematics courses taught in the mathematics departments in community colleges and the mathematics actually needed to be successful in the applied programs students are taking. The authors (National Center, 2013) note: "In a great many cases, the mathematics department course had little or nothing to do with the actual mathematics required to be successful in the applied programs the students were enrolled in" (p. 3).

The authors conclude whatever students did to pass mathematics courses in middle school, it does not appear to require learning the concepts in any durable way. What is needed in the first year of community college, according to authors of the National Center (2013) report, is not taught in our public schools. The mathematics that is most needed by community college students is actually elementary and middle school mathematics. But it is not learned well enough by many students to enable them to succeed in community college education. The report authors recommend: "A very high priority should be given to the improvement of the teaching of proportional relationships including percent, graphical representations, functions, and expressions and equations in our schools, including their application to concrete practical problems" (p. 2).

Though limited to the major duty or responsibility of the job for which each technician performed the greatest number of math competencies, the 39 math competencies documented in the modified DACUM process are consistent with results of the National Center on Education and the Economy (2013) report. Group interviews with faculty of the three community colleges reveal applications of math are critical in many of the occupational certificate and associate's degree programs. Some of the community college math faculty taught applied mathematics courses specifically designed for certain occupational programs (e.g., health). It was clearly apparent also from comments of mathematics faculty and faculty in occupational program areas that many students struggled with the kinds of basic math noted by the National Center on Education and the Economy (2013) report. Apparently, many students in the rural region come both to the high school foundational math courses and the community college math courses without a firm grasp of how basic math is a pre-requisite for success.

The math gaps identified in the RMEP project poses serious negative consequences for a student's individual academic success, perhaps also limiting their interest in taking the additional math in high school that keeps them on an educational pathway to attain at least a technician-level postsecondary credential in a STEM-related career field. After struggling to pass foundational math courses such as Algebra I, student self-selection of high school or dual enrollment STEM courses is unlikely. Without motivation and preparation to earn a postsecondary credential, students who remain in the rural region potentially also limit regional economic and workforce development strategies. Cost of remedial education and the struggle to succeed in the postsecondary program may be insurmountable barriers, forcing the high school graduate to experience an impoverished lifestyle associated with one or more low-pay jobs, intermittent unemployment, or few employment opportunities.

All technicians in the modified DACUM sessions suggested students should take Algebra I. Yet, for only 12 of the occupations did the respective technician suggest Algebra II as a course to take in high school. This reflects the different need for Algebra II for certain STEM-related occupations represented in the modified DACUM session. Authors of the National Center on Education and the Economy (2013) report also question the value of Algebra II as a readiness course for community college students.

Further, McClarty, Way, Porter, Beimers, and Miles (2013) found math knowledge and skills needed for college and careers may not be equivalent. The empirical evidence may not support setting a single performance standard for all college and career tracks. McClarty et al. (2013) note the National Assessment of Educational Progress (NAEP) studied preparedness for five job training programs: automotive master technician; licensed practical nurse; pharmacy technician; computer support specialist; and heating, ventilation, and air conditioning technician. Results showed that the recommendations varied greatly between replicate panels in the same industry and that the resulting recommendations for cut scores were unreasonable. Therefore, Loomis (2012) reported the National Assessment Governing Board did not plan to use the results of these studies to set workforce preparedness standards on NAEP.

Technicians in the RMEP modified DACUM sessions used mathematics in ways specific to their occupations. This is consistent with research evidence. Selden and Selden (2014) provide examples of studies that examine how mathematics is used in the workplace by automobile production workers, by nurses to calculate drug dosages, by bank employees, by biologists, and by scientists to interpret graphs. This difference in usage complicates attempts to clearly define college and career readiness. It also supports the RMEP project's strategy to identify math learning gaps by first asking STEM–related technicians to reveal math competencies they use in the workplace, rather than rely solely on math competencies in state standards or math courses required in the community college Associate degree program.

Implications

Determining the math gaps for the purpose of developing a model of shared responsibility that collectively enables teachers, parents/families, and communities to support student success in foundational math courses provided important lessons learned. Addressing the math gap revealed in the RMEP project also illustrates how school systems and community leaders can focus on helping students who might desire to stay in the rural region prepare adequately for current and future STEM occupations. This could help address the underinvestment in certain students (i.e., stayers) that Carr and Kefalas (2009) report is contributing to the "hollowing out" of rural places. Therefore, we offer five lessons learned in the RMEP project for others that seek to prepare public school graduates to work in STEM-related occupations as technicians. Second, we list six questions that could help guide future innovations and development efforts for rural workforce development.

Lessons Learned

1. Technicians who work in STEM occupations important to the future development of a rural region will readily volunteer to share information in a group setting such as the modified DACUM process, particularly if a monetary stipend is offered. Identification of the occupations and technicians, however, may take considerable effort. Although numerous economic development efforts may be underway in a rural region, priorities for workforce development may not clearly identify STEM occupations. State labor market data for the region must be reviewed. Workforce development efforts may focus primarily on emerging occupations (e.g., advanced manufacturing and health technicians) and undervalue other important STEM occupations important to the region, such as agricultural, environmental and natural resource occupations.

Moreover, if emphasis is on a student completing appropriate high school courses to earn a postsecondary credential for entry into the STEM technician occupation, care must be taken to ensure technicians identified for the DACUM session hold such a credential (i.e., certificate or associate's degree). Otherwise, in some occupations, an employer in the rural area may recommend a successful technician who learned the knowledge and skills on the job over several years but completed no formal postsecondary education. Also possible, a business may have persons performing technician jobs but is unable to attract and employ persons with the postsecondary credential. This person would not be able to reveal how certain high school courses are critical as preparation for the postsecondary technician-level program. Faculty of community college technician programs will be highly valuable in identifying program completers with a certificate or associate's degree who work in the region and might volunteer to participate in the DACUM process.

2. Teachers of foundational math courses on the project's development team consider the DACUM session an uncommon, yet highly beneficial, professional learning opportunity. Development team teachers report listening to the technicians in the modified DACUM sessions provide a unique opportunity for the first time in their careers to understand how mathematics is used in the workplace to perform a job. Teachers will eagerly record the examples discussed by the STEM technicians, realizing these examples could help them make math content more relevant to students. Teachers may also desire to interact with the technicians after the session to learn more about how the math is used. The teacher interaction with technicians in STEM occupations seems to hold valuable promise as a professional learning opportunity for math teachers to identify how to connect content to workplace applications and STEM careers. Participation in the DACUM session appears to particularly help the teachers have answers for students who might ask "why" they need to learn the math content.

3. Participation on a teacher development team may hold promise as a viable capacity building strategy.

These teachers could become important change agents in the region for making math instruction more relevant, particularly with continued support of a math specialist. Their roles in making content relevant to STEM occupations important to economic and workforce development of the rural region could fill an important void in limited career counseling in the rural schools. As teacher leaders, opportunities may evolve for facilitating the integration of academic (i.e., math) and career and technical education that stimulates student interest in additional STEM courses that best prepare students for success in pursuing at least a postsecondary certificate and or associate's degree credential.

4. Community college faculty can reveal math competencies students struggle with most in their courses. Interviews with faculty, however, need to clarify what postsecondary math courses and competencies are most appropriate for technician-level occupations. Both mathematics faculty and faculty representing the technical STEM-related career fields need to be present in the group interviews. Moreover, required mathematics courses are likely to differ for the different STEM-related technicians occupations. Community college programs may require students to complete specially designed applied math courses for a particular occupational program (e.g., health, information technology).

5. Aligning mathematics curricula, giving teachers opportunities to discuss issues of student content mastery, sharing of successful instructional strategies, and counseling middle and high school students about technician-level occupations and STEM-related careers appear necessary. Many of the math competencies used by STEM-related technicians in the workplace require student mastery of math content in lower level courses taught prior to the high school level Algebra I course. Failure to master these competencies greatly jeopardizes the student's chance of success in prerequisite high school and college courses required for the postsecondary credential. Considerable attention should be focused on helping middle school math teachers use pedagogy practices that ensure mastery of these competencies. Both the teachers on the project development team and community college faculty contribute this lack of mastery of basic math as a leading reason students struggle to learn math competencies in their courses.

Guiding Questions for Innovation and Research

Solutions to the math learning gap in rural areas like those in the RMEP project are critical for the student's and community's future success. We offer six questions that could help guide future development of new innovations and research.

1. What policies or strategies could encourage middle school teachers of math courses taught prior to Algebra I to collaborate with teachers of high school courses to ensure students master math content used by technicians in STEM-related occupations?
2. What instructional support materials, including technology, are necessary for public school math teachers to engage students in meaningful activities or projects that demonstrate students can apply the math knowledge consistent with requirements of a technician occupational?
3. How might public school math teachers, community college faculty in mathematics departments and technical occupational programs collaborate to reduce the struggles student experience in learning math required for earning a postsecondary credential in a STEM-related technician occupational field?
4. How can teacher education programs ensure teachers of mathematics in the public schools can effectively instruct students interested in pursuing technician-level occupations in STEM-related career fields?
5. What professional learning opportunities are most effective in helping math teachers in high poverty rural school settings effectively engage students in learning math competencies used by STEM-related technicians?
6. What innovations are necessary to aid public school employees, parents and family members, community college faculty, and community members in accurately providing academic and career counseling for rural youth about requirements of technician occupations in STEM-related career fields?

Increasingly, mastery of mathematical knowledge and skills must be part of the American dream toward a better life, regardless of how the dream is defined, or where one chooses to live and work. Support of research and development efforts are needed to discover ways to address the math learning gaps of students, particularly in high poverty rural areas. Making math relevant to contextual realities of such rural places is essential to the future well-being of both students and their communities.

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