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# Examining Associations between Adult Health and Literacy, Numeracy, Technological Problem-Solving Skills, and Post-Initial Learning in the U.S.

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**Abstract:** This paper uses data from the Program for the International Assessment of Adult Competencies (PIAAC) to analyze the relationship between self-reported health and (a) literacy, numeracy, and technological problem-solving skills, and (b) post-initial learning for U.S. respondents, and to determine whether those relationships vary by race/ethnicity and educational degree attainment. The main independent variables were scores on the PIAAC literacy, numeracy, and problem solving in technology-rich environments (PS-TRE) scales, and five types of post-initial learning during the previous 12 months: open or distance learning courses, workplace training, seminars or workshops, courses or private lessons, and participation in formal education. The results of ordinal logistic regression analyses showed that after controlling for respondents' sociodemographic characteristics, literacy is a stronger predictor of self-rated health than numeracy or PS-TRE scores. However, literacy matters far less than other factors

such as disability, educational attainment, health insurance, English proficiency, and nativity. Second, of the five post-initial learning activities, only participation in courses/private lessons was significantly related to health, after controlling for other variables. Third, there was no variation in the relationship between self-rated health and literacy, numeracy, and PS-TRE skills or post-initial learning by race/ethnicity. The relationship between health and PS-TRE skills differed by educational attainment: only the most highly educated respondents accrued health advantages from stronger technological problem-solving skills. Implications for research and policy are discussed.

## Executive Summary

Higher educational attainment is strongly associated with better health, but we know far less about how other social determinants—namely, literacy and numeracy proficiency, technological problem-solving skills[i], and continuing participation in formal and non-formal education—shape health outcomes. This paper uses data from the Program for the International Assessment of Adult Competencies (PIAAC) to identify whether these proficiencies and learning activities are associated with adult health status, and how those relationships vary across racial/ethnic and educational attainment groups. That is, do people across different racial/ethnic groups and levels of formal schooling accrue similar health advantages from these proficiencies and learning activities?

The study answers the following research questions: (1a) Are literacy, numeracy, and technological problem-solving skills associated with self-rated health, after controlling for race/ethnicity, socioeconomic status (SES), and other respondent characteristics? (1b) Does the relationship between skills in these areas and self-rated health vary across racial/ethnic groups? (1c) Does the relationship between skills in these areas and self-rated health vary across levels of formal educational attainment? (2a) Which types of post-initial learning activities are most strongly associated with self-rated health? (2b) Which types of post-initial learning matter most for the health statuses of different racial/ethnic groups? (2c) Which types of post-initial learning matter most for the health statuses of people at different levels of formal educational attainment? Post-initial learning includes the pursuit of formal and non-formal education and training beyond the respondent's highest level of completed schooling.[1]

The dependent variable is self-rated health (excellent, very good, good, fair, or poor). The independent variables are scores on the literacy, numeracy, and problem solving in technology-rich environments (PS-TRE) scales and participation in post-initial learning activities during the past year: open or distance learning courses, workplace training, seminars or workshops, courses or private lessons, and formal education. Racial/ethnic groups were non-Hispanic white, non-Hispanic black, Hispanic/Latino, Asian, and other (American Indian/Alaska Native, Native Hawaiian/Pacific Islander). There were six educational attainment levels: less than high school diploma, high school graduate, certificate from trade school or other, associate degree, bachelor's degree, and master's degree or higher. Ordinal logistic regression was used to analyze the data, and we accounted for demographic characteristics that are known to influence health (e.g., sex, age, marital status, nativity, employment status, disability). This allowed us to examine the unique contribution of literacy, numeracy, technological problem-solving skills, and post-initial learning to health status—above and beyond respondents' other characteristics.

We found that literacy, numeracy, and technological problem-solving skills are positively associated with self-rated health. Ten-point increases on these scales are associated with 10.5%, 8.5%, and 7.6% greater odds, respectively, of being in a better self-rated health category. However, after controlling for respondent characteristics, numeracy and PS-TRE were no longer significant. The effect size for literacy was reduced, but it remained significant. After introducing control variables, a 10-point increase on the literacy scale was associated with 2.6% greater odds

[i] The term "problem solving in technology-rich environments" (PS-TRE) was coined by PIAAC and is not used in scholarly literature. To make our paper more accessible to a lay audience and to situate it within the scholarly literature, we use "technological problem-solving skills" to signify the subset of skills measured by the PS-TRE scale. We use "PS-TRE" specifically when referring to PIAAC scores or the PS-TRE scale.

of being in a better health category. This suggests that U.S. adults may accrue greater health benefits from developing literacy than numeracy or technological problem-solving abilities, after accounting for other individual characteristics.

The results show although literacy is important, it is not among the strongest predictors of self-rated health. Several control variables, including disability, formal educational attainment, health insurance, English proficiency, and nativity (being born foreign born vs. US born), have much stronger relationships with health status. This suggests that to improve U.S. residents' health, literacy instruction needs to be accompanied by efforts to increase college attainment, access to health insurance, and English proficiency.

The relationships between self-reported health and literacy, numeracy, and PS-TRE scores did not differ across racial/ethnic groups. In other words, people of color and whites gain equal health advantages from strengthening their *literacy* proficiency (neither numeracy nor PS-TRE scores were significantly related to self-rated health after controlling for demographic variables). This indicates that the "diminishing returns hypothesis," whereby racial/ethnic minorities accumulate fewer health rewards than whites from increasing levels of educational attainment, does not apply to literacy, numeracy, and technological problem-solving skills.

Of the three PIAAC scales, only the relationship between PS-TRE and self-rated health differed by formal educational attainment. Respondents who had at least a master's degree gained more health benefits from technological problem-solving proficiency than people who had not completed high school. Thus, only the most highly educated U.S. adults experience improved health (although very modest) with better PS-TRE skills.

Regarding the relationship between post-initial learning and self-rated health, we found that participation in workplace training, seminars/workshops, courses/private lessons, and formal education in the past 12 months are all associated with better health, but open/distance education is not. However, after adjusting for sociodemographic characteristics, only courses/private lessons remained significantly associated with improved self-rated health. Further research is needed to understand what these activities entail and how they enhance health (e.g., through cognitive or skill development, information acquisition, social network formation, access to and mobilization of psychosocial or material resources). Since blacks and people with less schooling were the least likely to participate in these activities, increasing their involvement could yield health benefits for those disadvantaged groups.

The relationship between self-rated health and post-initial learning activities did not differ across racial/ethnic or educational attainment groups. Of all the learning activities, participation in courses/private lessons was most strongly associated with self-rated health, regardless of respondents' race/ethnicity or educational attainment. This suggests that the diminishing returns hypothesis does not apply to post-initial learning; rather, involvement in courses/private lessons generated similar health benefits for all racial/ethnic groups.

In sum, the study elucidates how various types of skills and post-initial learning are (and are not) related to self-reported health. It underscores the importance of literacy proficiency and participation in courses/private lessons for improving U.S. adults' health status, along with key demographic characteristics that strongly influence health (e.g., disability, educational degree, nativity, age) and promising areas for policy intervention (expanding access to college, health insurance, ESL instruction). Our findings also reveal that only the most highly educated adults accumulate health rewards from technological problem-solving skills, which highlights the need to explore why people with less education are less able to convert these skills into health benefits.

## Introduction

Higher educational attainment is strongly associated with better health, but we know much less about how basic skills such as literacy and continuing participation in formal and non-formal education shape health outcomes. Our study is situated in research on the social determinants of health, which traces how social and economic resources and opportunities influence adult health status. Specifically, this paper uses U.S. data from the Program for the International Assessment of Adult Competencies (PIAAC) to analyze the relationship between self-reported health and (a) literacy, numeracy, and technological problem-solving skills and (b) post-initial learning, and to determine whether those relationships vary by race/ethnicity and levels of formal educational attainment. That is, do people from differing racial/ethnic groups and levels of formal schooling experience similar health benefits from these proficiencies and post-initial learning activities? Post-initial learning entails participation in formal and non-formal education and training beyond one's highest level of completed schooling.[1] This study examined respondents' post-initial learning within the previous year.

The research questions are as follows: (1a) Are literacy, numeracy, and technological problem-solving skills associated with self-rated health net of controls for race/ethnicity, socioeconomic status (SES), and other respondent characteristics? (1b) Does the relationship between skills in these areas and self-rated health vary across racial/ethnic groups? (1c) Does the relationship between skills in these areas and self-rated health vary across levels of formal educational attainment? (2a) Which types of post-initial learning activities are most strongly associated with self-rated health? (2b) Which types of post-initial learning matter most for the health statuses of different racial/ethnic groups? (2c) Which types of post-initial learning matter most for the health statuses of people at different levels of educational attainment?

This study contributes to the scholarship in adult education, sociology, and demography by identifying how literacy, numeracy, technological problem-solving skills, and post-initial learning are associated with adult health status and how those relationships vary across racial/ethnic and educational attainment groups. In particular, the study adds to the burgeoning interest in research, policy, and practice concerning health and adult education.[2-15] It also contributes to the sociological and demographic literatures on the social determinants of health by focusing on literacy, numeracy, and technological problem-solving skills as specific types of human capital that influence health, potentially offering evidence for new areas for public health intervention.

## Literature Review

### Education as a Social Determinant of Health

To frame our analyses, we borrow from conceptual frameworks that emphasize formal educational attainment as a social determinant and fundamental cause of health and health disparities. Prior research in this arena consistently finds that people with higher levels of educational attainment enjoy better health, as indicated by higher self-rated health and physical functioning, and lower morbidity, mortality, and disability, than those with less education.[16-18] According to Link and Phelan,[19] educational attainment is a fundamental cause of health disparities because it influences access to and use of health-promoting resources through

employment and associated economic rewards, social-psychological mechanisms, and health lifestyle choices.[20-24]

First, regarding employment and its associated economic rewards, well-educated people are less likely to be unemployed and to experience economic hardship than those with less formal schooling, and are more likely to work full-time and to have higher incomes.[24] In turn, this income enables people to purchase high-quality health care. It also allows them to live in safer, more walkable neighborhoods with access to grocery stores with high-quality food, fitness facilities, and other amenities that enhance health, whereas people with lower educational attainment are often segregated in high-poverty, dangerous neighborhoods with scarce access to fresh fruits and vegetables, ubiquitous fast food restaurants, alcohol and tobacco advertising, unsafe sidewalks and parks, increased exposure to hazard waste, poor air quality and other environmental risks, and overall poorer quality of life.[20,25-32]

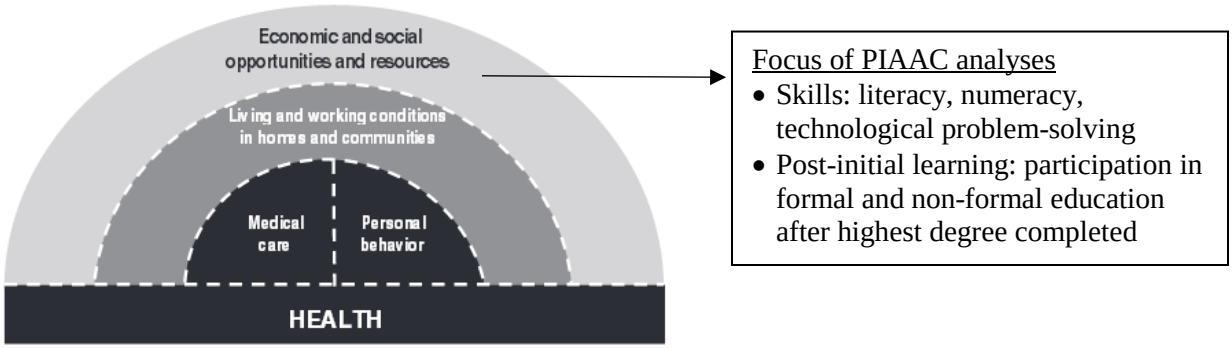
Educational attainment also enables people to work for employers that are more likely to provide health insurance and to work in less dangerous occupations.[20] Consequently, higher-educated employees are less exposed to dangerous chemicals, pollution, and equipment, and are less likely to engage in difficult manual labor that may lead to injury. Similarly, highly educated adults are more likely to exercise control in their workplace, which reduces health risks.[33-35] By contrast, adults without a college degree are concentrated in occupations that afford little control, flexibility, and decision-making authority, engendering a sense of powerlessness that undermines health. In a similar fashion, literacy, numeracy, technological problem solving, and post-initial learning may lead to better health through enhanced employment and income.

Second, educational attainment shapes key psychosocial and cognitive resources, including a sense of personal control, access to social networks, and social support, all of which ameliorate health.[20,21,36-38] In terms of personal control, education enables one to develop capacities that increase mastery, self-direction, communication skills, analytic skills, and critical thinking.[21] For instance, Baker and colleagues[39(321)] posit that education has an "independent, consistent, and substantial effect…on adult mortality" because it shapes reasoning, risk assessment, and decision making about health.[40,41] Being able to gather and interpret information, solve problems, and persist in adversity improves health because people with these skills are more knowledgeable about health, are more likely to engage in preventive behaviors, and believe that they are in control of their health.[24] Related to social support, those with higher levels of education report stronger social support than those with less education.[32] These social networks can provide emotional and material assistance during times of need, thereby reducing risk of depression and anxiety and encourage health care use during illness.[37]

Finally, educational attainment shapes health through lifestyle choices by providing access to knowledge, skills, and resources that help people make well-informed healthy choices.[20] These include obtaining necessary and routine medical services and engaging in healthy behaviors such as exercise, smoking and substance abuse abstinence, and healthy diet.[21,22,38,42]

Beyond formal educational attainment (i.e., completion of a degree program), this framework can elucidate relationships between health and continuing participation in formal non-formal education or training, as well as the specific skills one obtains from these endeavors, including literacy, numeracy, and technological problem solving. Figure 1 illustrates how our focus on skill development and post-initial learning fit within the social determinants of health framework, namely as a way to access the economic and social opportunities and resources that, in turn, enable people to improve their health in myriad ways.

**Figure 1: Social Determinants of Health**




Adapted from Braveman, Egerter, & Williams (2011, p. 383)

Although the PIAAC data do not enable us directly to test the causal pathways between skill development, post-initial learning, and health as laid out in the social determinants and fundamental cause frameworks, we argue the development of important life skills and engagement in continuing education—both formal and non-formal—may enhance adult health through similar processes, above and beyond the attainment of formal educational credentials. For instance, these skills and learning activities may introduce people to new social networks from whom they can seek advice and information about health promotion, access to health services, and healthy behaviors. Further, through participation in post-initial learning, people may develop skills or obtain credentials necessary to gain promotion at work or compete for a better or higher-paying job, which may enhance access to higher-quality health care and/or neighborhoods that enable a better quality of life. Finally, skills like literacy, numeracy, and technological problem solving, as well as participation in learning activities, may strengthen personal control and mastery, leading to a greater sense of control over one's life and a greater desire to protect one's health.

**Literacy, Numeracy, Technological Problem Solving, Post-initial Learning, and Health**

Compared to the research on educational attainment, we know far less about how literacy, numeracy, technological problem solving, and post-initial learning shape health status. These domains deserve greater attention because prior research suggests that they are important for health and may contribute to health status—above and beyond formal education credentials.

**Literacy.** Literacy capabilities have numerous implications for health, including the ability to read, understand, and draw conclusions from health-related information. Surprisingly few studies, however, have examined the relationship between health and *print literacy*—reading and comprehension, as measured by the PIAAC. The PIAAC defines literacy as follows:

> Literacy is understanding, evaluating, using and engaging with written text to participate in the society, to achieve one's goals and to develop one's knowledge and potential.[43]

Instead of examining print literacy writ large, most studies have focused on *health literacy*, using standardized instruments that measure reading and, in some cases, math ability on health-related

terminology and tasks such as interpreting medicine labels.[ii] Thus, print and health literacy overlap, but are not synonymous.

The 2003 National Assessment of Adult Literacy (NAAL) found that 43% of respondents (approximately 93 million U.S. adults) had basic or below basic prose literacy scores.[44] By contrast, 36% (80 million adults) had basic or below basic scores on the NAAL health literacy scale, which included health-related problems requiring prose literacy, document literacy, or quantitative skills.[45] The link between poor performance on standardized tests and adverse health outcomes is concerning, yet we should also recognize that these tests do not necessarily capture the capabilities and strategies people use to understand written information in everyday life or health professionals' skill in communicating health information to patients.[14]

Research suggests that low print or health literacy is disproportionately prevalent among the following groups: low-income people[45-48]; people with low levels of education, especially less than a high school education[45,46,48-50]; Latinos, African Americans, and Native Americans[45,47,48,50,51]; people with limited English proficiency[45,52]; and the elderly.[45,48] This suggests the need to control for these characteristics in any analysis of associations between literacy and health.

Even at the same education and income levels, some studies have found that print or health literacy proficiency independently shapes health behaviors, decisions, and use of information and services.[46,53-59] Although the precise causal mechanisms are debated, adults with lower print and health literacy scores tend to have worse health, "including knowledge, intermediate disease markers, measures of morbidity, general health status, and use of health resources."[60(1228)] In addition, research with health care patients reveals that their reading ability is often well below their highest grade completed, underscoring the importance of disnentangling literacy from years of schooling.[61]

In sum, educational attainment and literacy are not synonymous: people with the same educational credentials may have differing literacy skills, and these skills contribute to their health in specific ways. This literature informs our decision to examine the relationship between literacy and self-rated health, while controlling for personal characteristics that shape health.

**Numeracy.** The PIAAC defines numeracy as "the ability to access, use, interpret, and communicate mathematical information and ideas, to engage in and manage mathematical demands of a range of situations in adult life.[62] U.S. adults tend to have greater difficulty with numeracy than literacy. For example, 61% of U.S. PIAAC respondents scored at Level 2 or below on the numeracy scale,[iii] compared to 50% for literacy.[63] Similarly, over three-quarters of the patients in a food label comprehension study had ninth-grade literacy skills, but only 37% had equivalent math skills.[47] As with literacy, numeracy levels often lag behind years of schooling.[64] Many consumers of health care—even highly educated ones[64]—struggle with quantitative abilities such as understanding the risk of cancer or calculating the correct insulin dosage.[65-67] Such results are concerning because mathematical calculations, reasoning, and understanding influence risk assessment and decision making,[64,68,69] interpretation of numerical

[ii] Following Sørensen and colleagues (2012), we define health literacy as follows: "Health literacy is linked to literacy and entails people's knowledge, motivation and competences [*sic*] to access, understand, appraise, and apply health information in order to make judgments and take decisions in everyday life concerning healthcare, disease prevention and health promotion to maintain or improve quality of life during the life course" (p. 3).

[iii] The PIAAC reports five literacy and numeracy levels: Below Level 1, Level 1, Level 2, Level 3, and Level 4/5.

and graphical information,[47] and health behaviors, such as following medical dosing schedules.[41,67,70] For example, low numeracy scores explained women's and African Americans' lower HIV medication management scores,[71] and were associated with urban women's difficulty understanding and using contraceptives,[72] as well as overestimation of cancer risk and the benefits of experimental treatment.[64]

The evidence regarding numeracy and health, however, is "very new and still inconclusive," necessitating "a broader evidence base."[54(103)] The numeracy studies included in Berkman and colleagues' review provided "low" or "insufficient" evidence that participants with low versus adequate numeracy had different health outcomes, largely because many of the studies did not control for confounding factors such as formal educational attainment.[54] Our study seeks to clarify the relationship between numeracy and self-rated health.

Previous international PIAAC analyses suggest that numeracy is more strongly related to health than is literacy, although respondents' background characteristics were not accounted for.[73(slide 8),74] Our study extends those analyses by controlling for educational attainment and other sociodemographic characteristics.

**Technological problem-solving skills.** This study also focuses on technological problem-solving skills because they are needed to manage health, access information, and navigate the health care system in a technologically complex, information-saturated environment.[21,75-77] The PIAAC defines PS-TRE skills as "using digital technology, communication tools, and networks to acquire and evaluate information, communicate with others, and perform practical tasks."[78] Technological problem solving can influence health directly and indirectly. The use of digital tools to search for information, learn about medications, research providers, locate health support groups, or accomplish other health-related tasks "can educate patients about their condition, motivate patients to participate in their care, foster social support, evaluate treatment options, and build effective coping strategies."[79(111)] Digital skills can also enhance health indirectly by providing "access to most of the important social determinants of health including employment, housing, education and social networks."[80(349)] For instance, one study found that people with HIV who accessed health information via the Internet "were better informed about HIV disease and reported more use of active coping strategies and greater social support."[79(115)]

Many U.S. residents, however, struggle with technological problem-solving skills.[81] Fifty-four percent of U.S. respondents scored at Level 1 or below on the PIAAC PS-TRE scale[iv] (meaning they had difficulty using technology to complete more complex tasks), failed a test of basic functional computer skills, or had no computer experience.[63(84)] In addition, access to digital technologies, Internet usage for health, and the ability to use technological problem-solving skills in health situations are unequally distributed by income, educational attainment, race/ethnicity, age, and literacy ability.[80,82-85] By controlling for these characteristics, our analyses reveal the independent contribution of PS-TRE skills to health.

Our study builds on previous empirical research in this area, including studies that employ an eHealth literacy scale (Norman & Skinner, 2006a), because that research primarily involves self-rating of knowledge, skill, and confidence in using computers and technology in health situations. The few studies that assess the *ability* to use technology in health contexts do not analyze how these skills relate to health outcomes (e.g., van Deursen, 2012; van Deursen &

[iv] The PIAAC reports four PS-TRE proficiency levels: Below level 1, Level 1, Level 2, and Level 3.

van Dijk, 2011; Xie, 2011). Our study helps fill this gap in the empirical research by determining (a) whether technological problem-solving skills are associated with self-rated health and (b) whether these skills are more or less strongly related to health than literacy and numeracy after accounting for background characteristics.

**Post-initial learning.** Adult educators have long been interested in the "wider" (non-economic) benefits of learning across the life course, including health. Involvement in post-initial learning can help people develop cognitive skills and/or access social and economic resources that contribute directly or indirectly to health, as detailed in the social determinants of health literature, above. We need to understand the relationship between health status and post-initial learning because "education, which is a major component in the social determination of health, is no longer limited to youth or a prelude to the adult life course. It is now a dynamic, lifelong component of 'emergent social health gradients.'"[86(108)] Since each additional year of formal schooling contributes to health,[21] we aimed to test whether a similar pattern applies to participating in post-initial learning.

A handful of studies have explored how adult learning and continuing education influence health, primarily psychosocial outcomes such as social integration, a sense of purpose, and self-esteem,[87,88] as well as the ability to cope with illness and disability.[89] Research from the UK provides robust evidence that adult learning can enhance physical health. The 1958 National Child Development Study cohort showed that people who took three to 10 courses (e.g., academic, vocational, leisure) from age 33 to 42 were significantly more likely to stop smoking, exercise more often, and report greater life satisfaction.[90] Adult learning has also been found to be associated with preventive health care behaviors such as cancer screening.[91] We examine different types of post-initial learning (e.g., formal education, workshops) because prior research suggests that some adult learning activities are more strongly associated with health than others. For instance, research on the 1958 cohort of the U.K. National Child Development Study found that only participation in leisure courses for adults was associated with improved health behavior (smoking, alcohol, exercise); employer training, vocational accredited courses, and academic accredited courses were unrelated to health outcomes.[90]

Another strand of research shows that adult literacy programs in developing countries enable people to access and mobilize resources and to hone basic skills, dispositions, and cognitive abilities that enhance health knowledge (e.g., family planning, immunization, safe drinking water) and behaviors (e.g., seeking medical help, adopting preventive health measures).[92-96] Many of these programs, though, included curricular content on health, and the studies did not control for confounding factors.

In sum, the available evidence suggests that both formal schooling and "continued learning can help people gain socioeconomic, psychosocial and sociopolitical resources, all of which in turn lead to a healthier life."[87(677)] Our study responds to the call for more research on the relationship between adult learning and health.[97]

## Educational Attainment and Race/Ethnicity as Potential Moderators in Associations between Skills, Post-Initial Learning, and Health

The aforementioned skills and learning activities may matter more or less depending on one's formal educational attainment or race/ethnicity. First, previous research has not adequately explored whether developing basic skills and pursuing post-initial learning yield similar health rewards for people with different levels of schooling. A few studies—all with the elderly—have

found that print literacy significantly mediated educational disparities in health [98-100]. By contrast, our analyses elucidate whether people with less schooling experience greater health advantages from skill development and continuing education. For example, people with more schooling may interpret health information, documents, and advice with a more critical (skeptical) eye,[101] and may be more likely to "customize" health care and other institutions to meet their needs.[102] They may also have greater access to digital technologies and be better positioned to convert information and resources acquired through these technologies into health advantages.[80] Analyses of formal educational attainment as a moderator can help policy makers and educators identify which groups would benefit most from educational interventions.

We included race/ethnicity as a moderator variable because of entrenched racial health disparities in the U.S.[103-108] Racial health inequality often remains after accounting for educational attainment.[107-109] In addition, blacks experience "diminishing returns to education," meaning they accrue fewer health benefits than whites from increasing levels of formal education.[21,103,110-112] Race not only "channels" groups into more or less advantaged positions, but also transforms the nature of educational attainment.[104] The mechanisms through which this occurs are complex, but include poorer school quality and less challenging curricula in minority neighborhoods even at similar levels of income, lower incomes for people of color for the same level of education and work status,[113] less trust in the health care system,[114,115] fewer health rewards from personal control, social mastery, and social standing from education for people of color, and increased social isolation among people of color at higher levels of educational attainment.[116,117] Each of these mechanisms may reduce the health benefits of formal educational attainment for people of color compared to non-Hispanic whites.

This body of research provides a useful framework from which we can examine whether the racialized pattern of "diminishing returns" also applies to basic skills and post-initial learning activities. Although the PIAAC data do not allow us to test direct mechanisms, we can determine whether the health rewards from similar skills and learning activities are weaker for people of color than for whites.

## Methods

### Data

Data for this study come from the public use files of the 2012 PIAAC Survey of Adults Skills. The Survey of Adult Skills is an international survey of adults aged 16-65 conducted in 24 countries. It is designed to measure key cognitive and workplace skills needed for people to participate successfully in societies and economies. Our analyses used data from the U.S. PIAAC assessment. A total of 5,010 U.S. respondents completed this survey.

### Variables

Our outcome of interest was self-rated health. Respondents were asked: "In general, would you say your health is excellent, very good, good, fair, or poor?" We selected self-rated health because it is a comprehensive, accurate measure[v] of health outcomes (e.g., mortality,

[v] For example, Idler and Benyamini[119(21)] found that in 23 out of 27 U.S. and international studies, self-rated health was "an independent predictor of mortality," even after controlling for prior health problems. They conclude,

hospitalizations, health care utilization) in the United States and internationally.[118,119] So as not to lose any variation in our outcome, we maintained self-rated health in its ordinal scale (all five levels) for all analyses.

For our first set of research questions concerning associations between self-rated health and literacy, numeracy, and problem solving in technology-rich environments (PS-TRE), our main independent variables of interest were respondents' scores on the literacy, numeracy, and PS-TRE scales. Each respondent has ten plausible value scores on each of these scales. Respondents are not administered every literacy, numeracy, and problem-solving question in the PIAAC; instead, they respond to only a fraction of the entire assessment. Thus, plausible values were developed as a computational approximation to obtain consistent estimates of literacy, numeracy, and PS-TRE for each respondent. These are imputed values that resemble individual test scores and have approximately the same distribution as actual values. Special analytic techniques have been designed for use with these plausible values, and we employ these techniques throughout our analyses.[120,121]

For our second set of research questions related to associations between self-rated health and participation in post-initial learning during the past 12 months, we examined five binary (yes/no) independent variables: participation in (1) open or distance education courses, (2) organized sessions for on-the-job training or training by supervisors or coworkers, (3) seminars or workshops, (4) other courses or private lessons, and (5) formal education.

We examined two potential moderator variables for both sets of research questions: race/ethnicity and educational attainment. Race/ethnicity was measured by combining the race and Hispanic/Latino ethnicity variables into five dummy variables: non-Hispanic white (reference group), non-Hispanic black, Hispanic, Asian/Pacific Islander, and other race (American Indian/Alaska Native and multiracial). Educational attainment was measured with six dummy variables that captured respondent's highest qualification: did not complete high school (reference group), high school graduate, certificate from trade school or other, associate degree, bachelor's degree, and master's degree or higher.

We adjusted our regression models for several control variables that have been found to influence adult health status.[32,52,122-126] These control variables included age; sex; employment status (including inability to work due to a disability); whether the respondent was living with a spouse or a partner; whether the respondent has children aged 12 or younger; total number of people living in the household; nativity (born in the U.S. or abroad); mother's and father's educational attainment; whether the respondent reported having vision problems, hearing problems, or a diagnosed learning disability; health insurance status; and an English proficiency score comprised of a summed measure of respondent's ratings on the ability to speak, read, write, and understand spoken English. For each English proficiency question, respondents selected from four categories ranging from "very well" to "not at all." We summed the four items to create one measure, with lower scores representing greater English proficiency.

The public use version of the data does not include a measure of respondent's total income. There are measures of monthly and yearly earnings from employment for wage and salary earners and those who are self-employed, but because these values do not account for

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"Global self-ratings, which assess a currently unknown array of perceptions and weight them according to equally unknown and varying values and preferences, provide the respondents' views of global health status in a way that nothing else can. We would argue that the global rating represents an irreplaceable dimension of health status and in fact that an individual's health status cannot be assessed without it."[119(34)]

income from other sources like transfers and assets (e.g., retirement, social security, public assistance, child support, interest, rent from property), it does not accurately represent the total resources available to an individual or household. Further, use of the income from earnings variable would require us to restrict our sample to respondents who reported any earnings (only 65% of the sample). Because respondents without employment earnings are significantly different on almost all of our survey measures than those with employment earnings (e.g., respondents without reported employment earnings were more likely to have less than high school education, to be in the youngest and oldest age categories, and to be unemployed), we elected to exclude earnings as a control variable, thus ensuring that our sample reflected the most generalizable representation of U.S. adults.

After deletion of cases with missing information on our items of interest, our sample sizes ranged from 4,647 to 3,664 depending upon the outcome. Sample sizes for each set of analyses are presented in the applicable tables.

**Analytic Approach**

For each set of research questions, we begin by presenting basic descriptive statistics of our sample. For research questions related to associations between self-rated health and basic skills, we present mean scores with 95% confidence intervals for literacy, numeracy, and PS-TRE across the five health categories. These confidence intervals enable us to determine whether average literacy, numeracy, and PS-TRE scores are significantly different across the self-rated health categories (e.g., are literacy, numeracy, and/or PS-TRE scores significantly higher among respondents who reported excellent versus poor health). For research questions related to self-rated health and participation in post-initial learning, we present figures showing the percentages of respondents at each level of self-rated health by whether they participated in each post-initial learning activity, and figures displaying the percentages of respondents participating in each post-initial learning activity by race/ethnicity and by educational attainment. We then follow with a series of ordinal logistic regression models that predict the odds of being in a better self-rated health category (i.e., odds of having better health).[vi]

For each independent variable we first present a model that includes only that variable, without controlling for anything else. This enables us to determine whether there is an association between that independent variable and self-rated health before accounting for other important respondent characteristics that may affect both that independent variable (e.g., literacy) and their health. We then integrate all control variables into the second model to account for the potential confounding that can occur when you do not include these other important characteristics in the analyses. Finally, we separately examine interactions between each of our independent variables and race/ethnicity and educational attainment, again controlling for other important characteristics that may influence an individual's health. We weighted all analyses with the final sample weight provided with the data.[vii]

[vi] Cumulative logit plots identified no concerns with violating the proportional odds assumption.

[vii] Because PIAAC used a complex sample design, we used special procedures in Stata (PIAACTOOLS) to obtain correct estimates of basic descriptive statistics and to enable the analysis of plausible values that account for complex derivation of standard errors using the jackknife method implemented in PIAAC.[120] We assessed risk of multicollinearity (inability to distinguish how each skill contributes to health) by examining correlations among all independent and control variables and examining multicollinearity diagnostics. No problems were revealed.

## Results

### Associations between Self-Rated Health and Literacy, Numeracy, and Technological Problem-Solving Skills

Descriptive statistics for self-rated health, literacy, numeracy, problem-solving skills, and our control variables are presented in Table 1. The literacy score ranged from 103 to 424 (average = 272), and numeracy ranged from 45 to 427 (average = 255). These average scores fall within Level 2 for both scales (Level 2 includes scores from 226 to 275).[viii] The problem-solving score ranged from 114 to 425 (average = 278). This average score translates to Level 1; this level includes scores from 241 to 290.[ix] Over half of respondents (57.9%) rated their health as very good or excellent. The majority of the sample was non-Hispanic white, 11% were non-Hispanic black, 14% were Hispanic, 5% were Asian, and the remaining respondents were "other race." The majority of the sample had at least a high school diploma, but less than half participated in formal education post-high school. Most respondents were employed (65%) and were living with a spouse or partner (71%). About half of the sample was female, less than a quarter had a child aged 12 or younger, and about 15% was foreign-born. The majority of respondents' parents had obtained a high school diploma or better. Almost a quarter of respondents reported having vision or hearing problems or a diagnosed learning disability, and nearly 80% had health insurance. Less than 5% were unable to work due to a disability. Finally, respondents had an average

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The PIAACREG procedure within PIAACTOOLS allows the integration of only three plausible independent variables in any one model. Therefore, for our analyses of interaction effects, when we had more than three plausible values (e.g. plausible value for literacy, plausible variable for literacy among blacks, plausible value for literacy among Hispanics, plausible value for literacy among other Asians, plausible value for literacy among 'other race'), it was necessary for us to separate out our different groups (e.g., racial/ethnic groups) into their own models (e.g., compare blacks to whites in one model, compare Hispanics to whites in the next model, etc.). The coefficients for the interactions are the same for those separated models as they would be if we were able to include all interactions from the same variable in the same model.

[viii] At literacy Level 2, "the medium of texts may be digital or printed, and texts may comprise continuous, non-continuous, or mixed types. Tasks at this level require respondents to make matches between the text and information, and may require paraphrasing or low-level inferences. Some competing pieces of information may be present. Some tasks require the respondent to cycle through or integrate two or more pieces of information based on criteria; compare and contrast or reason about information requested in the question; or navigate within digital texts to access and identify information from various parts of a document."[43] At numeracy Level 2, the tasks "require the respondent to identify and act on mathematical information and ideas embedded in a range of common contexts where the mathematical content is fairly explicit or visual with relatively few distractors. Tasks tend to require the application of two or more steps or processes involving calculation with whole numbers and common decimals, percents [sic] and fractions; simple measurement and spatial representation; estimation; and interpretation of relatively simple data and statistics in texts, tables and graphs."[62]

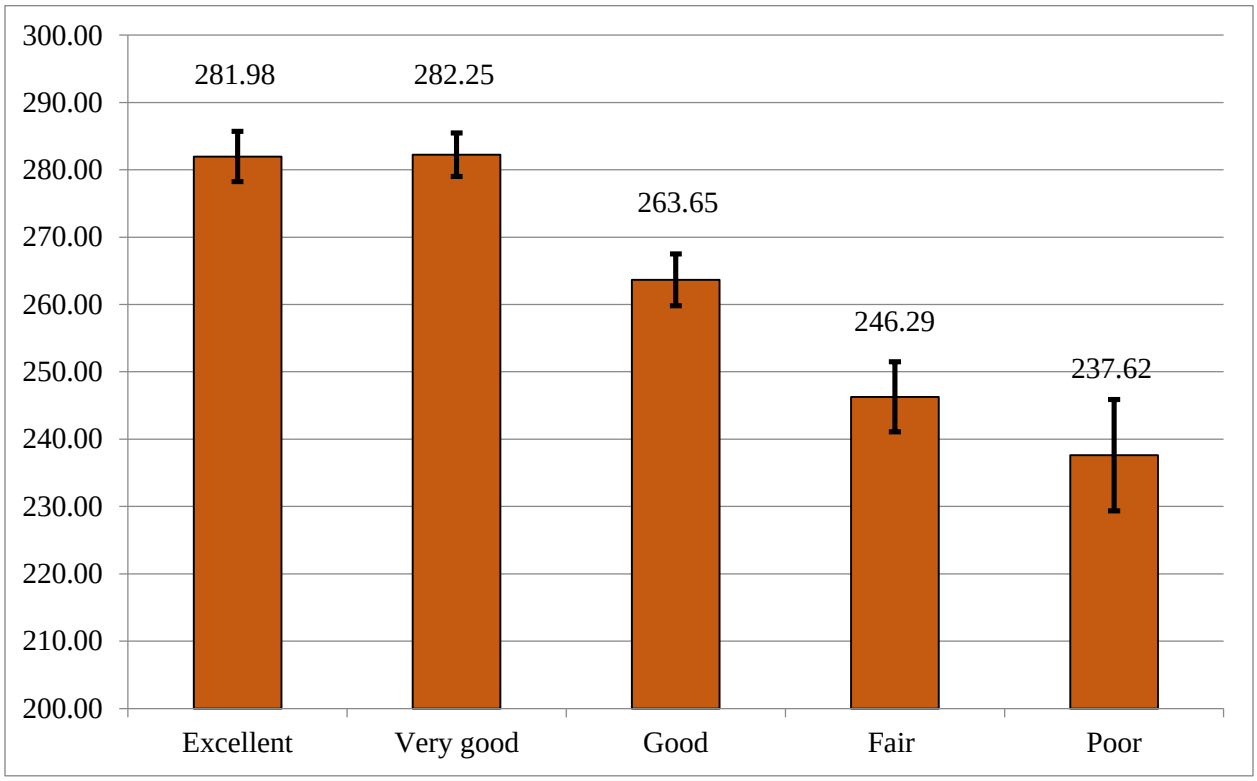
[ix] Level 1 "tasks typically require the use of widely available and familiar technology applications, such as e-mail software or a web browser. There is little or no navigation required to access the information or commands required to solve the problem. The problem may be solved regardless of the respondent's awareness and use of specific tools and functions (e.g. a sort function). The tasks involve few steps and a minimal number of operators. At the cognitive level, the respondent can readily infer the goal from the task statement; problem resolution requires the respondent to apply explicit criteria; and there are few monitoring demands (e.g. the respondent does not have to check whether he or she has used the appropriate procedure or made progress towards the solution). Identifying content and operators can be done through simple match. Only simple forms of reasoning, such as assigning items to categories, are required; there is no need to contrast or integrate information."[78]

English proficiency score of 4.87, indicating overall strong proficiency in the sample (lower scores indicate better proficiency).

<Table 1 about here>

Figures 2-4 display the average literacy, numeracy, and problem-solving scores by level of self-rated health. For all three items, there is a positive relationship between scale scores and self-rated health; respondents with higher scores report better self-rated health. The bars representing the confidence intervals around the means indicate that respondents who reported excellent or very good health had significantly higher literacy, numeracy, and problem-solving scores than respondents who reported good, fair, or poor health. Those who reported good health also had significantly higher literacy and numeracy scores (but not problem-solving scores) compared with those who reported fair or poor health.[x]

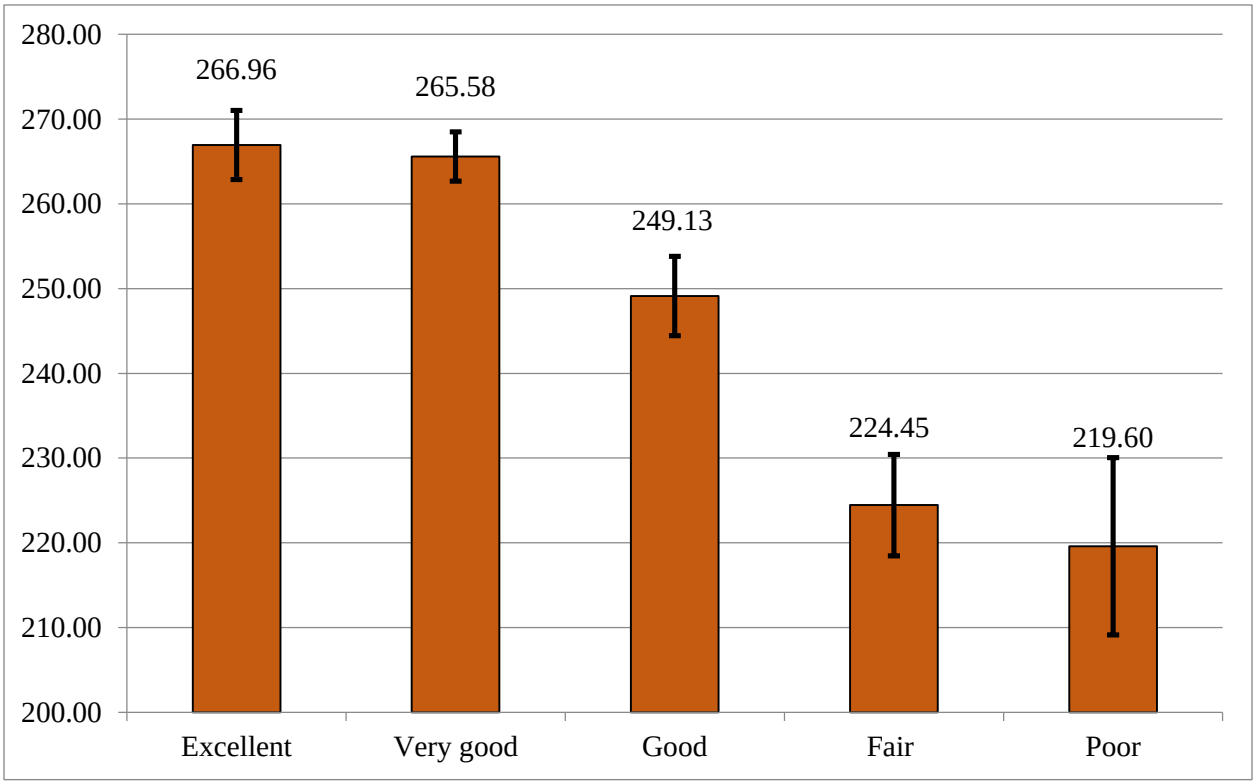
**Figure 2: Distribution of Mean Literacy Scores by Self-Rated Health**




*Note*: weighted; calculated using plausible values with PIAACTOOLS in Stata; bars represent 95% confidence intervals; non-overlapping bars represent significant differences in means at the $p<0.05$ level

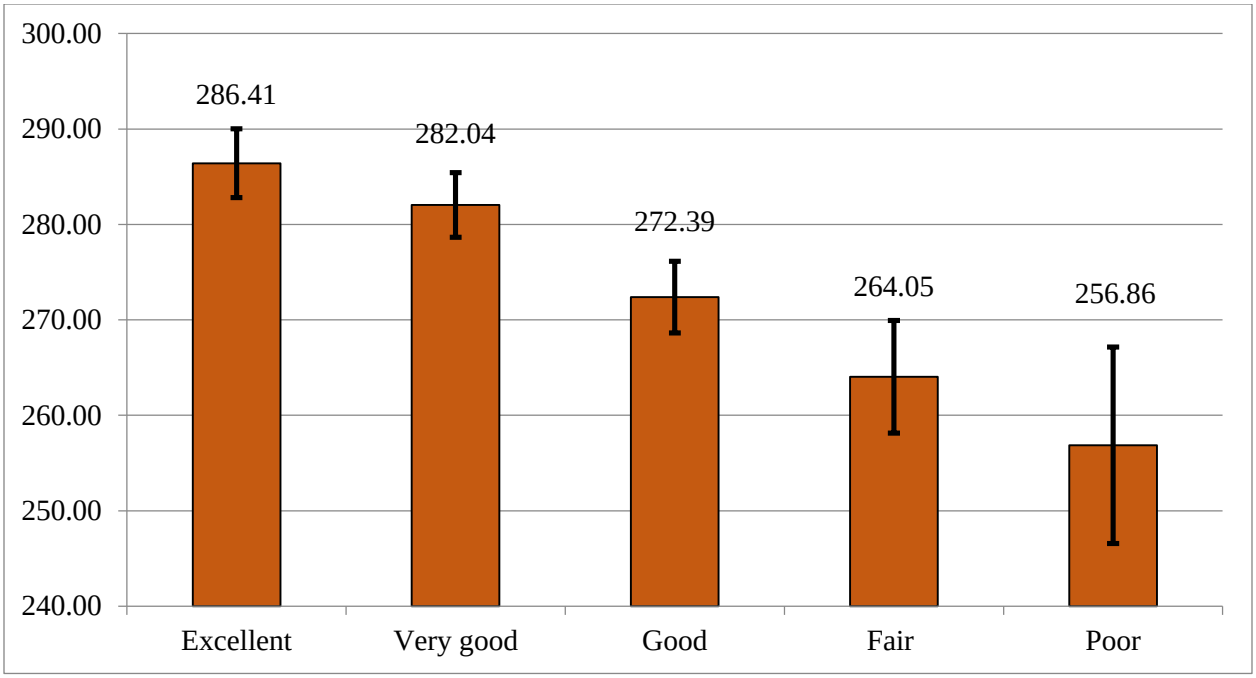
[x] PIAACOOLS is not designed to calculate summary statistics of statistical associations such as ANOVA.

**Figure 3: Distribution of Mean Numeracy Scores by Self-Rated Health**




*Note*: weighted; calculated using plausible values with PIAACTOOLS in Stata; bars represent 95% confidence intervals; non-overlapping bars represent significant differences in means at the $p<0.05$ level

**Figure 4: Distribution of Mean PS-TRE Scores by Self-Rated Health**




*Note*: weighted; calculated using plausible values with PIAACTOOLS in Stata; bars represent 95% confidence intervals; non-overlapping bars represent significant differences in means at the p<0.05 level

Results of our regression analyses predicting self-rated health from literacy, numeracy, and technological problem solving, before accounting for any control variables, are presented in Table 2. Models 1a, 2a, and 3a demonstrate that literacy, numeracy, and technological problem solving are all significantly and positively associated with health. Ten-point increases on the literacy, numeracy, and PS-TRE scales are associated with 10.5%, 8.5%, and 7.6% greater odds, respectively, of being in a better self-rated health category.[xi] Additional characteristics that may be associated with both self-rated health and skills in literacy, numeracy, and PS-TRE are included as control variables in Models 1b, 2b, and 3b (Table 3). After introducing these control variables, numeracy and technological problem solving were no longer significant. In addition, the effect size for literacy was reduced, but it remained significant. A 10-point increase on the literacy scale is associated with 2.6% greater odds of being in a better health category.[xii]

Although literacy remained significant in the model with control variables, the effect size is quite small (OR = 1.026); every 10-point increase on the literacy scale is associated with a 2.6% increase in the odds of being in a better health category. Indeed, several of the control variables were much more strongly associated with self-rated health than was literacy. For instance, having a bachelor's degree was associated with about 92% greater odds of being in a better health category than having less than high school, and having a master's degree or higher was associated with over twice the odds of being in a better health category compared with those who did not finish high school. Foreign-born respondents had almost 50% greater odds of being

[xi] Because literacy, numeracy, and PS-TRE skills are so highly correlated, they cannot be included in the same regression models due to risk of multicollinearity.

[xii] Supplemental analyses (not shown, but available upon request) revealed that it was not one particular variable or specific group of variables that eliminated the significant associations between numeracy and self-rated health and PS-TRE and self-rated health. Instead, it was the combination of all control variables except sex, living with a spouse or partner, having children aged 12 or younger, and number of people in the household (none of which were significant predictors of self-rated health) that eliminated the significance for both numeracy and PS-TRE.

in a better self-rated health category compared with U.S.-born respondents. Being retired or unable to work due to disability were associated with about 39% and 96% lower odds, respectively, of reporting better health compared to those who are employed. Parental education, age, health insurance, and English proficiency were also associated with self-rated health.

Finally, compared to whites, blacks had significantly worse self-rated health in the PS-TRE model, but not the literacy or numeracy models, and Asians had significantly worse self-rated health in all models. These different associations between race/ethnicity and self-rated health across the three models suggest the possibility of an interaction between race/ethnicity and the three skills on self-rated health. We now turn to that possibility.

<Table 2 about here>
<Table 3 about here>

**Assessing Race/Ethnicity and Formal Educational Attainment as Potential Moderators in the Relationship between Self-Rated Health and Literacy, Numeracy, and PS-TRE Skills.** To determine whether the relationship between self-rated health and literacy, numeracy, and PS-TRE varies by racial/ethnic group (do literacy, numeracy, and technological problem-solving skills matter more for health for some racial/ethnic groups than others?) or by formal education attainment (do literacy, numeracy, and technological problem-solving skills matter more for the health of people at different levels of formal educational attainment?) we ran several interaction models. The coefficients from these models are presented in the Appendix. All models include all of the control variables discussed earlier.

We found no significant interactions by race/ethnicity for literacy, numeracy, or technological problem-solving skills. This suggests that the associations between self-rated health and literacy, numeracy, and PS-TRE are the same across all of the racial/ethnic groups; literacy is positively associated with self-rated health for all racial/ethnic groups, and numeracy and PS-TRE skills are not significantly associated with self-rated health for any racial/ethnic group, after accounting for all of the control variables.

We found only one significant educational attainment interaction. The interaction coefficient for PS-TRE and master's degree or higher was positive and significant (although rather weak). This demonstrates that PS-TRE skills have a stronger positive association with self-rated health for respondents who have a master's degree or higher compared with those who did not complete high school. In other words, PS-TRE skills are more protective for health for the most highly educated than for those with the least schooling. We also tested interactions in unadjusted models (without any control variables), and the interaction results were unchanged.

**Associations between Self-Rated Health and Participation in Post-initial Learning**

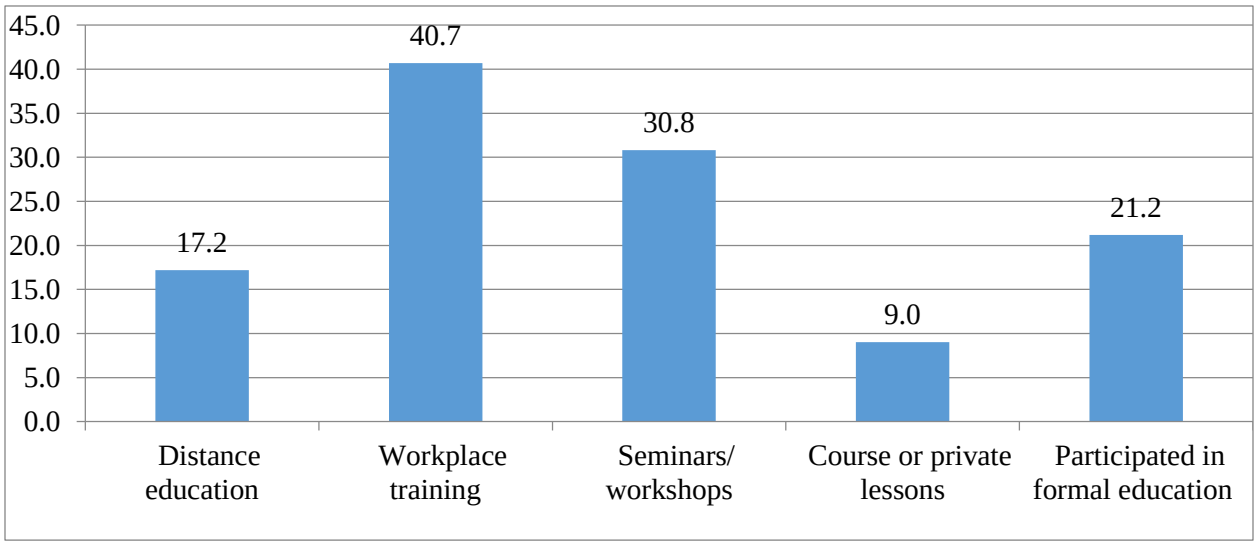
We now examine whether participation in post-initial learning is associated with self-rated health. The sample size is 4,473. We examine five types of participation in post-initial learning (all within the past 12 months): open or distance education, workplace training, seminars or workshops, private courses or lessons, and formal education.

Figure 5 displays the percentage of respondents who participated in each type of post-initial learning. Participation in workplace training was most common at 41%, followed by participation in seminars or workshops (31%), and participation in formal education (21%). Participation in courses or private lessons was least common at 9%.

Figures 6 and 7 show how participation in post-initial learning varies by race/ethnicity and level of formal educational attainment. For all types of post-initial learning, a lower percentage of non-Hispanic whites participated compared to at least one of the other racial/ethnic groups. All minority racial/ethnic groups are more likely than whites to have participated in formal education in the past 12 months. Asians are more likely than whites to have participated in courses or private lessons and seminars or workshops. Blacks are slightly more likely than whites to have participated in workplace training, and both blacks and "other race" groups are more likely to have participated in open or distance education courses.

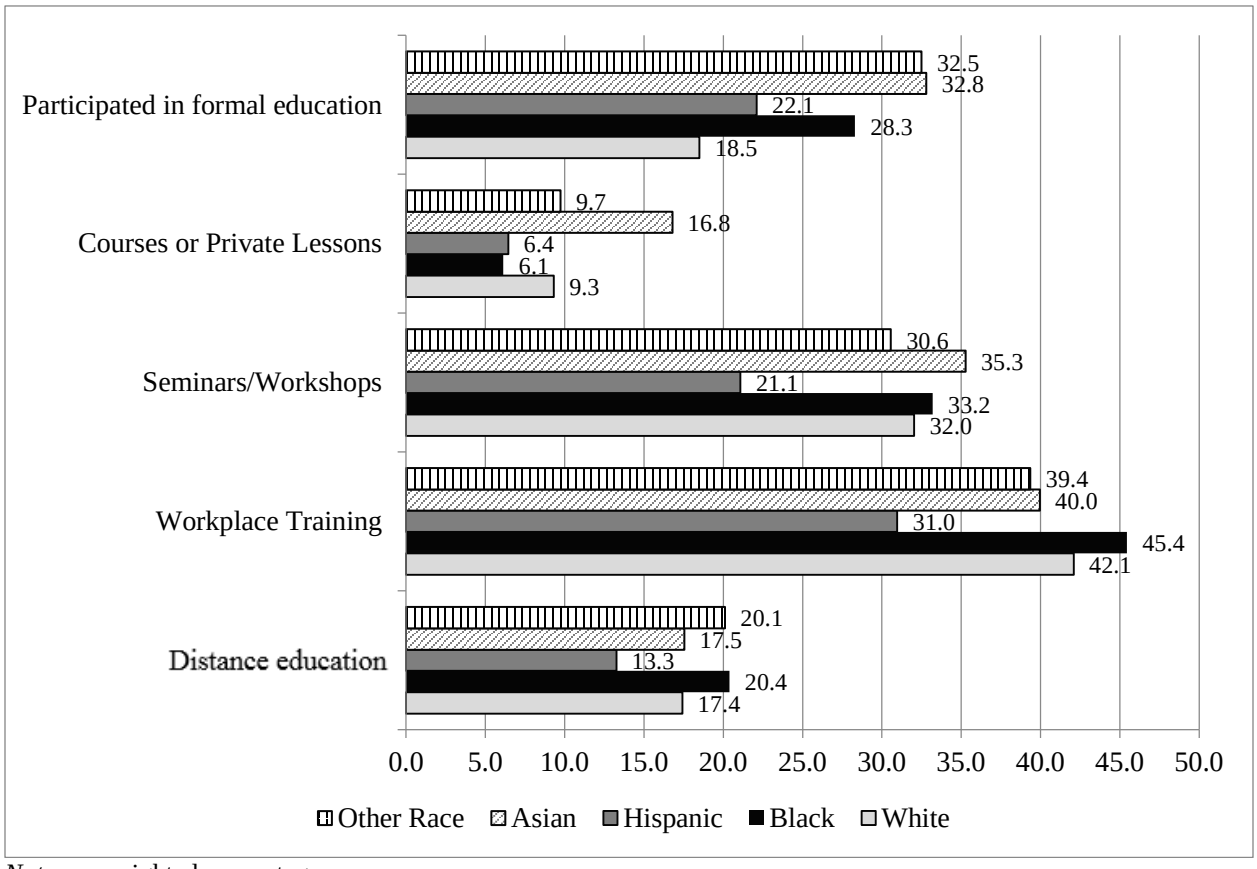
Participation in courses or private lessons, workplace training, and seminars or workshops all increase with higher levels of formal educational attainment. Participation in distance education shows a similar pattern, but a slightly lower percentage of respondents with a Bachelor's degree participate in distance education compared to those with an associate degree. Participating in formal education is most common among those with a high school diploma/some college and least common among those with a trade or other certificate.

**Figure 5: Percentage of Respondents Participating in Each Type of Post-Initial Learning Activity in Past 12 Months**



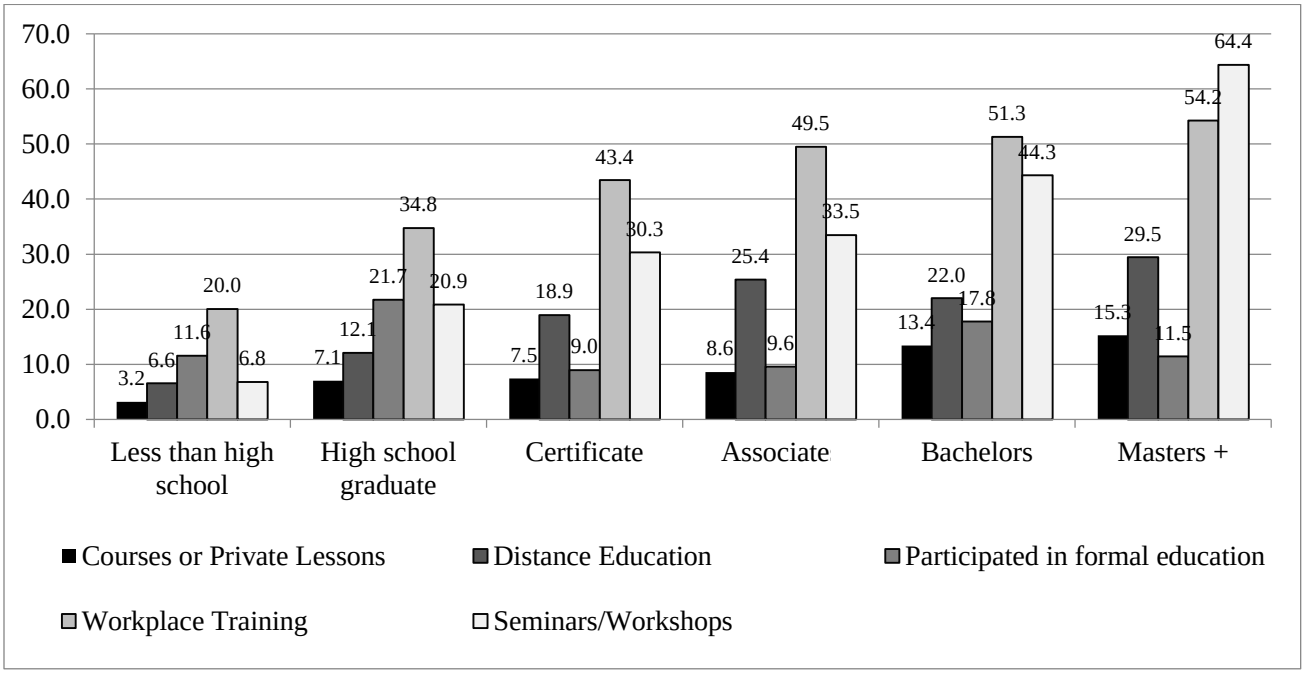

*Note*: weighted percentages
N=4,473

**Figure 6: Percentage of Respondents Participating in Each Type of Post-Initial Learning Activity in Past 12 Months, by Race/Ethnicity**




*Note*: weighted percentages
N=4,473

**Figure 7: Percentage of Respondents Participating in Each Type of Post-initial Learning Activity in Past 12 months, by Level of Educational Attainment**



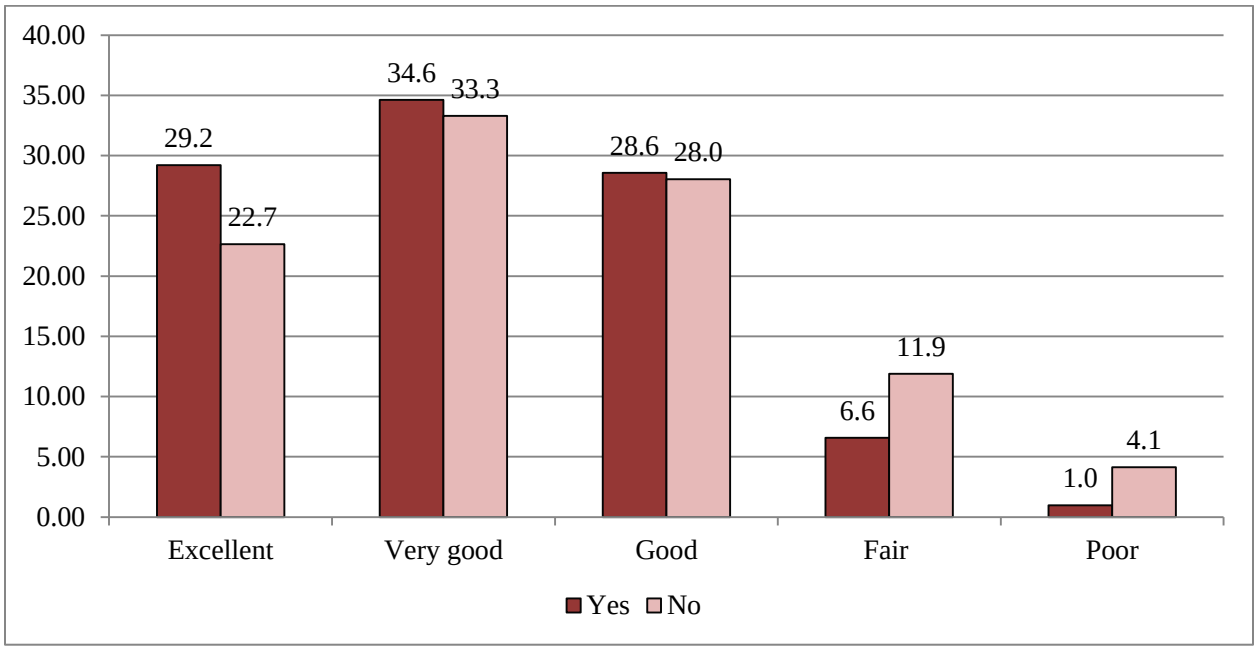

*Note*: weighted percentages
N=4,473

Figures 8-12 display variation in self-rated health by whether respondents participated in each type of post-initial learning in the past 12 months, without controlling for any respondent characteristics that may influence their health or ability to participate in these activities. We found that:

- Respondents who participated in open or distance education (Figure 8) are more likely to report excellent health and less likely to report fair or poor health than those who did not participate in this activity.
- Respondents who participated in workplace training (Figure (9) are more likely than those who do not participate to report excellent or very good health and less likely to report fair or poor health.
- Those who participated in seminars or workshops (Figure 10) are more likely than those who did not participate in those activities to report excellent or very good health, but they are also more likely to report fair health than those who did not participate in seminars or workshops.
- Respondents who participated in courses or private lessons (Figure 11) are more likely to report excellent health and less likely to report the other health categories compared with those who did not participate in courses or private lessons.
- Finally, participating in formal education (Figure 12) is associated with worse health; these individuals were less likely to report excellent health and more likely to report poor health than those who did participate in formal education over the past 12 months. This may be because participation in formal education was more common among those at

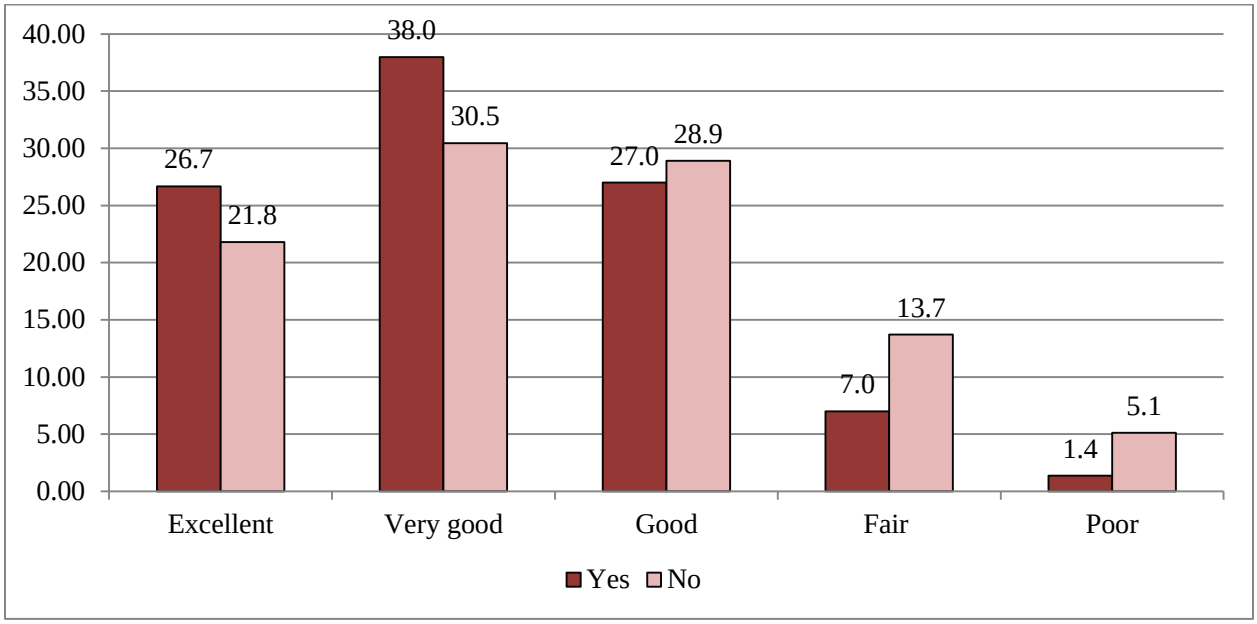
lower levels of educational attainment (e.g., high school graduates) than those at higher levels (e.g., those with advanced degrees), and because people with lower educational attainment tend to have worse health than more highly educated persons.

**Figure 8: Self-Rated Health by Participation in Open or Distance Education**



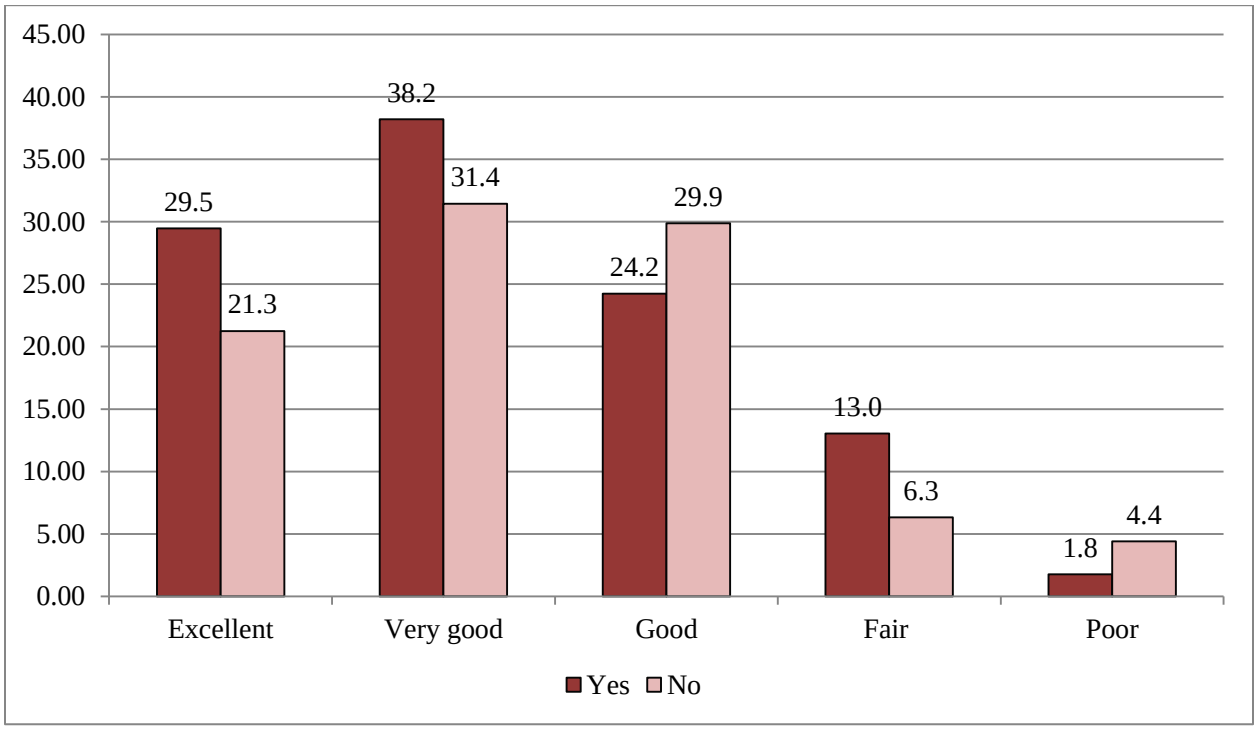

*Note*: weighted unadjusted percentages
N=4,473

**Figure 9: Self-Rated Health by Participation in Workplace Training**



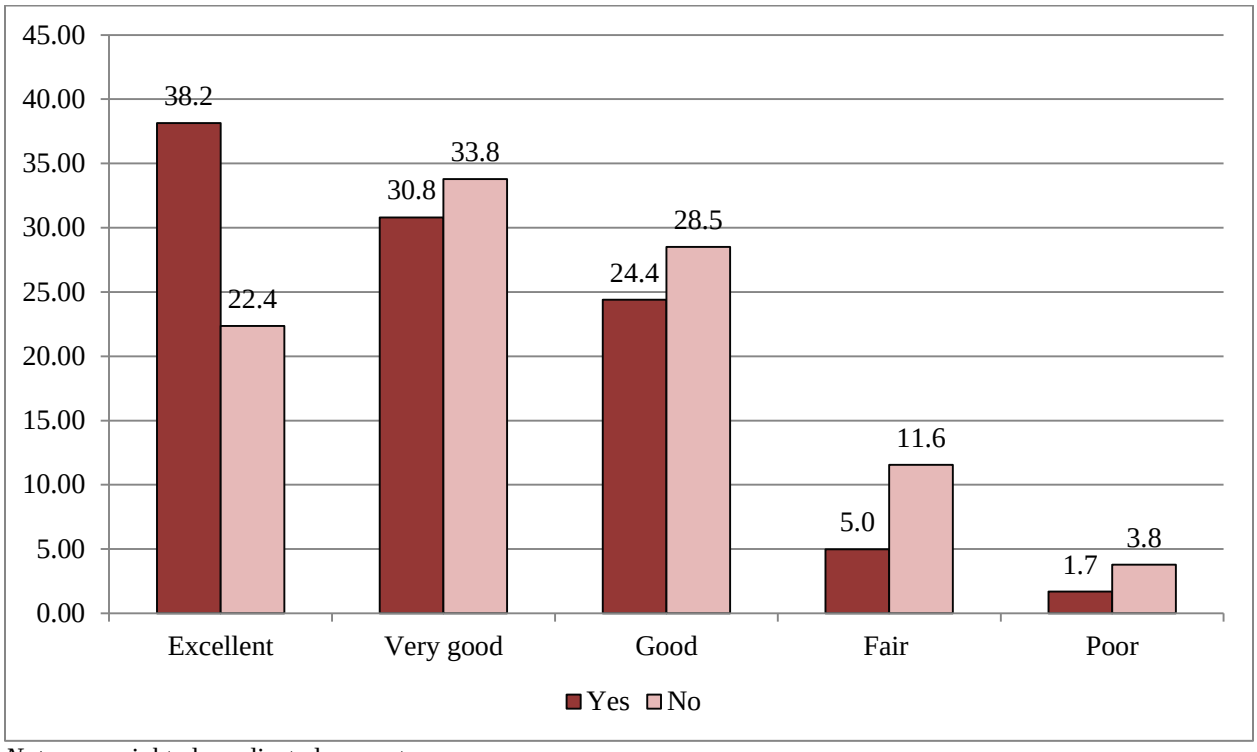

*Note*: weighted unadjusted percentages
N=4,473

**Figure 10: Self-Rated Health by Participation in Seminars or Workshops**



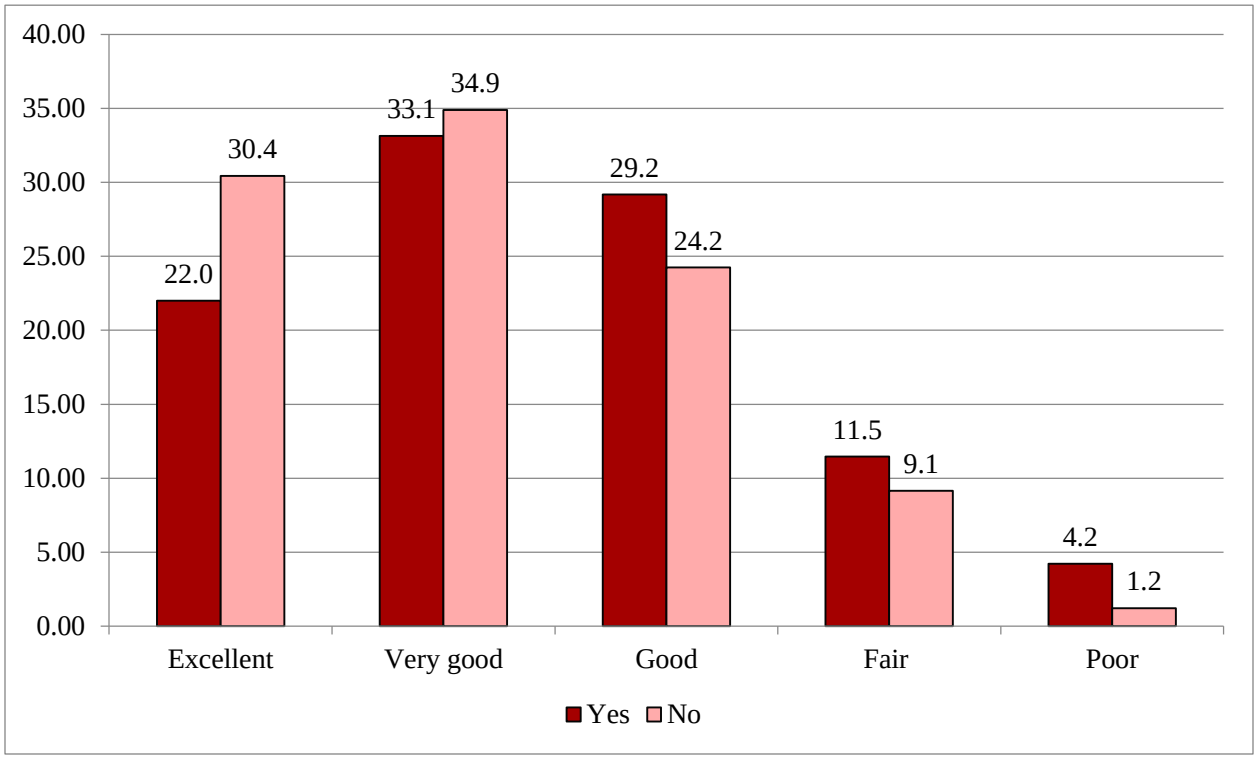

*Note*: weighted unadjusted percentages
N=4,473

**Figure 11: Self-Rated Health by Participation in Courses or Private Lessons**




*Note*: weighted unadjusted percentages
N=4,473

**Figure 12: Self-Rated Health by Participation in Formal Education**




*Note*: weighted unadjusted percentages
N=4,473

Results of unadjusted (no control variables) and adjusted (all control variables included) ordinal logistic regression models examining the associations between self-rated health and participation in post-initial learning activities are presented in Table 4. Because these five activities were not highly correlated, we could include them together in the same regression models to control for concomitant participation. As shown in Model 1 of Table 4, participation in workplace training, seminars or workshops, courses or private lessons, and formal education were all associated with increased odds of being in a better health category, but the strongest effect was for participation in courses or private lessons. Respondents who participated in four types of learning activities had greater odds of being in a better health category, compared to those who did not participate: workplace training (38% greater odds), formal education (46% greater odds), seminars or workshops (50% greater odds), and courses or private lessons (84% greater odds). Participation in open or distance education was not significantly associated with self-rated health.

After introducing control variables in Model 2, workplace training, seminars and workshops, and formal education were no longer significant, and the effect of courses or private lessons became weaker. However, the association for participation in courses or private lessons remained robust at 59% greater odds of being in a better health category.[xiii] Results for the

[xiii] Supplemental analysis (not shown, but available upon request), demonstrated that two control variables—educational attainment and employment status—eliminated the statistical significance for the other four types of post-initial learning. This suggests that those two variables explain the significant association between these types of

control variables are largely the same as in the previous analysis, so we do not repeat that summary here.

<Table 4 about here>

**Assessing Race/Ethnicity and Formal Educational Attainment as Potential Moderators in the Relationship between Self-Rated Health and Participation in Post-Initial Learning.** To determine whether certain types of post-initial learning were stronger predictors of self-rated health for certain racial/ethnic groups versus others, we ran ordinal logistic regression models interacting each type of post-initial learning with race/ethnicity. This allowed us to determine whether different racial/ethnic groups gain similar health benefits from the same learning activities. There were no significant interactions between race/ethnicity and any of the post-initial learning activities. This means that no racial/ethnic group experiences greater health rewards than others from pursuing post-initial learning.

Participation in private courses or lessons is the only type of post-initial learning activity to remain positively associated with self-rated health, and as the interaction analyses show, this activity has the same positive association with self-rated health across all racial/ethnic groups. A table with log odds from those interaction models is presented in the Appendix.

Finally, to determine whether certain types of post-initial learning were stronger predictors of self-rated health for people at different levels of educational attainment, we ran models interacting each type of post-initial learning with educational attainment categories. This allowed us to determine whether people with different levels of schooling gain similar health benefits from the same learning activities. There were no significant interactions between educational attainment and any of the post-initial learning activities, except participation in formal education. In this model, the association between participating in formal education in the past 12 months was weaker for respondents with a high school diploma than for those with less than high school. This means that compared to high school graduates, people with less than a high school education gain more health rewards from pursuing formal education. We did not find significant interactions for any of the other models, which indicates that the associations between self-rated health and distance education, workplace training, seminars or workshops, and courses or private lessons were the same across all levels of educational attainment. In other words, respondents experience similar health benefits from these activities, regardless of how much or little prior schooling they have.

## Discussion

This paper explored basic skills and post-initial learning activities as potential social determinants of adult health in the U.S. Our study is the first to use PIAAC data to identify how literacy, numeracy, technological problem solving, and post-initial learning are associated with adult health status, and how those relationships vary (or do not) across racial/ethnic and formal educational attainment groups. The results indicate that although literacy, numeracy, and technological problem-solving skills are positively associated with self-rated health, only literacy remains significant after controlling for selected sociodemographic variables. Consistent with previous research, we found a positive association between numeracy and self-rated

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post-initial learning and self-rated health. In other words, people who are employed and have higher educational attainment are more likely both to participate in these activities and report better health.

health[47,64,67,69,71] and technological problem-solving skills and health.[82,83,85,127] However, unlike previous research—including PIAAC analyses[73,74]—we tested whether that relationship remained after controlling for various individual characteristics, and found that these skills were no longer significant predictors of health. This suggests that people may experience greater health benefits from developing literacy than numeracy or technological problem-solving abilities. Additional research is needed to determine the mechanisms by which literacy enhances health, why numeracy and PS-TRE have a smaller effect on health than literacy, and whether our findings pertain to other PIAAC countries.

Although literacy matters for health, its effect size (a 3% increase in the odds of being in a better health category for a 10-point increase in literacy score) is not as large as for many of our control variables. This indicates that although important, literacy is not among the strongest predictors of self-rated health. Thus, enhancing individual literacy skills is important but insufficient for improving U.S. respondents' health status. People cannot change many of the variables that more strongly predicted self-reported health, namely, nativity, being retired or unable to work because of disability, age, and parental education. However, other variables that significantly increase the chances of better self-rated health are promising areas for policy intervention, including ESL instruction for non-native English speakers and efforts to increase college attainment and access to health insurance for low-SES groups, who are most likely to suffer from poor health. In sum, we found that literacy matters, but it is not a magic bullet for improving health among U.S. adults.

We also found that overall, the relationships between self-reported health and literacy, numeracy, and technological problem solving did not differ across racial/ethnic groups. This indicates that the "diminishing returns hypothesis," whereby people of color accumulate fewer health rewards than whites from increasingly higher educational attainment,[104,110-112] does not hold for literacy, numeracy, and technological problem-solving skills. Rather, minority racial/ethnic groups derive equal health benefits from greater literacy proficiency. As shown in our main effects models, numeracy and PS-TRE skills were not significantly associated with self-rated health after including demographic control variables. In addition, the interaction models showed that these two skills are not associated with self-rated health for any particular racial/ethnic group.

Of the three PIAAC scales, only the relationship between PS-TRE and self-rated health differed by formal educational attainment. We found a very small but positive interaction between technological problem solving and having a master's degree or higher. This means that respondents who had at least a master's degree gained more health benefits from technological problem-solving proficiency than those who did not complete high school. The literature emphasizes that people with limited education and income need to develop technological problem-solving skills to manage their health.[77,82,83,85] However, our results raise questions about the health returns from increased technological problem-solving ability for those with trade certificates, associate degrees, and bachelor degrees. PS-TRE skills were not any more strongly associated with self-rated health for those groups than they were for people who had not completed high school. Our results showed that PS-TRE skills only predicted health for the most highly educated. This group experiences positive effects on health (although very modest) with better PS-TRE skills.

Possible explanations are that highly educated people have greater access to computers and the Internet and are more likely to use the Internet for health matters.[76] Because of their advantaged socioeconomic position, the highly educated may be better able to act on the

knowledge, information, and resources acquired through digital technologies. In turn, this may create a "vicious cycle of digital exclusion" that exacerbates health and socioeconomic disadvantages for people with limited schooling.[80(355)]

Regarding our second set of research questions, we found that participation in workplace training, seminars/workshops, courses/private lessons, and formal education in the past 12 months are all associated with better self-rated health, but open/distance education is not. However, after adjusting for sociodemographic characteristics, only participation in courses/private lessons remained significant. This learning activity is related to improved health above and beyond any health benefits derived from employment, educational attainment, parental educational attainment, health insurance, or any other control variables we included.

Descriptive statistics revealed that Asians and highly educated respondents were the most likely to participate in courses/private lessons, whereas blacks and respondents with less schooling were the least likely. Since this learning activity is associated with better health, one potential intervention may be to increase participation in these activities among blacks and people with lower levels of education.

A limitation of the PIAAC dataset is that it does not indicate the topical content of courses/private lessons. Thus, further qualitative and quantitative research is needed to understand what these learning activities entail (e.g., language, cooking, sports, arts, computer skills, hobbies, career-related topics), what respondents learn in these courses/lessons, and the mechanisms by which these activities are associated with better health. The course type and content matter because Feinstein and Hamnond[128] found that only leisure courses predicted adult health outcomes, whereas academic or vocational accredited courses and employer training had no effect. We need to know, for instance, whether courses/lessons include health topics. If not, do they improve health through cognitive or skill development, information acquisition, social network formation, access to and mobilization of psychosocial or material resources, or some other pathway? Although we controlled for background characteristics, taking courses/private lessons may be related to some other trait (not measured by the PIAAC) that improves health, or people with better health may be more likely to take these courses.[86]

Analyses of whether post-initial learning mattered more for the health of different racial/ethnic groups or levels of educational attainment showed that there was no variation in the strength of these relationships across these categories. Of all the post-initial learning activities, participation in courses/private lessons was most strongly associated with self-rated health for every racial/ethnic group and level of educational attainment. Similar to the results reported above, this finding suggests that the diminishing returns hypothesis does not apply to post-initial learning; rather, involvement in post-initial learning generated similar health benefits for all racial/ethnic groups.

Given the well-established link between educational attainment and health, it was surprising that pursuing formal education in the past year was not related to better self-reported health, after controlling for relevant background factors. Prior research shows that in addition to the acquisition of educational credentials (degree completion), "each additional year of education (after high school) provides a bounty of resources that allow persons to garner health and, eventually, longevity advantages."[21(14)] Though beyond the scope of this paper, future PIAAC analyses should assess whether respondents who *completed* their formal education course(s) or a full year of additional study reported better self-rated health. Our results suggest that merely participating in formal education does not predict better health status.

Our additional analyses revealed that employment status (particularly being retired or disabled) eliminated the significance of participating in formal education. Further research is needed to analyze the sub-set of respondents who are not retired or disabled. Specifically, among working-age adults, do those who pursue formal education report better health compared to those who do not? This could help clarify whether the skills that working-age adults develop through studying for a formal degree translate into improved health. PIAAC data provide an opportunity for this kind of subsequent analysis.

The results of this study should be considered in light of some limitations. First, due to the skip patterns in the data, there was an insufficient sample size for examining how literacy instruction or GED instruction influences self-reported health. We needed a larger sample of GED participants than what is available in the PIAAC in order to control for a variety of characteristics that influence both self-rated health and participation in GED instruction. GED programs serve the very groups that are most likely to suffer from poor health: people of color and adults with limited schooling and high rates of poverty. Given the growing interest in adult education and health and integrating health-related topics into adult basic education and ESL classes,[2-4,6-15,129] further research should examine whether and how these classes (with or without explicit health content) shape health outcomes.

Second, the PIAAC cannot be used to determine causal relationships because the data are cross-sectional (collected at one point in time). People with better health may be able to concentrate better on the survey questions, thereby improving their scores. In addition, healthier people may be more likely to continue their education or participate in other learning activities. Longitudinal studies that track people from childhood into adulthood or through adulthood would allow us to examine the causal relationship between adult health and skill acquisition throughout the life course.[86]

Third, we could not control for respondent income because the PIAAC includes only income from employment earnings. Income from all sources, including transfers and assets, is an important health-promoting resource. Future versions of the PIAAC should consider including questions that elucidate household income from all sources.

Finally, some of the PIAAC variables are subject to recall bias (inaccurate memory), including parental education and participation in post-initial learning activities during the past year. Despite these limitations, our study is the first to examine the relationships between adult self-rated health and literacy, numeracy, technological problem-solving skills, and participation in post-initial learning activities.

## Conclusion

In sum, the study elucidates how various types of skills and post-initial learning are (and are not) related to self-reported health. It underscores the importance of literacy proficiency and participation in courses/private lessons for improving U.S. adults' health status, along with key demographic characteristics that strongly influence health (e.g., disability, nativity, age) and promising areas for policy intervention (expanding access to college, health insurance, ESL instruction). Our findings also reveal that only the most highly educated adults accumulate health rewards from technological problem-solving skills, which highlights the need to explore why people with less education are less able to convert these skills into health benefits.

First, literacy is a stronger predictor of U.S. respondents' self-rated health than numeracy or technological problem-solving skills, yet literacy is less salient than other factors such as

disability, educational attainment, health insurance, English proficiency, and nativity. This underscores the need to couple literacy and ESL instruction with policies to increase college completion and access to health insurance.

Second, there was no variation in the relationship between self-rated health and literacy, numeracy, and technological problem-solving skills by race/ethnicity and little variation across categories of educational attainment; the same held true for the relationship between health and post-initial learning. This finding is important because it suggests that racial/ethnic groups can benefit equally from developing literacy skills and participating in courses/private lessons, the post-initial learning activity that was the strongest predictor of health. Comparison of these U.S. results with international PIAAC data could reveal whether our findings apply elsewhere. Similarly, substituting nativity for race/ethnicity could elucidate whether literacy, numeracy, PS-TRE skills, and post-initial learning matter more for the health status of foreign- versus U.S.-born adults, which is especially important given changing U.S. demographics.

Third, having access to geographic identifiers (i.e., county or state FIPS [federal information processing standards] codes) within the U.S. PIAAC data would enable researchers to examine how relationships between literacy, numeracy, PS-TRE skills, post-initial learning, and health vary across geographic contexts and whether variations are explained compositional or contextual characteristics of these places (i.e., demographic attributes of the people who live there vs. the features of a specific locale). Currently, the U.S. Census regions (Northeast, Midwest, South, and West) are the finest-grain geographic variable in the PIAAC dataset.

Fourth, exploring health care utilization as the dependent variable can help us understand how these proficiencies and educational activities shape adults' use of health care services, particularly preventative health services such as flu shots, mammograms, or screening for various diseases. For instance, do limited literacy, numeracy, and technological problem-solving skills impede people from using these services, even after accounting for their self-rated health, insurance status, income, education level, and other characteristics?

Finally, the U.S. PIAAC National Supplement study, which will include unemployed, younger, and older adults, can be used to examine how access to health insurance for these sub-groups may change the relationship between health indicators and literacy, numeracy, PS-TRE skills, and post-initial learning before and after implementation of the Affordable Care Act (ACA). The ACA has reduced Americans' uninsured rate from 18.0% in 2013 to 13.4% in 2014.[130] Our study provides a foundation for these types of future research.

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**Table 1: Descriptive Statistics for Self-Rated Health, Literacy, Numeracy, PS-TRE, and Control Variables**

| Percentages or mean (std) | | Min | Max |
|---|---|---|---|
| Literacy | 271.60 (48.6) | 102.9 | 424.3 |
| Numeracy | 255.33 (55.9) | 44.7 | 426.9 |
| PS-TRE[a] | 278.49 (43.1) | 114.1 | 425.0 |
| Self-Rated Health | | | |
| Excellent | 24.1 | | |
| Very Good | 33.8 | | |
| Good | 28.0 | | |
| Fair | 10.7 | | |
| Poor | 3.4 | | |
| Race/Ethnicity | | | |
| Non-Hispanic white | 66.7 | | |
| Non-Hispanic black | 11.4 | | |
| Hispanic | 14.1 | | |
| Asian | 5.3 | | |
| Other race | 2.5 | | |
| Educational Attainment | | | |
| Did not complete high school (ref) | 13.5 | | |
| High school graduate/some college | 40.9 | | |
| Certificate from trade school or other | 8.6 | | |
| Associate degree | 9.2 | | |
| Bachelor's degree | 16.9 | | |
| Master's degree or higher | 10.9 | | |
| Female | 51.1 | | |
| Employment Status | | | |
| Employed | 65.1 | | |
| Unemployed | 7.8 | | |
| Pupil, student, apprentice, internship | 10.1 | | |
| Retired | 3.5 | | |
| Disabled | 4.5 | | |
| Homemaker or other | 9.0 | | |
| Lives with a spouse or partner | 71.4 | | |
| Has children aged 12 or younger | 22.2 | | |
| Number of people living in household | 3.22 (1.53) | 1.0 | 7.0 |
| Foreign born | 14.9 | | |
| Mother's Educational Attainment | | | |
| Did not complete high school | 25.8 | | |
| Completed high school | 47.4 | | |
| Attended college or more | 26.8 | | |
| Father's Educational Attainment | | | |

| | | | |
|---|---|---|---|
| Did not complete high school | 27.0 | | |
| Completed high school | 44.8 | | |
| Attended college or more | 28.2 | | |
| Has vision/hearing problems or diagnosed learning disability | 22.8 | | |
| Age | | | |
| 24 or less | 18.1 | | |
| 25-34 | 20.6 | | |
| 35-44 | 20.2 | | |
| 45-54 | 21.8 | | |
| 55 or older | 19.4 | | |
| Has health insurance | 79.8 | | |
| English proficiency level (lower score=better) | 4.87 (2.1) | 4.0 | 16.0 |

*Note*: Means and standard deviations for literacy, numeracy, and PS-TRE were calculating using the PIAACDES method within PIAACTOOLS in Stata to account for plausible values.

N=4,647 for literacy and numeracy

[a]N=3942 for PS-TRE

All values are weighted

**Table 2. Odds Ratios and 95% Confidence Intervals from Unadjusted Ordinal Logistic Regression Models of Self-Rated Health Regressed on Literacy, Numeracy, and PS-TRE Skills**

| | LITERACY Model 1a | | NUMERACY Model 2a | | PS-TRE Model 3a | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Literacy | 1.105*** | 1.090-1.120 | ----- | ----- | ----- | ----- |
| Numeracy | ----- | ----- | 1.085*** | 1.073-1.098 | ----- | ----- |
| PS-TRE | ----- | ----- | ----- | ----- | 1.076*** | 1.057-1.095 |

*Note*: The literacy, numeracy, and PS-TRE estimates represent changes of 10-point increments. Calculated using plausible values with PIAACTOOLS (piaacreg) in Stata.

***p<.001; weighted; two-tailed tests

N=4,647 (literacy and numeracy); N=3,942 (PS-TRE)

**Table 3. Odds Ratios and 95% Confidence Intervals from Adjusted Ordinal Logistic Regression Models of Self-Rated Health Regressed on Literacy, Numeracy, and PS-TRE Skills**

| | LITERACY Model 1b | | NUMERACY Model 2b | | PS-TRE Model 3b | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Literacy | 1.026* | 1.004-1.049 | ----- | ----- | ----- | ----- |
| Numeracy | ----- | ----- | 1.010 | 0.922-1.028 | ----- | ----- |
| PS-TRE | ----- | ----- | ----- | ----- | 1.004 | 0.983-1.026 |
| *Race/Ethnicity* | | | | | | |
| Non-Hispanic white (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| Non-Hispanic black | 0.850 | 0.696-1.038 | 0.825 | 0.675-1.010 | 0.772* | 0.611-0.975 |
| Hispanic | 1.284 | 0.984-1.676 | 1.004 | 0.771-1.308 | 0.991 | 0.719-1.367 |
| Asian/Pacific Islander | 0.690** | 0.522-0.911 | 0.677** | 0.513-0.894 | 0.688* | 0.476-0.994 |
| Other race | 0.895 | 0.608-1.317 | 0.895 | 0.608-1.317 | 0.868 | 0.565-1.333 |
| *Educational Attainment* | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| High school graduate | 1.082 | 0.829-1.413 | 1.102 | 0.846-1.436 | 1.016 | 0.740-1.396 |
| Certificate from trade school or other | 1.112 | 0.765-1.617 | 1.135 | 0.901-1.431 | 1.048 | 0.700-1.570 |
| Associate degree | 1.334 | 0.998-1.783 | 1.387 | 1.044-1.843 | 1.262 | 0.884-1.803 |
| Bachelor's degree | 1.917*** | 1.393-2.639 | 2.016*** | 1.473-2.758 | 1.865** | 1.305-2.664 |
| Master's degree or higher | 2.212*** | 1.588-3.081 | 2.375*** | 1.722-3.275 | 2.166*** | 1.484-3.162 |
| Female | 0.892 | 0.789-1.010 | 0.902 | 0.800-1.017 | 0.923 | 0.813-1.049 |
| *Employment Status* | | | | | | |
| Employed (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| Unemployed | 0.641** | 0.478-0.861 | 0.642** | 0.477-0.865 | 0.698* | 0.512-0.951 |
| Pupil, student, apprentice, internship | 0.934 | 0.709-1.232 | 0.954 | 0.727-1.253 | 0.891 | 0.673-1.180 |
| Retired | 0.613** | 0.453-0.828 | 0.614** | 0.455-0.829 | 0.700 | 0.457-1.074 |
| Disabled | 0.041*** | 0.029-0.059 | 0.041*** | 0.029-0.057 | 0.029*** | 0.018-0.045 |
| Homemaker or other | 0.856 | 0.659-1.114 | 0.862 | 0.661-1.123 | 0.861 | 0.624-1.187 |
| Lives with a spouse or partner | 1.106 | 0.951-1.286 | 1.110 | 0.954-1.290 | 1.021 | 0.839-1.242 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Has children aged 12 or younger | 1.042 | 0.850-1.277 | 1.036 | 0.845-1.270 | 1.033 | 0.810-1.317 |
| Number of people living in household | 1.037 | 0.985-1.091 | 1.026 | 0.494-2.132 | 1.040 | 0.982-1.101 |
| Foreign born | 1.483** | 1.145-1.921 | 1.142 | 0.742-1.758 | 1.448* | 1.079-1.943 |
| *Mother's Educational Attainment* | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| Completed high school | 1.231* | 1.044-1.452 | 1.246** | 1.057-1.469 | 1.384** | 1.133-1.690 |
| Attended college or more | 1.194 | 0.968-1.472 | 1.221 | 0.990-1.506 | 1.353** | 1.084-1.688 |
| *Father's Educational Attainment* | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| Completed high school | 1.058 | 0.924-1.211 | 1.067 | 0.932-1.222 | 1.039 | 0.888-1.215 |
| Attended college or more | 1.361** | 1.130-1.639 | 1.385** | 1.150-1.669 | 1.391** | 1.130-1.712 |
| Has vision/hearing problems or diagnosed learning disability | 0.583*** | 0.493-0.690 | 0.576*** | 0.486-0.683 | 0.578*** | 0.481-0.693 |
| Age | | | | | | |
| 18-24 (ref) | ----- | ----- | ----- | ----- | ----- | ----- |
| 25-34 | 0.635** | 0.494-0.816 | 0.634** | 0.493-0.815 | 0.670* | 0.487-0.920 |
| 35-44 | 0.492*** | 0.377-0.642 | 0.491*** | 0.377-0.639 | 0.510*** | 0.371-0.702 |
| 45-54 | 0.339*** | 0.339-0.642 | 0.462*** | 0.336-0.636 | 0.498*** | 0.346-0.716 |
| 55 or older | 0.365*** | 0.365-0.622 | 0.469*** | 0.358-0.613 | 0.564** | 0.411-0.775 |
| Has health insurance | 1.054* | 1.054-1.482 | 1.270** | 1.071-1.506 | 1.331** | 1.088-1.629 |
| English proficiency level (lower score=better) | 0.924*** | 0.887-0.963 | 0.919*** | 0.881-0.957 | 0.919** | 0.869-0.973 |

*Note*: The literacy, numeracy, and PS-TRE estimates represent changes of 10-point increments. Calculated using plausible values with PIAACTOOLS (piaacreg) in Stata.

*p<.05; **p<.01; ***p<.001; weighted; two-tailed tests

N=4,647 (literacy and numeracy); N=3,942 (PS-TRE)

**Table 4. Odds Ratios and 95% Confidence Intervals from Ordinal Logistic Regression Models for Participation in Post-initial Learning Activities Regressed on Self-Rated Health**

| | Model 1 | | Model 2[a] | |
|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI |
| *Post-Initial Learning Activities* | | | | |
| Distance education | 1.084 | 0.934-1.259 | 0.988 | 0.849-1.151 |
| Workplace training | 1.373*** | 1.221-1.543 | 1.010 | 0.892-1.144 |
| Seminars/workshops | 1.498*** | 1.321-1.700 | 1.116 | 0.975-1.277 |
| Course or private lessons | 1.817*** | 1.504-2.195 | 1.586*** | 1.306-1.925 |
| Participated in formal education | 1.464*** | 1.282-1.671 | 1.092 | 0.927-1.287 |
| AIC | 12571.80 | | 11577.36 | |

*Note*: ***p<.001; weighted; two-tailed tests

[a] Model 2 controls for race/ethnicity, formal educational attainment, employment status, living with spouse or partner, presence of children under 12 in household, number of people in household, U.S. vs. foreign born, mother's and father's educational attainment, vision, hearing, and learning disabilities, age, insurance status, and English proficiency. Coefficients for control variables are not shown in order to conserve space but are available from the authors upon request. Coefficients for control variables from this analysis are similar to those shown in Table 3.

N=4,473

**APPENDIX A. Log Odds and Standard Errors for Models Assessing Interactions between Race/Ethnicity and Literacy, Numeracy, and PS-TRE Skills on Self-Rated Health**

| **LITERACY** | **Model 1c** | | | **Model 1d** | | | **Model 1e** | | | **Model 1f** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Literacy | 0.027 | (.011) | * | 0.025 | (.011) | * | 0.026 | (.012) | * | 0.024 | (.011) | * |
| *Race/Ethnicity* | | | | | | | | | | | | |
| Non-Hispanic white (ref) | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Non-Hispanic black | 0.754 | (.737) | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Hispanic | ----- | ----- | | -0.311 | (.724) | | ----- | ----- | | ----- | ----- | |
| Asian | ----- | ----- | | ----- | ----- | | 0.499 | (.861) | | ----- | ----- | |
| other Race | ----- | ----- | | ----- | ----- | | ----- | ----- | | 0.428 | (1.529) | |
| *Interactions* | | | | | | | | | | | | |
| Literacy * non-Hispanic black | -0.037 | (.028) | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Literacy * Hispanic | ----- | ----- | | 0.016 | (.028) | | ----- | ----- | | ----- | ----- | |
| Literacy * Asian/Pacific Islander | ----- | ----- | | ----- | ----- | | -0.029 | (.028) | | ----- | ----- | |
| Literacy * other race | ----- | ----- | | ----- | ----- | | ----- | ----- | | -0.019 | (.054) | |
| **NUMERACY** | **Model 2c** | | | **Model 2d** | | | **Model 2e** | | | **Model 2f** | | |
| Numeracy | 0.007 | (.009) | | 0.007 | (.009) | | 0.008 | (.009) | | 0.006 | (.001) | |
| *Race/Ethnicity* | | | | | | | | | | | | |
| Non-Hispanic white (ref) | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Non-Hispanic black | 0.419 | (.634) | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Hispanic | ----- | ----- | | -0.427 | (.575) | | ----- | ----- | | ----- | ----- | |
| Asian | ----- | ----- | | ----- | ----- | | 0.302 | (.692) | | ----- | ----- | |
| Other race | ----- | ----- | | ----- | ----- | | ----- | ----- | | -0.229 | (1.245) | |
| *Interactions* | | | | | | | | | | | | |
| Numeracy * non-Hispanic black | -0.028 | (.027) | | ----- | ----- | | ----- | ----- | | ----- | ----- | |
| Numeracy * Hispanic | ----- | ----- | | 0.021 | (.023) | | ----- | ----- | | ----- | ----- | |
| Numeracy * Asian/Pacific Islander | ----- | ----- | | ----- | ----- | | -0.240 | (.023) | | ----- | ----- | |
| Numeracy * other Race | ----- | ----- | | ----- | ----- | | ----- | ----- | | 0.005 | (.047) | |

| PS-TRE | Model 3c | | Model 3d | | Model 3e | | Model 3f | |
|---|---|---|---|---|---|---|---|---|
| PS-TRE | 0.005 | (.012) | 0.006 | (.012) | 0.007 | (.013) | 0.005 | (.012) |
| *Race/Ethnicity* | | | | | | | | |
| Non-Hispanic white (ref) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Non-Hispanic black | 0.768 | (.852) | ----- | ----- | ----- | ----- | ----- | ----- |
| Hispanic | ----- | ----- | 0.079 | (.983) | ----- | ----- | ----- | ----- |
| Asian/Pacific Islander | ----- | ----- | ----- | ----- | -0.362 | (1.449) | ----- | ----- |
| Other race | ----- | ----- | ----- | ----- | ----- | ----- | 0.197 | (1.433) |
| *Interactions* | | | | | | | | |
| PS-TRE * non-Hispanic black | -0.040 | (.032) | ----- | ----- | ----- | ----- | ----- | ----- |
| PS-TRE * Hispanic | ----- | ----- | 0.000 | (.036) | ----- | ----- | ----- | ----- |
| PS-TRE * Asian | ----- | ----- | ----- | ----- | 0.000 | (.046) | ----- | ----- |
| PS-TRE * other Race | ----- | ----- | ----- | ----- | ----- | ----- | -0.012 | (.052) |

*Note*: Calculated using plausible values with PIAACTOOLS (piaacreg) in Stata
Log odds are shown instead of odds ratios because odds ratios from main effects models cannot be interpreted in isolation from interaction effects
All models control for race/ethnicity, formal educational attainment, employment status, living with spouse or partner, presence of children under 12 in household, number of people in household, U.S. vs. foreign born, mother's and father's educational attainment, vision, hearing, and learning disabilities, age, insurance status, and English proficiency. Coefficients from control variables are largely unchanged from main effects models and are not shown to conserve space

*p<.05 weighted; two-tailed tests

N=4,647 (literacy and numeracy); N=3,942 (PS-TRE)

**APPENDIX B. Log Odds and Standard Errors for Models Assessing Interactions between Formal Educational Attainment and Literacy, Numeracy, and PS-TRE Skills on Self-Rated Health**

| **LITERACY** | **Model 1g** | | **Model 1h** | | **Model 1i** | | **Model 1j** | | **Model 1k** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Literacy | 0.029 | (.026) | 0.042 | (.029) | 0.053 | (.029) | 0.020 | (.030) | 0.030 | (.030) |
| *Educational Attainment* | | | | | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| High school graduate | 0.111 | (.657) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Certificate from trade school or other | ----- | ----- | 0.709 | (.960) | ----- | ----- | ----- | ----- | ----- | ----- |
| Associate degree | ----- | ----- | ----- | ----- | 1.684 | (1.044) | ----- | ----- | ----- | ----- |
| Bachelor's degree | ----- | ----- | ----- | ----- | ----- | ----- | 0.248 | (.885) | ----- | ----- |
| Master's degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0.375 | (1.206) |
| *Interactions* | | | | | | | | | | |
| Literacy * High School Graduate | -0.001 | (.025) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Literacy * Certificate from trade school/other | ----- | ----- | -0.017 | (.036) | ----- | ----- | ----- | ----- | ----- | ----- |
| Literacy * Associate Degree | ----- | ----- | ----- | ----- | -0.045 | (.037) | ----- | ----- | ----- | ----- |
| Literacy * Bachelor's Degree | ----- | ----- | ----- | ----- | ----- | ----- | 0.015 | (.032) | ----- | ----- |
| Literacy * Master's Degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0.018 | (.042) |
| **NUMERACY** | **Model 2g** | | **Model 2h** | | **Model 2i** | | **Model 2j** | | **Model 2k** | |
| Numeracy | 0.021 | (.023) | 0.037 | (.024) | 0.047 | (.025) | 0.019 | (.025) | 0.030 | (.024) |
| *Educational Attainment* | | | | | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| High school graduate | 0.349 | (.529) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Certificate from trade school or other | ----- | ----- | 0.959 | (.764) | ----- | ----- | ----- | ----- | ----- | ----- |
| Associate degree | ----- | ----- | ----- | ----- | 0.031 | (1.777) | ----- | ----- | ----- | ----- |
| Bachelor's degree | ----- | ----- | ----- | ----- | ----- | ----- | 0.719 | (.714) | ----- | ----- |
| Master's degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 1.010 | (.895) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Interactions* | | | | | | | | | | | |
| Numeracy * High School Graduate | -0.011 | (.022) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | |
| Numeracy * Certificate from trade school/other | ----- | ----- | -0.028 | (.030) | ----- | ----- | ----- | ----- | ----- | ----- | |
| Numeracy * Associate Degree | ----- | ----- | ----- | ----- | -0.052 | (.031) | ----- | ----- | ----- | ----- | |
| Numeracy * Bachelor's Degree | ----- | ----- | ----- | ----- | ----- | ----- | -0.001 | (.028) | ----- | ----- | |
| Numeracy * Master's Degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | -0.004 | (.032) | |
| **PS-TRE** | **Model 3g** | | **Model 3h** | | **Model 3i** | | | **Model 3j** | | **Model 3k** | |
| PS-TRE | -0.045 | (.027) | -0.030 | (.033) | 0.027 | (.012) | * | -0.038 | (.034) | -0.050 | (.035) |
| *Educational Attainment* | | | | | | | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | |
| High school graduate | -1.189 | (.780) | | | | | | | | | |
| Certificate from trade school or other | ----- | ----- | -0.125 | (1.245) | ----- | ----- | ----- | ----- | ----- | ----- | |
| Associate degree | ----- | ----- | ----- | ----- | 1.136 | (.795) | ----- | ----- | ----- | ----- | |
| Bachelor's degree | ----- | ----- | ----- | ----- | ----- | ----- | -0.873 | (1.026) | ----- | ----- | |
| Master's degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | -1.438 | (1.234) | |
| *Interactions* | | | | | | | | | | | |
| PS-TRE * High School Graduate | 0.048 | (.028) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | |
| PS-TRE * Certificate from trade school/other | ----- | ----- | 0.018 | (.043) | ----- | ----- | ----- | ----- | ----- | ----- | |
| PS-TRE * Associate Degree | ----- | ----- | ----- | ----- | -0.042 | (.027) | ----- | ----- | ----- | ----- | |
| PS-TRE * Bachelor's Degree | ----- | ----- | ----- | ----- | ----- | ----- | 0.064 | (.037) | ----- | ----- | |
| PS-TRE * Master's Degree or higher | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0.095 | (.044) | * |

*Note*: Calculated using plausible values with PIAACTOOLS (piaacreg) in Stata
Log odds are shown instead of odds ratios because odds ratios from main effects models cannot be interpreted in isolation from interaction effects
All models control for all variables in Models 1b, 2b, and 3b - coefficients from control variables are largely unchanged from main effects models and are not shown to conserve space

*p<.05weighted; two-tailed tests

N=4,647 (literacy and numeracy); N=3,942 (PS-TRE)

**APPENDIX C. Log Odds and Standard Errors from Adjusted Ordinal Logistic Regression Models for Interaction Effects between Race/Ethnicity and Participation in Post-Initial Learning on Self-Rated Health**

| | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|
| *Race/Ethnicity* | | | | | |
| Non-Hispanic white (ref) | ----- | ----- | ----- | ----- | ----- |
| Non-Hispanic black | -0.286 (.100)** | -0.376 (.121)** | -0.198 (.110) | -0.326 (.093)*** | -0.285 (.106)** |
| Hispanic | -0.129 (.110) | -0.015 (.122) | -0.068 (.115) | -0.111 (.107) | -0.093 (.117) |
| Asian/Pacific Islander | -0.5233 (.152)*** | -0.488 (.175)** | -0.312 (.169) | -0.458 (.152)** | -0.586 (.168)*** |
| Other race | -0.079 (.210) | -0.265 (.242) | 0.073 (.225) | -0.157 (.197) | -0.129 (.228) |
| *Post-Initial Learning Activities* | | | | | |
| Distance education | -0.064 (.092) | -0.013 (.078) | 0.000 (.078) | -0.012 (.078) | -0.007 (.078) |
| *Non-Hispanic black | -0.017 (.223) | ----- | ----- | ----- | ----- |
| *Hispanic | 0.304 (.238) | ----- | ----- | ----- | ----- |
| *Asian/Pacific Islander | 0.525 (.331) | ----- | ----- | ----- | ----- |
| *Other race | -0.150 (.467) | ----- | ----- | ----- | ----- |
| Workplace training | 0.009 (.064) | -0.003 (.074) | 0.111 (.064) | 0.008 (.064) | 0.014 (.064) |
| *Non-Hispanic black | ----- | 0.181 (.178) | ----- | ----- | ----- |
| *Hispanic | ----- | -0.188 (.175) | ----- | ----- | ----- |
| *Asian/Pacific Islander | ----- | 0.168 (.254) | ----- | ----- | ----- |
| *Other race | ----- | 0.354 (.384) | ----- | ----- | ----- |
| Seminars/workshops | 0.107 (.069) | 0.106 (.069) | 0.172 (.080)* | 0.105 (.069) | 0.101 (.069) |
| *Non-Hispanic black | ----- | ----- | -0.280 (.189) | ----- | ----- |
| *Hispanic | ----- | ----- | -0.023 (.198) | ----- | ----- |
| *Asian/Pacific Islander | ----- | ----- | -0.319 (.260) | ----- | ----- |
| *Other race | ----- | ----- | -0.643 (.405) | ----- | ----- |
| Course or private lessons | 0.459 (.099)*** | 0.454 (.099)*** | 0.460 (.099)*** | 0.342 (.118)** | 0.459 (.099)*** |
| *Non-Hispanic black | ----- | ----- | ----- | 0.493 (.366) | ----- |
| *Hispanic | ----- | ----- | ----- | 0.424 (.331) | ----- |
| *Asian/Pacific Islander | ----- | ----- | ----- | 0.233 (.343) | ----- |
| *Other race | ----- | ----- | ----- | 0.390 (.638) | ----- |

| | | | | | |
|---|---|---|---|---|---|
| Participation in Formal Education | 0.081 (.084) | 0.084 (.084) | 0.080 (.084) | 0.082 (.084) | 0.045 (.101) |
| *Non-Hispanic black | ----- | ----- | ----- | ----- | -0.014 (.202) |
| *Hispanic | ----- | ----- | ----- | ----- | 0.044 (.202) |
| *Asian/Pacific Islander | ----- | ----- | ----- | ----- | 0.482 (.272) |
| *Other race | ----- | ----- | ----- | ----- | 0.063 (.403) |

*Note*: Log odds are shown instead of odds ratios because odds ratios from main effects models cannot be interpreted in isolation from interaction effects
All models control for race/ethnicity, formal educational attainment, employment status, living with spouse or partner, presence of children under 12 in household, number of people in household, U.S. vs. foreign born, mother's and father's educational attainment, vision, hearing, and learning disabilities, age, insurance status, and English proficiency.

*p<.05; **p<.01; ***p<.001; weighted; two-tailed tests

N=4,473

**Appendix D. Log Odds and Standard Errors from Adjusted Ordinal Logistic Regression Models for Interaction Effects between Formal Educational Attainment and Participation in Post-Initial Learning on Self-Rated Health**

| | Model 8 | Model 9 | Model 10 | Model 11 | Model 12 |
|---|---|---|---|---|---|
| *Post-Initial Learning Activities* | | | | | |
| Distance education | -0.057 (.364) | -0.011 (.078) | -0.014 (.078) | -0.014 (.078) | -0.008 (.078) |
| *High school graduate | -0.029 (.384) | ----- | ----- | ----- | ----- |
| *Certificate/trade | -0.252 (.432) | ----- | ----- | ----- | ----- |
| *Associate degree | 0.388 (.417) | ----- | ----- | ----- | ----- |
| *Bachelor's degree | 0.166 (.397) | ----- | ----- | ----- | ----- |
| *Master's degree or more | -0.047 (.406) | ----- | ----- | ----- | ----- |
| Workplace training | 0.016 (.064) | -0.123 (.226) | 0.011 (.064) | 0.009 (.064) | 0.008 (.064) |
| *High school graduate | ----- | 0.097 (.241) | ----- | ----- | ----- |
| *Certificate/trade | ----- | 0.344 (.291) | ----- | ----- | ----- |
| *Associate degree | ----- | 0.231 (.287) | ----- | ----- | ----- |
| *Bachelor's degree | ----- | 0.106 (.261) | ----- | ----- | ----- |
| *Master's degree or more | ----- | 0.133 (.280) | ----- | ----- | ----- |
| Seminars/workshops | 0.101 (.069) | 0.104 (.069) | 0.408 (.358) | 0.107 (.069) | 0.109 (.069) |
| *High school graduate | ----- | ----- | -0.347 (.371) | ----- | ----- |
| *Certificate/trade | ----- | ----- | -0.293 (.409) | ----- | ----- |
| *Associate degree | ----- | ----- | -0.349 (.404) | ----- | ----- |
| *Bachelor's degree | ----- | ----- | -0.129 (.381) | ----- | ----- |
| *Master's degree or more | ----- | ----- | -0.490 (.397) | ----- | ----- |
| Course or private lessons | 0.455 (.099)*** | 0.458 (.099)*** | 0.464 (.099)*** | 0.967 (.511) | 0.455 (.099)*** |
| *High school graduate | ----- | ----- | ----- | -0.674 (.537) | ----- |
| *Certificate/trade | ----- | ----- | ----- | -0.506 (.619) | ----- |
| *Associate degree | ----- | ----- | ----- | 0.018 (.604) | ----- |
| *Bachelor's degree | ----- | ----- | ----- | -0.520 (.547) | ----- |
| *Master's degree or more | ----- | ----- | ----- | -0.551 (.561) | ----- |
| Participated in formal education | 0.075 (.084) | 0.081 (.084) | 0.078 (.084) | 0.071 (.084) | 0.579 (.286)* |
| *High school graduate | ----- | ----- | ----- | ----- | -0.642 (.301)* |

| | | | | | |
|---|---|---|---|---|---|
| *Certificate/trade | ----- | ----- | ----- | ----- | -0.660 (.357) |
| *Associate degree | ----- | ----- | ----- | ----- | -0.337 (.339) |
| *Bachelor's degree | ----- | ----- | ----- | ----- | -0.424 (.328) |
| *Master's degree or more | ----- | ----- | ----- | ----- | -0.450 (.368) |
| *Formal Educational Attainment* | | | | | |
| Did not complete high school (ref) | ----- | ----- | ----- | ----- | ----- |
| High school graduate | 0.166 (.113) | 0.142 (.123) | 0.187 (.114) | 0.187 (.112) | 0.245 (.117)* |
| Certificate from trade school or other | 0.226 (.149) | 0.047 (.168) | 0.188 (.153) | 0.190 (.143) | 0.269 (.153) |
| Associate degree | 0.273 (.152) | 0.282 (.172) | 0.397 (.155)* | 0.335 (.141)* | 0.364 (.160)* |
| Bachelor's degree | 0.699 (.139)*** | 0.712 (.156)*** | 0.671 (.145)*** | 0.747 (.136)*** | 0.771 (.142)*** |
| Master's degree or more | 0.906 (.158)*** | 0.850 (.178)*** | 1.025 (.183)*** | 0.903 (.150)*** | 0.932 (.154)*** |

*Note*: Log odds are shown instead of odds ratios because odds ratios from main effects models cannot be interpreted in isolation from interaction effects
All models control for race/ethnicity, formal educational attainment, employment status, living with spouse or partner, presence of children under 12 in household, number of people in household, U.S. vs. foreign born, mother's and father's educational attainment, vision, hearing, and learning disabilities, age, insurance status, and English proficiency.

*p<.05; **p<.01; ***p<.001; weighted; two-tailed tests
N=4,473