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Empirical study

Using an opportunity-propensity framework to estimate individual-, classroom-, and school-level predictors of middle school science achievement

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ABSTRACT

Using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (N = 4447), this analysis employs an opportunity-propensity (O-P) framework (Byrnes, 2003; Byrnes & Miller, 2007; Byrnes & Wasik 2009) to examine the influence of multiple student, teacher, classroom, and school factors on eighth-grade science achievement. Saçkes, Trundle, Bell, and O'Connell (2011) fit an O-P structural equation model (SEM) to the same database to explain science achievement growth from Kindergarten to third grade. We extend this work by fitting an O-P SEM to this database to predict science achievement growth from fifth to eighth grade. This middle school model includes an opportunity variable – science curriculum track placement – that operates only in middle and high school. This variable and the school's poverty rate are significant predictors of several opportunity factors. We replicate previous findings that propensity factors are the strongest determinants of science achievement, notably prior achievement. However, we find more opportunity factors than previous studies that are also significant. Other things being equal, having a state-certified teacher is the second strongest predictor of achievement within the model. Placement in a science honors course and being enrolled in a low income school are also linked to small but significant impacts on science achievement.

1. Introduction

Reports such as the National Academy of Science's (2007) *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* mark a renewed concern that U.S. students are not being prepared for successful careers in STEM (Science, Technology, Engineering, and Mathematics) subjects at a rate that is congruent with the country's needs. Issuing warnings about the United States' declining innovative edge and the economic pressures of globalization and rapid technological advances, many advocates are seeking to reform current STEM education at the K-12 level. Although the President's Council of Advisors on Science and Technology (2012) cautioned that we need a 33% increase in the number of bachelor's degrees awarded annually, completion rates for undergraduate STEM majors have barely increased since 2004 (currently 34%, up from 33%) (National Student Clearinghouse Research Center, 2014). Female, Black, and Hispanic Americans are particularly underrepresented in certain STEM fields in relation to their proportion of the total U.S. population (National Science Foundation, 2014).

Middle school is a crucial time for students to learn science and begin to formulate their attitudes toward it as a potential lifetime activity. Indeed, measures of science achievement in middle school are strongly related to the later achievement of a career in science (Mau, 2003). By eighth grade, female students begin showing disproportionate signs of disinterest in science careers and non-Asian racial minorities are less likely than Whites to enroll in more academically demanding science classes (Catsambis, 1995). Performance in middle school science classes is predictive of high school course choices, which are important precursors of later STEM careers (Burkam & Lee, 2003; Reynolds, 1991; Schneider, Swanson, & Riegle-Crumb, 1998; Schneider, 2003; Singh, Granville, & Dika, 2002; Tyson, Lee, Borman, & Hanson, 2007).

In this paper, we investigate predictors of eighth-grade science achievement using data from the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K). Drawing upon an opportunity-propensity (O-P) framework (Byrnes, 2003; Byrnes & Miller, 2007) to analyze a comprehensive list of student, teacher, classroom, and school factors, we ask which predictors concerning opportunities to learn (e.g. classroom, teacher, and school variables) and propensity to learn (e.g. student's motivation and science knowledge) within or leading up to the students' eighth-grade science learning environments

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are associated with greater eighth-grade science achievement. A particular strength of our study is the inclusion of classroom, teacher, and school opportunity factors that have not been fully included in previous empirical work within this framework.

In particular, and unique within this literature, we examine the determinants and consequences of middle school curriculum track placement (honors, standard, or remedial science). Track placement is a key middle school opportunity variable that could not be included in prior studies that focused on elementary school. We find that this variable is strongly related to other middle school science learning opportunity variables as well as to science achievement. Our analyses suggest that even though factors relating to family background and propensity to learn are the strongest predictors of eighth-grade science achievement, school-wide demographics, science instructional track placement, and teacher certification level are also significantly related to student outcomes when tested within a comprehensive model of opportunities and propensities to learn.

2. Conceptual framework

As noted by Byrnes and Miller (2007), much of the research on predictors of science achievement has focused on student-level variables. Most studies have not included the wide array of contextual variables necessary to disentangle the relative importance of individual, classroom, and school factors on science achievement. Combining both student-level and contextual predictors in the same analysis is the goal of this paper. As for a conceptual framework within which to undertake these analyses, we have identified the opportunity-propensity framework (Byrnes, 2003; Byrnes & Miller, 2007) as an appropriately inclusive structure that has been employed in a preponderance of recent science achievement studies.

2.1. Opportunity-propensity framework

This framework expands on the productivity model (Walberg, 1981) by hypothesizing that academic achievement is most strongly impacted by three categories of factors—opportunity, propensity, and antecedent or distal factors—that shape students' performance in learning environments. It is hypothesized that students will learn more when two conditions are met. They must be given quality opportunities to increase their skills (opportunity factors) and they must be able and motivated to make use of these opportunities (propensity factors). While antecedent factors (such as family income at an earlier age) are considered static and preceding any exposure to learning opportunities, they can explain why some children may benefit more than their peers from the learning opportunities they experience. Antecedent factors lead to propensities and opportunities, which lead to student achievement (Byrnes & Miller, 2007; Byrnes & Wasik, 2009).

Although this framework is focused on academic achievement within learning environments, it is related to ecological models of human development (e.g. Bronfenbrenner, 1977) that emphasize the reciprocal relationship between characteristics of a developing human being and the contexts (ecological niches) within which the individual develops. Development within an environment is not solely reactive. Instead, it involves interactions among the individual, their perception of the environment, their resulting behaviors, the outcomes when these behaviors are enacted within this environment, and feedback to the individual from experiencing these environments, including effects on the individual's future environmental locations.

Within this framework, opportunity to learn factors include exposure to academic content (e.g. amount of homework assigned, ability level of class), the characteristics and quality of teaching (e.g. the teacher's experience, certification status, and content knowledge), and the quality of classroom equipment and resources. In contrast, propensity factors center on students' ability and desire to learn the material presented to them. The framework's authors posit that even when students are offered opportunities to learn, their propensity to take advantage of these opportunities will vary across individuals. Common examples of propensity factors include prior subject knowledge and academic motivation. One important feature of the O-P framework is that it is intended to focus on student learning at specific time periods. The theory assumes that as a child develops, antecedent opportunity and propensity factors affect skills and motivation, which in turn affect the student's propensity to learn at a later time period.

Byrnes and Miller (2007) used an O-P framework to study science achievement with data from the National Education Longitudinal Study of 1988 (NELS:88). They found that specific antecedent, opportunity, and propensity factors explained 58–61% of the variation in predicting tenth- and twelfth-grade standardized science test scores. The strongest predictors of tenth-grade science achievement were antecedent (e.g., earlier socioeconomic status, parental expectations) and propensity (prior science achievement, high school graduation efficacy, and plans to attend college) factors. However, their implementation of the O-P framework employed a set of opportunity factors limited to science course taking, two teacher-reported measures of the student's responsiveness and academic emphasis, and student reports of teacher quality. Thus, Byrnes and Miller omitted school level factors and their measure of teacher quality is entirely based on student questionnaire responses. It may be that their failure to find meaningful effects of opportunity factors was due to the limited number of these factors included in their analyses.

Saçkes, Trundle, Bell, and O'Connell (2011) advanced the O-P literature by presenting a more complex model of opportunity and propensity factors present in the experiences of students in Kindergarten through third grade. Using data from the Early Childhood Longitudinal Study: Kindergarten Cohort (ECLS-K), they incorporated the idea that certain opportunity factors (e.g. learning related materials) are predictive of instruction patterns (e.g. instructional activities using those materials) within children's Kindergarten learning environments. Saçkes, Trundle, Bell, and O'Connell (2011) used a Structural Equation Model (SEM) to analyze the unique impact of Kindergarten opportunity and propensity factors on immediate achievement in Kindergarten, and then whether any impact remained on third-grade science achievement. They found that antecedent (gender and family socioeconomic status) and propensity (pre-Kindergarten achievement and current motivation) factors were significant predictors of achievement in both Kindergarten and third grade, and that the availability of Kindergarten science learning opportunities were not good predictors of students' immediate or later science achievement.

These analyses, along with a follow-up study by Saçkes, Trundle, and Bell (2013), are the only ones that use the O-P framework to study science achievement. However, multiple other studies use the O-P framework to analyze impacts on math and reading achievement. While not directly related, these studies provide helpful guidance on the types of variables and datasets used within analyses that incorporate this framework. Table 1 identifies all of the peer-reviewed studies that have utilized the O-P framework to study achievement in science, math, or reading within elementary and secondary school. The table also breaks down the sample, outcome(s) of interest, variables included in the model, and notable findings from each study.

Byrnes and Miller-Cotto (2016) present the most developed version of the O-P framework to date, using data from the ECLS-K to analyze patterns of growth in math and reading achievement for third and eighth graders. This analysis takes advantage of the rich instructional variables present in the ECLS-K as measures of learning opportunities, and incorporates internalizing behaviors as a propensity variable that measures anxiety and likelihood to perform well in stressful academic situations. Since this analysis is focused on growth in test scores, rather than variables that predict achievement, Byrnes and Miller-Coto use hierarchical linear growth models (HLM). In this model specification, prior achievement is not used as a predictor, since test score *gains* are treated as the outcome. With prior achievement omitted from the