II. Literature Review

This chapter summarizes the relevant literature on the relationship between nutrition and learning and draws implications from the literature for the Design and Feasibility Study of the Impact of the School Breakfast Program on Learning. The literature suggests a relationship between eating breakfast, improved dietary status, and enhanced cognitive performance. Although the literature is suggestive of positive educational benefits, no study has been able to definitively conclude that eating a *school breakfast* results in improvements in long-term or short-term cognition or learning or in academic achievement. The inconclusive findings reflect limitations of the studies, such as the use of unreliable measures of breakfast participation and academic achievement, or the use of nonexperimental designs that do not adequately control for selection effects.

The first section of the chapter reviews three areas of previous research that are useful for the SBP Design Study: (1) the link between nutrition and child development; (2) the contribution of breakfast to children's behavioral and cognitive development; and (3) the relationship between SBP participation and children's dietary status, academic achievement, and other school-related outcomes. Another review of the literature on breakfast and learning provides summaries of key references (Briefel et al., 1999). The second section presents a conceptual model to describe how SBP participation would be expected to influence students' learning. In addition, it draws implications from both the previous research and the conceptual model for use in developing alternative designs to estimate the relationship between the SBP and learning.

A. The Literature

1. The link between nutrition and cognitive development

A large body of research documents the effects of inadequate nutrient intakes on children in developing countries, and a more limited group of studies focuses on the effects of dietary inadequacies on residents of developed countries, such as the United States. The literature includes experimental studies of the effects of nutritional deprivation on the cognitive functioning of animals, correlational studies linking hunger or undernutrition and the developmental outcomes of children, and experimental studies of the effects of nutritional supplementation programs on children. These studies provide solid evidence of a link between nutrition and cognitive development, although the extent to which undernutrition must be severe (rather than moderate or mild) to substantially affect development is unclear.

Animal studies provided some evidence of a link between nutritional deprivation and cognitive performance measures (Morley and Lucas, 1997). Similarly, a study of children in developing countries showed that permanent structural damage to the human brain can be attributed to the extremely detrimental effects of severe undernutrition in early childhood, a period in which the brain develops rapidly (Brown and Pollitt, 1996). Although this level of undernutrition is extremely rare in the United States (Pollitt, 1988), important aspects of cognitive development may occur after periods of rapid brain growth early in life, so that negative effects on cognitive development potentially could result even from moderate or mild degrees of undernutrition. Both of these factors point to the potential importance of nutrition intervention throughout childhood and suggest that programs like the SBP could play a major role in the cognitive development of some children.

Much of the research on the relationship between nutrition and human development involves analysis of the effects of nutritional supplementation on cognitive or behavioral development (Gorman, 1995). Examining this research for evidence of the links between nutrition (or nutrition supplementation) and cognitive development helps us understand the degree to which an intervention such as the SBP has promise for promoting children's cognitive development. The remainder of this section discusses this area of research, focusing in particular on three different strands: (1) the effects of protein-energy supplementation interventions, (2) the effects of iron-repletion therapy on iron-anemic children, and (3) the relationship between hunger and cognitive/psychosocial outcomes. Throughout this review of the nutrition-cognitive development literature, it is important to distinguish between studies conducted in developed countries, such as the United States, and those conducted in developing nations, in which severe malnutrition is much more common.

a. The effects of protein-energy supplementation on cognitive and behavioral development

Most of these intervention studies were conducted in populations of mildly to moderately malnourished children in developing countries (for example, Colombia, Guatemala, Indonesia, Jamaica, and Taiwan). Gorman (1995) reviewed intervention studies that examined the effects of supplements provided during critical early periods of brain development (gestation and infancy); the evidence from these studies suggests that protein-energy supplementation is associated with improved motor and/or cognitive development. Two studies of this type examined the role of individual socioeconomic differences on the strength of the observed impacts; they yielded conflicting results (Gorman, 1995). In a nutrition supplementation trial in Guatemala, children living in families with low socioeconomic status (SES) were more likely than children in higher SES families to respond to protein-energy supplementation (Freeman et al., 1980). Waber et al. (1981) obtained the opposite result in Colombia, where children from families with better resources derived relatively greater benefit from supplementation. Rush et al. (1980) conducted a supplementation study in New York City similar to those two studies.

The researchers found that, with the exception of a visual habituation task, the supplementation of pregnant women had no effect on any of the behavioral measures examined in the women's children. Some researchers attribute this dearth of significant effects to the lack of evidence that the women who participated in the trial were nutritionally at risk (Pollitt, 1988). Unfortunately, few other studies of the effects of protein-energy supplementation during early periods of brain development have been conducted in developed nations, precluding investigators from definitively stating that such supplementation interventions lead to improved motor/cognitive development only in developing countries in which severe undernutrition exists.

Studies on the effects of protein-energy supplementation generally have been well designed; they have used experimental or quasi-experimental methodologies that provide internally valid estimates. However, for three reasons, the applicability of these intervention studies to the current SBP design study is limited: (1) they were generally based on small sample sizes (well under 500 subjects in most cases); (2) they involved the provision of a single food or nutrient supplement, rather than a wider range of foods such as are provided in a more general nutrition program like the SBP; and (3) they focused largely on undernourished children in developing countries.

b. The effects of iron-repletion therapy and iron deficiencies on cognitive and behavioral development

A large body of literature exists on the effects of iron-repletion therapy on cognitive and behavioral outcomes in iron-deficient and/or anemic children. In a review of the literature on the developmental impact of nutrition, Pollitt (1988) stated that the majority of studies conducted in developing countries and in the United States during the 1980s provide evidence that iron-deficiency anemia negatively affects cognitive functioning. Furthermore, experimental studies conducted in developed countries have found that, when compared with anemic children given a placebo, anemic children treated with iron-repletion therapy exhibit statistically significant improvements in motor and mental development scores (Pollitt, 1988).

An Indonesian study based on a clinical trial research design provided similar results, but the effects of the iron-repletion therapy generally were smaller than those in most U.S. studies. In particular, the motor and mental development scores of iron-treated anemic children remained significantly below those of iron-replete (nonanemic) children (Pollitt, 1988). The apparent inability of iron treatment to increase the motor development of iron-deficient children to the level of their non-anemic peers, despite its success in normalizing hemoglobin levels, also was found in a study conducted in Costa Rica (Lozoff et al., 1991). Pollitt (1988) suggested that differences between the impact of iron-repletion therapy in developed and developing countries may be attributable to other nutritional deficiencies in children from poor countries that may limit the ability of iron interventions to produce positive effects.

In a recent review of studies of the effect of iron deficiency on cognitive development, Grantham-McGregor and Ani (2001) note that most are non-experimental, longitudinal studies and conclude that making causal inferences about the iron deficiency-cognitive development relationship from longitudinal studies is difficult due to the possible confounding effect of poor socioeconomic status and environmental factors. They also report that studies conducted on children older than two years of age are somewhat more conclusive (in finding that iron deficiency interferes with cognitive development) than those for younger children, though they indicate that there is still a need for more rigorous, randomized controlled trials, particularly amongst children younger than two years of age (Grantham-McGregor and Ani, 2001).

One longitudinal, observational study conducted in the U.S. looked at a sample of over 3,700 10 year-old Dade County students who had participated in the WIC program before the age of 5 (Hurtado et al., 1999). The authors found that after controlling for confounding factors (birthweight, maternal education, sex, race/ethnicity, age at time of study, and age at entry to WIC), a child's risk of placement in special education classes increased by 1.28 for each decrement of iron level (Hb) at the time of entry to WIC. The study also found that students who were anemic at the time of entry to WIC were more likely to be disabled, black, low birthweight, and have mothers with less than a high school education. The findings from the Hurtado et al. (1999) study reinforce the fact that there is a connection between socioeconomic status and anemia.

Although the findings from these well-designed studies of the impact of iron repletion therapy on development are interesting, they have limited applicability to the current study for the same reasons that apply to the protein-energy supplementation studies. Similarly, many of the studies reviewed by Grantham-McGregor and Ani (2001) suffer from the same limitations, and also tend to have nonexperimental designs. However, the evidence of positive impacts of iron-repletion therapy suggests that school breakfasts containing levels of iron sufficient to help participating, iron-deficient children reach the RDA may help improve the cognitive and academic outcomes of those children.

c. The effects of hunger on cognition and psychosocial outcomes

Despite the high degree of interest in the impact of hunger on the cognitive and psychosocial outcomes of American children, few well-designed studies of this relationship have been conducted. One major research initiative examining this relationship is the Community Childhood Hunger Identification Project (CCHIP). CCHIP researchers have examined the link between hunger and cognitive and psychosocial outcomes in low-income children in Baltimore, Philadelphia, and Pittsburgh (Murphy et al., 1998a; and Kleinman et al., 1998).

Murphy et al. (1998a) found hunger status to be associated with children's behavior as measured by total scores on the Pediatric Symptom Checklist (PSC), which is used as a psychosocial screen, and on the Child Behavior Checklist, which identifies psychosocial symptoms. In particular, the authors found that, relative to other children, hungry children had significantly higher levels of hyperactivity and were more likely to be absent from school. Kleinman et al. (1998) reported that 25 percent of hungry children repeated a grade, compared with 19 percent of children at risk of hunger and with 12 percent of children who were not hungry. In addition, hungry children were three times more likely than at-risk children and seven times more likely than children who were not hungry to have PSC scores indicating dysfunction.

A number of limitations qualify the interpretation of the findings of these two correlational studies and are relevant for the SBP design study. First, the fact that parents were offered the choice to accept or decline an invitation for their children to participate in the studies raises the possibility of sample selection bias. Sample selection bias would make the findings less generalizable to the low-income population as a whole. Second, the studies' use of cross-sectional data limits the ability to prove a causal relationship between hunger and psychosocial outcomes. Third, parents provided subjective evaluations of the degree of hunger their children experienced. If other problems influenced the responses, the parents may have reported hunger in their children with error. Finally, the studies did not control for variables to account for other challenges low-income children face, such as violence or inadequate family support networks. The absence of control variables increases the likelihood that the differences between hungry and nonhungry children arose from factors other than hunger.

2. The link between breakfast and cognition

Another relevant group of studies comprises those that examined the effect of eating breakfast on cognitive outcomes. Although the literature includes studies of various groups (children, adolescents, young adults, the elderly), this review will discuss only the ones that focused on elementary school children, as this group is the one most relevant to the SBP design study. In general, research on the breakfast-cognition relationship in children shows that eating breakfast (as opposed to fasting) is associated with improvements in some short-term cognitive functions, specifically, cognitive tasks involving memory (Pollitt and Mathews, 1998).The effects tend to be largest in nutritionally at-risk children on mornings that follow an overnight fast.

The most common methodology used in these studies was a randomized, blinded, crossover design in which researchers took the following steps: (1) randomly assigned children to a treatment group that received breakfast on the morning of the experiment after an overnight fast, or to a control group that received no breakfast on that morning, (2) blindly administered cognitive tests to the children several hours after breakfast, (3) switched treatment and control groups on a subsequent day, and (4) readministered cognitive tests to the children.

The estimated effects of breakfast eating on the cognitive development of middle-class, well-nourished children are mixed, with some studies finding a positive relationship (in some or all children) and others finding no relationship. Pollitt et al. (1981) found that the effects of eating breakfast differed significantly with the children's intelligence quotient (IQ); breakfast was positively associated with performance on a test of visual matching (the Matching Familiar Figures Test, or MFFT) among children with IQs below the group median but was not associated with the performance of children with IQs above the median. However, when Pollitt et al. (1983) replicated this study using a different sample, they found that eating breakfast was positively related to visual matching (as measured by the MFFT) among all children, regardless of IQ.

In addition, Conners and Blouin (1982/1983) found that breakfast was positively related to performance on a test of visual stimuli (the Continuous Performance Task) and on an arithmetic test among well-nourished 9- to 11-year-old children. Conversely, Cromer et al. (1990) found no significant differences between children who ate breakfast and those who did not in any of the cognitive measures examined. The results of these studies, although not definitive, suggest that breakfast eating leads to improvements in certain tasks of short-term cognition among well-nourished, middle-class youngsters.

The literature on studies conducted in *developing* countries provides one unambiguous finding—the effects of breakfast on cognition are moderated to some extent by nutritional status. Simeon and Grantham-McGregor (1989), Chandler et al. (1995), and Pollitt et al. (1998) each conducted a randomized, crossover study examining the effect of eating breakfast on the cognitive functions of low SES children with varying nutritional statuses. The results of the studies consistently showed that, compared with skipping breakfast, eating breakfast positively influenced the performance of undernourished children on a variety of cognitive tests (for example, the MFFT, verbal fluency tests, the Stimulus Discrimination Test, and the Sternberg Memory Search Test). In each study, neither eating breakfast nor skipping breakfast influenced the cognitive test performance of adequately nourished children.

Lopez et al. (1993) examined the same relationships as were examined in those three studies, but among children in Chile and without using a crossover design. In contrast to the findings from the three studies, this study found that breakfast eating was not significantly associated with cognitive performance among either adequately nourished children or undernourished children. A number of factors may explain these results.

First, the researchers did not conduct the study in a hospital or metabolic ward, so they had no control over the timing or composition of dinner the night before the experiment. Second, almost one-fourth of the subjects had eaten breakfast at home on the day of the experiment and consequently were assigned to the breakfast condition. This course of action indicates that true randomization did not occur (Pollitt and Mathews, 1998). Finally, many of the children were using a computer for the first time, and it is possible that high levels of motivation caused them to perform better than they normally would have (Lopez et al., 1993).

One study analyzed the effect of breakfast timing on the cognitive functions of students (Vaisman et al. 1996). In that study, students who ate breakfast at school, which was served half an hour before testing, had significantly higher test scores than did both those who ate breakfast at home two hours before school and those who did not eat breakfast. Another study, by Michaud et al. (1991), focused on the effects of breakfast size on short-term memory and concentration. In that study, energy intake at breakfast was not related to children's scores on a concentration test.

3. The effects of the School Breakfast Program

As described below, research has examined the effects of SBP participation on students' dietary intake and found that the program improved the intake of a number of different nutrients, particularly by low-income children. In this section we review studies that have examined the effects of breakfast program participation on school-related outcomes, such as student achievement, cognition, attendance, and psychosocial measures. They generally found that participation is linked with higher attendance, though the findings of these students about the effects of participation on students' cognition and academic achievement were inconclusive. Moreover, the studies suffer from various methodological limitations, so the question of how breakfast program participation influences children's learning in school remains unanswered.

a. Program effects on breakfast eating and dietary intake

A key research issue is whether the availability of the SBP in a school increases the likelihood that students will eat breakfast.[1] Early evidence suggested that the availability of the SBP does not affect whether students eat breakfast (Devaney and Fraker, 1989; and Gleason, 1995).[2] To define breakfast eating, however, both studies used either students' self-reports of breakfast eating or the intake of a relatively small minimum amount of food energy (50 calories). Devaney and Stuart (1998) replicated the two studies' findings, but, when they defined breakfast as consisting of a minimum of 10 percent of the Recommended Energy Allowance (REA), they found that the availability of the SBP increased the percentage of low-income children eating breakfast.

[1]This question arises not only by the presumption that breakfast eating will improve students' performance, but by research showing that breakfast eating positively affects 24-hour intake (Devaney and Fraker, 1989; Morgan et al., 1986; and Nicklas et al., 1998).

[2]The findings of Nicklas et al. (1993) are an exception. These researchers found that, after the SBP was introduced in Bogalusa, Louisiana, the percentage of 10-year-old students who skipped breakfast (that is, consumed no calories) declined.

Early research on the effects of SBP participation on students' dietary intake found mixed effects of the program. Using data on students in public schools during the 1980-1981 school year, Devaney and Fraker (1989) and Wellisch et al. (1983) found SBP participation to positively affect the intake of calcium and magnesium, and to negatively affect the intake of vitamin A, iron, and cholesterol. Devaney et al. (1987) used the same data and found that SBP participants were more likely than nonparticipants to drink milk, but less likely to consume eggs and ready-to-eat cereals, potentially explaining some of the effects of participation on the intake of vitamins and minerals.

Between the 1980-1981 school year and the 1991-1992 school year, when data from the first School Nutrition Dietary Assessment (SNDA-1) study were collected, the SBP not only grew but also had different effects on the dietary intake of students. Using SNDA-1 data, Gordon and McKinney (1995) found no difference in SBP participants' and nonparticipants' intakes of eggs or ready-to-eat cereals.

However, participants consumed more milk, cheese, meat, grains, and fruit juice than did nonparticipants. Devaney et al. (1993) and Gordon et al. (1995) found that SBP participation positively and significantly affected students' 24-hour intakes of food energy, protein, thiamin, calcium, phosphorus, and magnesium. They found no significant effect of participation on fat, saturated fat, sodium, or cholesterol intake. Using a small sample of preschool children, Worobey and Worobey (1999a) found that SBP participation led to a decreased intake of refined sugar. In a similar study by Worobey and Worobey (1999b), SBP participation led to a decrease in fat intake among a small sample of preschooler children.

The research on the dietary effects of SBP participation has been well designed and based on large, nationally representative samples.[3] However, the studies share two features that limit their applicability to the current design study. First, they estimated the effects of SBP participation prior to changes in federal regulations governing the school meal programs that may have influenced the composition and effects of the SBP.

Second, the studies were nonexperimental and therefore subject to selection bias, so unobserved differences between participants and nonparticipants may be driving their results. All the studies attempted to control for observable differences between the groups, and Devaney et al. (1993), Devaney and Fraker (1989), and Gordon et al. (1995) used econometric techniques to control for unobserved differences between them. However, these techniques have weaknesses, and the degree to which selection bias affected the studies' estimates is not known.

b. Program effects on school-related outcomes findings

Two clear findings relevant for the current study emerge from this literature, which is summarized in Table II.1. Breakfast program participation is positively related to students' attendance (Abell Foundation, 1998; Cook et al., 1996; Jacoby et al., 1996; Meyers et al., 1989;

[3]The two studies by Worobey and Worobey (1999a and 1999b) are exceptions, as they were based on extremely small and geographically limited samples of preschool children.

Murphy et al., 1998b and 1999; and Powell et al., 1998) and is negatively related to their tardiness (Abell Foundation, 1998; Cook et al., 1996; Meyers et al., 1989; and Murphy et al., 1998b and 1999).

The size of these effects is moderate; however, some of the studies either failed to conduct significance tests or had relatively small samples and did not find the effects to be statistically significant. Nevertheless, given that the findings are common to many different studies, are based on different samples, and use different methodologies, the findings that breakfast program participation leads to higher attendance and leads to less tardiness are credible (Briefel et al., 1999). The most recent major review of this literature, by Pollitt and Matthews (1998), reached the same conclusion.

Previous studies obtained differing estimated effects of SBP participation on academic achievement. Meyers et al. (1989) found the largest effects, with participation in the regular SBP estimated to lead to a significant increase of 10 percent of a standard deviation in a child's battery score on the Comprehensive Test of Basic Skills (CTBS). However, even this study failed to find statistically significant effects of SBP participation on the subtests that comprise the CTBS. Participation was estimated to have positive, but not significant, effects on language and math subtest scores and essentially no effect on the reading subtest score.

Table II.1—Summary of studies of the effect of SBP/USBP participation on school outcomes

Study	School outcomes examined	Design	Type of breakfast program	Sample	Findings (estimated effects of breakfast program)	Status
Abell Foundation (1998)	Attendance; tardiness; disciplinary incidents	Nonexperimental	U.S. USBP	3 treatment and 3 control schools in Baltimore, MD (school-level analysis)	Positive significant effect on attendance; negative significant effect on tardiness	Not published
Chandler et al. (1995)	Cognitive functioning	Experimental	Jamaican SBP	197 primary school students in 4 schools	Positive significant effect on verbal fluency; no significant effect on three other cognitive tests	Published
Cook et al. (1996)	Attendance; tardiness	Nonexperimental	U.S. USBP	USBP participants and nonparticipants in Central Falls, RI	Positive significant effect on attendance Negative significant effect on tardiness	Not published
Jacoby et al. (1996)	Attendance; achievement test scores; cognitive functioning	Experimental	Peruvian SBP	352 fourth and fifth graders in 10 Peruvian schools	Positive significant effect on attendance Positive significant effect on vocabulary and math tests among heavy children but insignificant effects overall Insignificant effects on cognitive functioning	Published
Meyers et al. (1989)	Attendance; tardiness; achievement test scores	Nonexperimental	U.S. SBP	1,023 third through sixth graders in 6 schools in Lawrence, MA	Positive significant effect on attendance Negative significant effect on tardiness Positive significant effect on CTBS test battery Positive insignificant effect on language and math test scores No effect on reading test scores	Published
Murphy et al. (1998a and 1998b)	Attendance; tardiness; math grades; psychosocial outcomes	Nonexperimental	U.S. USBP	133 students from 3 schools (1 in Philadelphia, PA; 2 in Baltimore)	Positive significant effect on attendance Negative significant effect on tardiness Positive significant effect on math grades Positive significant effect on psychosocial outcomes	Published
Murphy et al. (1999)	Attendance; tardiness; disciplinary measures; nurse visits; psychosocial outcomes	Nonexperimental	U.S. USBP	6 USBP and 6 regular SBP schools in Maryland (school-level analysis); 91 students (student-level analysis)	No significant effect on attendance or tardiness No significant effect on disciplinary measures Negative significant effect on nurse visits Positive significant effect on psychosocial outcomes	Not published

Study	School outcomes examined	Design	Type of breakfast program	Sample	Findings (estimated effects of breakfast program)	Status
Powell et al. (1983)	Attendance; achievement test scores; physical growth	Nonexperimental	Jamaican SBP	114 (12- and 13-year-old) students in 3 classes in a single Jamaican school	Positive significant effect on attendance Positive significant effect on arithmetic test scores No effect on reading and spelling test scores No effect on physical growth	Published
Powell et al. (1998)	Attendance; achievement test scores; physical growth	Experimental	Jamaican SBP	407 second through fifth graders in 16 rural Jamaican schools	Positive significant effect on attendance Insignificant overall effects on test scores Positive significant effect on arithmetic test scores in younger students	Published
Wahlstrom and Begalle (1999)	Achievement test scores; nurse visits	Nonexperimental	U.S. USBP	6 treatment and 4 control schools in Minnesota	Inconclusive results with respect to test scores Negative effect on nurse visits (significance not tested)	Published
Test of Basic Skills; SBP = n; USBP = universal-free l.	Cognitive functioning	Nonexperimental	U.S. SBP	12 preschool children in New Jersey	Positive significant effects on fine motor skills and visual perception/discrimination	Published

The other studies of the effects of breakfast program participation on academic achievement were based on foreign programs.[4] Powell et al. (1983) found that participation in a school breakfast program in Jamaica was positively and significantly related to arithmetic test scores but failed to find significant effects on spelling and reading test scores. In a later study by Powell et al. (1998), participation in the Jamaican program was not significantly related to test scores overall, although it was positively and significantly related to test scores in younger children.

Noriega et al. (2000) found that participation in a school breakfast program in Mexico had no significant effects on scores from a variety of attention, memory, and cognition tests. Finally, Jacoby et al. (1996) found that participation in a breakfast program in Peru was not significantly related to achievement overall; however, the researchers did find positive effects on vocabulary scores among a subset of heavier children whom they hypothesized were undernourished.

Three studies focused on the effects of breakfast program participation on short-term cognitive outcomes. Like the studies on academic achievement, these studies obtained mixed findings. Jacoby et al. (1996) found that participation in the Peruvian breakfast program was insignificantly related to students' performance on a coding test (the only short-term cognitive outcome they examined). Chandler et al. (1995) found that participation in the Jamaican breakfast program had positive and significant effects on a verbal fluency test, but that it was insignificantly related to performance on three other short-term cognitive tests.

The authors noted that their finding of a positive effect on verbal fluency was consistent with findings from another Jamaican study, by Simeon and Grantham-McGregor (1989), which examined the effects of eating breakfast versus no breakfast on cognitive outcomes. The authors also hypothesized that the effects of participation were limited to verbal fluency because verbal fluency was the only one of the four cognitive outcomes examined that involved "initiating and maintaining a mental process in the absence of any externally based organization," rather than relied on students' reactions to external stimuli (Chandler et al., 1995).

The only U.S. study to examine the effect of SBP participation on cognitive outcomes was a nonexperimental one based on a very small sample of preschool children in New Jersey (Worobey and Worobey, 1999b). In that study, a group of preschool students participating in a breakfast program very much like the SBP improved their test performance more than did a group of control students who continued to eat breakfast at home during the same period. The results were strongest for computer-based tasks related to visual perception, classification, and discrimination.

A few studies examined the effects of breakfast program participation on other outcomes. Murphy et al. (1999) and Wahlstrom and Begalle (1999) found that enrollment in a USBP school was

[4] Two other studies of universal-free school breakfast programs (USBPs) in the United States are relevant. Although Murphy et al. (1998b) did not examine test scores, they found that USBP participation was positively and significantly related to students' math grades in two large eastern cities. Wahlstrom and Begalle (1999) presented data on mean test scores from the periods preceding and subsequent to USBP implementation in several USBP schools and comparison schools in Minnesota. However, they did not conduct significance tests, and they made no claims about the implications of their data with respect to the effects of the USBP on academic achievement.

associated with decreases in the number of nurse visits and improvements in teachers' and parents' perceptions of the learning environment in school. (These relationships were not necessarily statistically significant.) Murphy et al. (1998b) and Murphy et al. (1999) found that USBP participation was significantly associated with children's psychosocial outcomes. The researchers argued that program participation led to lower levels of anxiety, hyperactivity, childhood depression, and psychosocial dysfunction.

Methodological issues

Because of limitations of the research, most of the conclusions from the literature on the effects of breakfast program participation on students' school-related outcomes remain inconclusive. These limitations are cited briefly in the following list and then are explored in greater depth in this section.

- ***Limited attention to any one outcome.*** A relatively small number of studies examined the effects of participation on any given outcome. (The exception was studies that focused on attendance/tardiness as an outcome).

- ***Differences in breakfast program interventions.*** Previous studies examined the effects of different types of breakfast programs that serve different populations of students. The comparability of these different methods of estimating effects is uncertain.

- ***Nonnational representativeness.*** The studies were not nationally representative and so have low external validity.

- ***Nonexperimental Designs.*** Most of the studies used nonexperimental designs subject to selection bias, and thus, may have low internal validity.

- ***Small sample sizes.*** Many of the studies analyzed relatively small samples of students and of schools.

- ***Significance tests ignoring the number of schools in the sample.*** The studies typically conducted significance tests that did not adequately account for the small sample size of schools.

Small number of studies devoted to any given outcome. Relative to the number of studies that examined the effects of eating breakfast on behavioral and cognitive development or the general link between nutrition and cognitive development, a relatively small number of studies have examined the effects of participation in school breakfast programs. Although most of the studies estimated the effects of participation on attendance and tardiness, relatively few of them estimated the effects of participation on any other outcome. For example, only four studies (Jacoby et al., 1996; Meyers et al., 1989; Powell et al., 1983; and Powell et al., 1998) examined the influence of participation on achievement test scores, and only three (Chandler et al., 1995; Jacoby et al., 1996; Worobey and Worobey, 1999) focused on short-term congnitive outcomes. Similarly, two studies (Murphy et al., 1998a, 1999) examined students' psychosocial outcomes, and two others focused on students' visits to the school nurse (Murphy et al., 1999; Wahlstrom and Begalle, 1999). Given the other methodological limitations of these studies, their small number makes it difficult to draw definitive conclusions from them.

Differences in breakfast program interventions. The studies of breakfast programs estimated the effects of different types of breakfast programs serving very different types of populations. Chandler et al. (1995), Jacoby et al. (1996), Noriega et al. (2000), and Powell et al. (1983 and 1998) estimated the effects of foreign breakfast programs, which serve meals to relatively poor and undernourished children. Although the studies provide useful information, one cannot necessarily make inferences about the effects of participation in the SBP on the basis of the estimated effects of school breakfast programs in Jamaica or Peru.

The studies that examined U.S. breakfast programs also varied somewhat in the programs examined. Meyers et al. (1989) estimated the effects of participation in the regular SBP, whereas the remaining studies focused on some type of USBP. It is not clear whether the effects of participating in a USBP would be the same as the effects of participating in the regular SBP, but none of these studies investigated potential differences in this effect.

Nonnational representativeness. The studies of the effects of breakfast program participation analyzed samples drawn from limited populations. Meyers et al. (1989) examined the effects of SBP participation in a single city (Lawrence, MA) in schools where children tended to be poor. This study's findings may not translate to different parts of the United States or to wealthier populations of students. The USBP studies typically examined programs operating in a single city or in multiple sites within a single state. None of the studies examining the effects of breakfast program participation on school-related outcomes were based on a population that is nationally representative (or even representative of a single state).

Nonexperimental designs. Three of the five studies of foreign breakfast programs (by Chandler et al., 1995; Jacoby et al., 1996; and Powell et al., 1998) used an experimental design. Classrooms of students were randomly assigned to receive either a full school breakfast or a placebo breakfast typically consisting of an orange slice. Because of the experimental design, program participants and nonparticipants should not have differed systematically before the program started. Thus, any subsequent differences in outcomes between the two groups could be attributed to either the effects of the program or to random chance. These studies have high levels of internal validity.

In contrast, the studies of the U.S. breakfast program used a nonexperimental design (that is, individual students [or schools] decided whether they would or would not participate in the program). Thus, the researchers were unable to guarantee that program participants were similar to nonparticipants. The use of a nonexperimental design required the researchers to control for relevant preexisting differences between the two groups when measuring differences in outcomes between the groups. The studies controlled for preexisting differences in a variety of ways, although most used a pre-post design for both treatment group and control group members. Each of the studies is subject to the criticism that their findings were driven more by preexisting participant-nonparticipant differences than by effects of the breakfast program. The internal validity of these studies is lower than that of the experimental studies.

Small sample sizes. Finally, even if the studies had controlled properly for all relevant preexisting differences between participants and nonparticipants (or had used an experimental design), it would have been necessary to statistically test for whether the resulting differences in outcome measures between the two groups were due to the effects of the program or to chance. In general, the larger th*e samples in the studies, the smaller the likelihood that an estimated effect of a given size was due to chance.

If the results of these studies are to be generalizable beyond the specific sites (and the specific points in time) in which the programs were examined, both the size of the sample of schools being studied and the size of the sample of students being studied are relevant. However, most of the studies used relatively small samples. For example, Murphy et al. (1998b) analyzed a sample of 133 students in three schools, Powell et al. (1983) analyzed a sample of 115 students in a single school, Worobey and Worobey (1999b) analyzed fewer than 20 students in a single preschool, and the Abell Foundation (1998) analyzed schoolwide data from only three USBP schools and three non-USBP schools. Even in studies that had large samples of students, the students came from relatively few schools. For example, Meyers et al. (1989) analyzed a sample of more than 1,000 students, but these students came from only six schools within a single school district.

Significance tests that ignore the sample size of schools. In principle, tests of statistical significance enable researchers to determine the extent to which they can be confident that their estimates reflect the true effects of participation, rather than random chance. These significance tests take into account the sample sizes of students [numbers of students]. In practice, however, the significance tests used in the studies of school breakfast programs appear to have taken advantage of the assumption that the observations of students' outcomes and characteristics were statistically independent of one another.[5]

This assumption might be reasonable for a sample of students drawn from a single school (although the results of the analysis of the sample would not be generalizable beyond that school). However, most of the studies drew their samples from more than one school. Therefore, one would expect the outcomes among students attending the same school to be related to one another, due to schoolwide characteristics that affected all the school's students. For example, one school may have had a particularly strong curriculum, so that all the sample members drawn from that school may have had relatively positive outcome values. Given the relatively small samples of schools in these studies, properly taking into account this correlation across different sample members within the same school would likely have led to lower significance levels.[6]

[5]The studies did not present sufficiently detailed descriptions of their methodologies to enable us determine whether this assumption was maintained throughout their analysis. However, the assumption is a common one in significance testing, and most of the studies did not mention having relaxed it. Furthermore, the studies achieved levels of statistical significance that would have been unlikely had they developed this assumption of independence.

[6]To give a sense of the size of the effect, consider the following example. Suppose that a study randomly assigned the students of the three schools to receive school breakfasts, with the students of three schools that did not receive school breakfasts serving as the control group. Suppose further that 20 students were sampled randomly from each of the 6 schools, for a total sample size of 120 (including 60 SBP participants and 60 nonparticipants). For an outcome measure with an overall variance of 1, an estimate of the

This limitation is particularly relevant for studies in which breakfast participation status was determined at the school (or classroom) level. For example, Powell et al. (1983) studied the effects of participation in a trial in which students of one classroom were given a school breakfast and those of the two other classrooms were not. Outcomes were then measured in all 115 students in the three classrooms, and the effects of participation were determined by comparing outcomes in students in the breakfast classroom with outcomes in students in the non-breakfast classrooms. However, certain factors that have large effects on these outcomes are likely to vary only at the classroom level.

The quality of the breakfast classroom teacher may have been much different than that of the other teachers, and the effect of this factor on students' attendance, cognition, and achievement could have been strong enough to overwhelm any effects of the breakfast. If there were many breakfast classrooms, the average quality of teachers in the breakfast and non-breakfast classrooms would likely have been similar. With a small number of classrooms (or schools), however, factors such as this one probably differ for participating and nonparticipating students. It is important to account for this fact when conducting significance tests and assessing results.

B. Implications of Research

1. Conceptual framework

The purpose of this design study is to develop and assess alternative ways of testing the hypothesis that participation in the School Breakfast Program leads to improved learning by children. The research summarized in the preceding section does not definitively establish the existence of this relationship, but some of the studies do support the belief that various intermediate relationships may underlie the overall SBP-learning relationship. For example, research suggests that the availability of the SBP in a school promotes breakfast eating among students at the school (Devaney and Stuart, 1998). Other studies show a link between breakfast eating and short-term cognition (Pollitt and Matthews, 1998). If short-term cognition leads to improved learning, then these two findings could be components of a relationship between the availability of the SBP in a school and students' learning and academic achievement in that school.

Although research suggests some reasons for believing that SBP participation may promote learning, it is useful to clarify these reasons, as fully specifying the potential linkages through which participation could conceivably influence learning is helpful for designing empirical studies testing the relationship between participation and learning. This section describes a conceptual framework that presents the pathways through which participation could influence learning.

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effect of participation on the outcome would have a standard error of 0.31, if the sample size of schools were adequately considered. (We assumed the school-level variance in the outcome measure accounted for 10 percent of the overall variance.) If one were to ignore the sample size of the schools (and the sample was assumed to be randomly drawn), the standard error of the estimate of the participation effect would be 0.17. If the estimated effect were 0.34, it would be statistically significant ($t = 2.0$) under the statistical test that ignored the sample size of schools, but would be far from significant ($t = 1.1$) under the statistical test that took into account that sample.

School breakfast participation can affect school performance directly or through intermediate factors, such as improved dietary intake, nutritional status, or health. The underlying rationale is as follows:

- Some children do not eat breakfast or do not eat a nutritious breakfast.

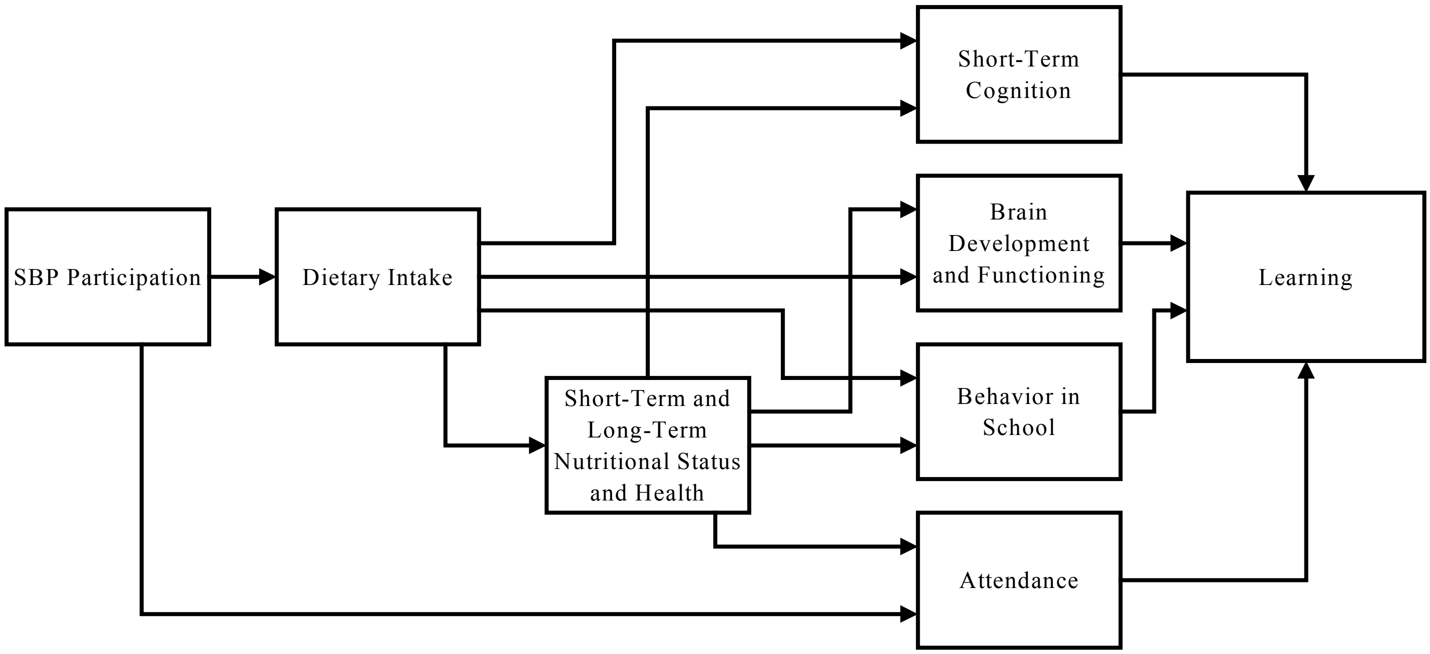
- Providing school breakfasts will increase the consumption of breakfasts, thereby increasing the number of students who eat a nutritious breakfast.

- Eating a nutritious breakfast leads to enhanced readiness to learn, improved cognitive and behavioral outcomes, improved dietary status, and, ultimately, higher academic achievement and school performance.

Figure II.1 summarizes the conceptual framework for analyzing the effects of SBP participation on learning. According to the framework, breakfast program participation directly influences dietary intake and school attendance, intermediate outcomes that may ultimately lead to improved learning.

By eating a school breakfast, students' dietary intakes (both at breakfast and over 24 hours) may be improved. This improved dietary intake, in turn, potentially leads to improvements in students' nutritional and health status. Together, improved dietary intake and health status are hypothesized to influence three key outcomes: (1) short-term cognition, (2) brain development and functioning, and (3) behavior in school. In addition, health status may influence students' school attendance.

Figure II.1—Conceptual framework for analyzing effects of SBP participation on learning



The conceptual framework serves two main purposes for this design study. First, it specifies the intermediate outcomes that SBP participation potentially influences. A good design should incorporate as many of these intermediate outcomes as is feasible. If the study were to fail to show a relationship between SBP participation and learning, for example, then knowing whether participation influences the intermediate outcomes would aid in the interpretation of the results and would suggest avenues for future research.

Second, it provides a basis for the specification of the model or models to be estimated. In particular, the control variables to be included in the model should include the factors that directly influence student learning or that influence any of the intermediate outcomes (which, in turn, may influence learning).

The framework also may help identify factors that modify the effect of SBP participation. For example, if one of the primary ways in which participation influences learning is through its effect on dietary intake, then one might expect the effect to be larger for children whose nutrient intakes at home are most likely to be inadequate (that is, low-income children).

If the study showed that participation leads to improvements in students' short-term cognition, but not to improvements in learning or academic achievement, future work would focus on examining competing explanations for the absence of an overall effect. For example, certain types of short-term cognition may not strongly influence students' learning. Alternatively, improvements in short-term cognition may influence learning only in the long term, suggesting a study with longer-term follow-up measures of students' SBP participation and learning. Identifying the key intermediate variables and incorporating them into the design would also be important if the study were to show a positive and significant effect of participation on learning. Table II.2 describes the potential relationships between a variety of intermediate outcomes and learning. For example, such a study would be able to provide information about whether the overall effect occurred because students benefited more from their time in class (that is, their short-term cognition improved), because they were spending more time in class (that is, their attendance improved), or because of some other reason or combination of reasons.

Short-term cognition refers to the ability to recognize, absorb, and process information. In school, having highly developed short-term cognition enables students to benefit more from their classes (particularly during the late morning), which improves their base for future learning. Dietary intake potentially influences short-term cognition is two ways. First, researchers have hypothesized and empirical studies have found that higher breakfast calorie intake levels lead to higher glucose levels available to the brain and, therefore, to higher energy levels in the late morning (Benton and Parker, 1998). These higher energy levels improve students' late-morning cognitive functioning. Second, better dietary intake leads to improvements in health status, which prevents such factors as headaches, upset stomachs, or other symptoms from interfering with learning. Improved health status also decreases the number of days missed due to illness.

Regularly participating in a school breakfast program may also influence learning and academic achievement through a mechanism unrelated to dietary intake. Students may want to participate in the breakfast program because they (1) prefer the food at school to the food at home, (2) enjoy spending time with their friends during breakfast, or (3) appreciate the attention of breakfast program staff. For any of these reasons, SBP participation may lead to more regular school attendance and, therefore, to more time spent in class. Students who increase the time they spend in class (and who pay attention during that additional classroom time) have the potential to learn more.

Table II.2—Implications of conceptual model with respect to intermediate outcomes

IntermediateOutcome	How Does SBP Participation Influence Outcome?	How Does Outcome Influence Learning?
Dietary intake	SBP participation has a direct positive effect on dietary intake.	Improvements in dietary intake lead to improvements in short-term cognition, brain development, and behavior in school (both directly and through the positive effect dietary intake has on health status); these outcomes in turn lead to improved learning. Improvements in dietary intake also positively influence school attendance through improvements in health status; greater attendance then leads to improved learning.
School attendance	SBP participation has a direct positive effect on dietary intake. Participation also positively influences attendance indirectly by improving dietary intake, which leads to	Improved school attendance has a direct positive effect on learning.

	improved health status, which leads to improved school attendance.	
Health status	SBP participation first leads to improvements in dietary intake, which lead in turn to improved health status.	Improved health status positively influences short-term cognition, brain development, behavior in school, and school attendance; improvements in these four outcomes then lead to improved learning.
Short-term cognition	SBP participation first leads to an improvement in dietary intake, which in the short term leads to an increase in blood glucose levels and in the long term leads to an improvement in health status. Both the increase in short-term blood glucose levels and in health status can positively influence short-term cognition.	Improved short-term cognition has a direct positive effect on learning.
Brain development	SBP participation leads first leads to an improvement in dietary intake, which leads to an improvement in health status. Both dietary intake and health status positively influence brain development.	Improved brain development has a direct positive effect on learning.
Behavior in school	SBP participation leads first leads to an improvement in dietary intake, which leads to an improvement in health status. Both dietary intake and health status positively influence behavior in school.	Improved behavior in school has a direct positive effect on learning

Initially, scientists viewed the main link between dietary intake and cognition as primarily the result of the effects of malnutrition on brain development. As described by Brown and Pollitt (1996), scientists had hypothesized that underfeeding in childhood led to “permanent, structural damage to the brain.” Although the effects of malnutrition in early childhood on brain development no longer are believed to be necessarily permanent or the only means through which nutrition affects learning, they still are thought to be a potentially important means by which dietary intake influences children’s intellectual development. Furthermore, other aspects of children’s health status that also are affected by dietary intake may reduce or magnify this effect.

Obviously, the most important question to be addressed in the study being designed in this project is whether SBP participation leads to increased learning by children. However, the conceptual framework presented in Figure II.1 and the previous studies outlined in Table II.1 suggest several additional research issues and questions for this design study:

- Does SBP participation directly influence dietary intake and attendance—the primary outcomes through which it could affect learning? If there is an overall effect of participation on learning, does it arise primarily though the effect of participation on dietary intake or through the effect on attendance?

- Which of the factors that could directly influence learning (short-term cognition, behavior, and/or attendance) does SBP participation directly or indirectly influence? Are any of these intermediate factors more important than the others in explaining the relationship between participation and learning?

- What role does students' health status play in the model? Is health status an important means through which participation is linked with the other outcomes of interest?

- If no overall relationship between participation and learning is found, at which point does the conceptual model break down? Which link in the model is least likely to hold (or least likely to be statistically detected even if it does hold)?

Designing a study that can answer at least some of these questions will greatly increase the usefulness of the policy implications of the study results for policymakers.

2. Design alternatives

The research literature summarized in Section A has established four important research findings. First, a link between nutrition and cognitive development exists and has been shown to be strongest and most well established in severely undernourished children in developing countries. Second, eating breakfast leads to improvements in children's short-term cognition, especially in children who are generally undernourished. Third, children who usually eat school breakfasts are more likely than nonparticipants to eat a substantial breakfast and generally have greater intakes of selected nutrients. Fourth, breakfast program participation leads to greater attendance in school and to lower levels of tardiness. However, we do not know whether participation influences health status, short-term cognition, or learning and academic achievement, as limitations of studies that investigated these issues leave the findings inconclusive. Thus, it is desirable to design a study that will both reassess these questions and add to the evidence from some of the better-established research findings.

A study on the influence of SBP participation on such outcomes as learning, cognition, and health status should attempt to address the weaknesses of the previous research. It should also be designed in a way that takes into account the conceptual framework described in this chapter, and that addresses some of the issues arising from the framework. In particular, the study design should try to incorporate as many of the following features as possible:

- ***Examine multiple outcomes.*** The study should examine as many of the intermediate outcomes as possible, including short-term cognition, behavior and attendance in school, health status, and dietary intake. If the approach suggested by the conceptual framework were used, appropriately measuring many of these outcomes would be quite challenging and potentially costly. However, that approach would increase the value of the research to the literature as a whole.

- ***Examine the U.S. Breakfast Program.*** Because the SBP is the policy of interest, the study should examine this program either in its standard form or as part of the USBP that currently is being implemented in a number of sites across the country. If the study examines the USBP, it should include a sample of students attending schools that offer the regular SBP and should compare the estimated effects of participation in the USBP and regular SBP.

- ***Collect data from a nationally representative sample.*** Ideally, the study would be able to produce estimates that could be generalized to the United States as a whole (that is, the study would have external validity). To produce these estimates, the study would have to use a nationally representative sample.

- ***Use an experimental design.*** To produce estimates that have the greatest internal validity, the study should use an experimental design. Under this design, either students or schools would be randomly assigned to a treatment group that participates in the breakfast program or to a control group that does not participate. The differences between the groups would be random, so any systematic differences arising after participation in the program could be attributed to the program.

- ***Use large samples of students and schools.*** To generate enough statistical power to detect relevant participant-nonparticipant differences in key outcomes, the study should collect data from a large number of students attending a relatively large number of schools. Although the appropriate number of students and schools has yet to be determined, the sample sizes used in many of the previous studies of the impact of breakfast programs were too small to achieve the aims of this design study.

- ***Conduct statistical tests that take into account the sample size of students and the sample size of schools.*** If the significance tests conducted as part of the study ignore the fact that the sample of students is collected from a limited number of schools, then they are likely to understate the variability of the estimates, and to overstate their statistical significance. The study should take into account this design feature so that valid estimates and conclusions are produced.

There are many tradeoffs among these study features and between the features and study costs. For example, a study using an experimental design would be challenging to implement nationally, so that it would be difficult to use a nationally representative sample. It also would not be possible to collect data on a nationally representative sample of USBP participants and nonparticipants, as that program is not available nationally.

There also are tradeoffs between the size of the samples analyzed, the number of outcomes measured, and the cost of the study. It may be feasible to collect data on a limited number of easily measured outcomes from a large sample of students, but it probably is not feasible to collect data from a large sample on a wide range of outcomes, including such difficult-to-measure outcomes as short-term cognition.

Given the design features the study is attempting to incorporate, the following four design alternatives:

1. ***USBP study.*** Under contract with the Food and Nutrition Service, Mathematica Policy Research, Inc. designed an evaluation of six USBP pilot programs. The design included a three-year study of elementary schools participating in the USBP and focused on the effects of the program on a variety of outcomes, including dietary intake and academic achievement. Abt Associates, Inc. currently is conducting this evaluation.

2. ***SBP applicant design.*** No study of a U.S. breakfast program has used an experimental design to estimate the effects of participation on learning/academic achievement. Such a study would be difficult to implement, but it is important to fully explore the design's benefits and feasibility. One experimental design involves random assignment at either the classroom or school level and includes only schools applying to participate in the SBP for the first time. Rather than approving or denying SBP participation to treatment and control schools or classrooms, random assignment could be a mechanism for either beginning the SBP in one school year or delaying it until a subsequent year for participating schools/classrooms. This design would have the benefits of random assignment and internal validity; however, it would likely have to be implemented in a limited geographic area (or set of areas) and thus would not necessarily have great external validity.

3. ***ECLS-K-based study.*** The Early Childhood Longitudinal Survey, Kindergarten Cohort, (ECLS-K) is a longitudinal dataset collecting information on a large, nationally representative sample of students from the kindergarten class of 1998. The dataset includes follow-up information collected through the students' fifth grade year (if they progress at a normal rate in school) and includes a wealth of information on the students' cognitive development and academic progress. (It also contains information on SBP participation.) A study using ECLS-K data to examine the effects of SBP participation on learning would incorporate many of the key features listed in this section. It would be nationally representative and would include large sample sizes. If supplementary data were collected on sample members' dietary intakes, it would be possible to examine a large number of outcomes. This design alternative would be unable to incorporate one feature—an experimental design.

4. ***NHANES-based study.*** The National Health and Nutrition Examination Survey (NHANES) provides data on a nationally representative sample of students. This design would be nonexperimental in nature and offers the benefit of being able to examine outcomes relating to dietary intake, nutritional status, and health status. However, the survey currently collects limited information on learning outcomes, school attendance, social and emotional development, or school characteristics. A study using NHANES data to examine the effects of SBP participation on learning would incorporate many of the key features listed in this section.

We develop each of these design options more fully in Chapter III. The conceptual framework and the literature provide the basis for a discussion of the advantages and disadvantages of each of the four options. The designs' structures were refined on the basis of comments from the Economic Research Service and from a panel of experts on design-related issues and on the SBP. (See Appendix A for a list of the experts as well as a summary of the May 2000 expert panel meeting.)