# STEM in the Early Years

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## Abstract

This paper addresses the challenges facing early childhood educators regarding science, technology, engineering, and mathematics (STEM) education. The first section discusses some distinctions between academic and intellectual goals and their implications for early childhood pedagogy. The second section outlines the potential contribution of the Project Approach to addressing basic STEM goals, and the final section discusses issues related to standards.

## Introduction

One of the most important goals of all education, at every level, is to support and strengthen the disposition to go on learning throughout life. In the case of young children, the disposition to learn can be assumed to be in-born—granted, stronger in some newborns than in others. Indeed, it is a good idea for parents and early educators of young children to keep in mind that young children always learn—some more readily than others—and not always what we want them to learn. Along similar lines, it is useful to remember that learning is largely experience dependent. Thus, an important question to bring to this discussion is what experiences are most likely to foster the disposition to go on learning?

The challenges facing early childhood educators regarding science, technology, engineering, and mathematics (STEM) education are taken up here in three sections. The paper begins with a discussion of some distinctions between academic and intellectual goals and their implications for early childhood pedagogy. Then the potential contribution of the Project Approach to addressing basic STEM goals is outlined, and finally a discussion of issues related to standards is offered.

## Some Distinctions between Academic and Intellectual Goals for Young Children

A strong trend has emerged in the United States over the past 20-plus years to emphasize supporting young children's readiness for school by introducing formal academic instruction during the preschool and kindergarten years. The issues involved are not simple matters of choice between emphasizing academic instruction versus traditional spontaneous play activities. A main argument is that much of the discussion and debate about appropriate preschool curricula is based on a misleading dichotomy. I suggest that a more useful way of looking at the choices involved in preschool and kindergarten curriculum approaches is to examine the distinctions between *academic* and *intellectual* goals and activities rather than to insist on a dichotomy of either formal instruction or play.

Academic goals are those concerned with acquiring small discrete bits of disembedded information, usually related to preliteracy skills, that must be practiced in drills, and worksheets, and other kinds of exercises designed to prepare children for later literacy and numeracy learning. In an academic curriculum, the items learned and practiced require correct answers, rely heavily on memorization, on the application of formulae versus the search for understanding, and consist largely of giving the teacher the correct answers that the children know she awaits. Although one of the traditional meanings of the term *academic* is "of little practical value," these bits of information are essential components of reading and writing and other academic competences. The question here is not *whether* academic skills matter; rather the question is *when* does the acquisition of academic skills matter?

Intellectual goals and their related activities, on the other hand, address the life of the mind in its fullest sense, including a range of aesthetic and moral sensibilities. The formal definition of the concept of *intellectual* emphasizes reasoning, hypothesizing, predicting, the quest for understanding and conjecturing, as well as the development and analysis of ideas. An appropriate curriculum for young children focuses on supporting their in-born intellectual dispositions, for example, the disposition to make the best sense they can of their own experience and their own environment. An appropriate curriculum in the early years is one that encourages and motivates children to seek mastery of basic academic skills (e.g., beginning writing skills) *in the service of their intellectual pursuits.* The children should be able to sense the purposefulness of their efforts to master a variety of academic skills (e.g., writing, counting, measuring) and to appreciate their usefulness and their various purposes. These intellectual pursuits include the whole range of knowledge, understanding, skills, and dispositions related to STEM goals.

There are at least two points to emphasize in connection with the importance of intellectual goals. The first is that it is easy to mistakenly assume that because some young children have not been exposed to the knowledge and skills associated with "school readiness" they lack the basic intellectual dispositions, such as to make sense of experience, to analyze, hypothesize, predict, as do their peers of more affluent backgrounds. Children of very low-income families may not have been read to or had opportunities to hold a pencil at home. But I suggest that it is a good idea to assume that they too have lively minds. Indeed, the intellectual challenges that many children face in coping with precarious environments in poor neighborhoods are likely to be substantial and often complex.

Second, while intellectual dispositions may be weakened or even damaged by excessive and premature formal instruction, they are also not likely to be strengthened by many of the trivial if not banal activities frequently offered in child care, preschool, and kindergarten programs. In other words, in our preschool and kindergarten practices, we are not caught between formal academic lessons *or* cutting and pasting "refrigerator art" activities. I visited a school district in one of our western states not long ago in which the kindergartens had adopted as a theme for the year "Teddy Bears." In that classroom, each of the children was expected to "show and tell" about his or her own teddy bears, to count a collection, to measure their lengths and obtain their weights, and to make up stories with them as main characters. While such activities are probably not harmful and may even be fun for the children, they are not intellectually engaging or stimulating, and in my view, they seriously underestimate children's intellectual potential. Indeed, I believe that we tend to overestimate children academically and underestimate them intellectually.

By contrast, when young children engage in projects in which they conduct investigations of significant objects and events around them for which they have developed the research questions, their intellectual capacities are very likely to be provoked and eagerly employed, as suggested in the example in the section that follows.

In the course of these investigations (that are referred to as projects, see Katz & Chard, 2000; Helm & Katz, 2001) that are a part of their curriculum, the children's minds are fully engaged as they themselves find out how things work, what things are made of, what people around them do to contribute to their well-being, and so forth, as can be seen in many reports of project work in the early years. (See reports of projects in each issue of *Early Childhood Research & Practice,* http://ecrp.uiuc.edu.) Furthermore, the usefulness and importance of being able to read, write, measure, and count become self-evident to children in the course of good project work.

Another factor to consider here is that in most cases, academic instruction puts children in a passive and receptive role, rather than in an active and interactive one. On the other hand, in investigations or projects, the children are active and take responsibility and initiative in determining the research questions and how to collect the relevant data, how to represent and to report it, and so forth (see Katz & Chard, 2000).

Another important consideration related to the distinctions between academic and intellectual goals and activities is that while many academic skills are both useful and essential, the question to raise here is a developmental one, namely: At what point in the course of development are academic exercises most appropriate? We all agree with the proposition that learning to read (and at the same time acquiring the disposition to be a reader) is a major educational goal. But just *when* this process of learning to read and write should be started, and with what intensity, raises many questions among those concerned with our youngest children.

One of the factors accounting for increasing interest in formulating clear outcomes and standards for preschool programs may be the recent and growing recognition of the role of stimulation in early brain development. However, Blair's analysis of neurological research does not imply that formal academic instruction is the way to optimize early brain development (Blair, 2002). On the contrary, Blair proposes a neurobiological model of school readiness based on his analysis of recent neurological data, the implications of which are that preschool programs are best when they focus on social, emotional, and intellectual goals rather than narrow academics. Blair's analysis emphasizes the positive role of early experiences that provoke self-regulation, initiative, and what he calls synchronous interaction in which the child is interactive with others rather than a mere passive recipient of isolated bits of information. On the basis of his model, an *intellectually* rather than *academically* focused approach is most likely to yield desirable "school readiness" as well as longer-term benefits related to the goals of STEM education.

Furthermore, the common-sense notion that "earlier is better" is not supported by longitudinal studies of the long-term effects of different kinds of preschool curriculum models. On the contrary, a number of longitudinal follow-up studies indicate that while formal instruction produces good test results *in the short term*, preschool curriculum and teaching methods emphasizing children's interactive roles and providing frequent opportunities for them to exercise initiative, while not so impressive in the short term, yield better school participation and achievement *in the long term* (Golbeck, 2001, Marcon, 2002).

There are two more points to emphasize about the implications of these data concerning the effects of different preschool curricula. One is that only in the long term are the disadvantages of early formal instruction apparent. The disadvantages are not usually observable in the short term. To some unknowable extent, the apparent short-term benefits of formal instruction are related to the extent to which the curriculum prepares the children to respond to the items on the tests! Preschoolers who do not have formal academic instruction on items on the tests are less likely to perform well on them.

The second point is that early formal instruction, in the long term, tends to be more damaging to boys than to girls. Explanations for this finding are not entirely clear. One important interpretation of these data may be that in most cultures, girls generally learn to accept a passive role early and accept it more easily than do boys. On the whole, boys appear to prefer active and interactive experiences. Another possible explanation is the well-known fact that girls mature neurologically slightly earlier than boys.

Taken together, these distinctions suggest that early introduction of formal academic instruction may not be in the best interests of many of our children and, in fact, may be damaging in the long term. However, early childhood curriculum and teaching methods are best when they address children's lively minds so that they have frequent opportunities to be fully intellectually engaged in the kinds of investigations known as the Project Approach, as outlined below, as well as to engage in spontaneous play, and not just cutting and pasting and producing "refrigerator art."

# The Project Approach Related to STEM Goals

In terms of the aims of the STEM program, what goals and objectives are appropriate during the early years of education? Answers to this question can be addressed in terms of four basic learning goals: (1) knowledge/understanding, (2) skills, (3) dispositions, and (4) feelings. In the matter of goals and objectives related to science, young children are likely to gain greatly in all four of these kinds of learning goals when they have opportunities to engage in in-depth investigations of phenomena around them worthy of their knowledge and understanding. We refer to these investigations as projects (Katz & Chard, 2000).

Projects are based on the classical procedures of science in that they begin with a set of questions about the phenomena of interest, proceed to predictions of possible answers to the questions, followed by the gathering of data that can be expected to answer the questions as predicted.

Similarly, in the case of project work with young children, once the topic of investigation has been agreed upon (usually by the children together with their teacher), the children are encouraged to predict what the answers to their questions might be. This step is followed by a discussion of what data will be needed to answer their questions and to test their predictions. Data gathering, called fieldwork, that can be expected to provide answers to their questions is then planned and undertaken by the children. Following a wide range of relevant fieldwork, which can include conducting surveys, interviews, asking questions of visiting experts, conducting experiments, drawing and measuring relevant phenomena, etc., findings are discussed as new knowledge and understandings are agreed upon. A simple example of a project with young children is given below.

## All about Balls

Early in the kindergarten year in a small town near our university, a teacher in my class who had to conduct a project with her class was not able to take them on field trips for a variety of reasons. So she asked her class to ask their parents and grandparents, neighbors, and others if they would look in their basements and attics and see if they could find any old balls to give them to take to their class for a project investigating them.

Within about two weeks their collection included more than 20 different kinds of balls, including a basketball, beach ball, bowling ball, football, soccer ball, golf ball, ping pong ball, marbles, billiard ball, tennis ball, and many more. One child brought a world globe to add to the collection. The teacher asked the class if they thought it was a ball. When they responded positively, she asked them why, and they pointed out that it was round. She happened to have a paper plate on her desk and held it up and said to the class, “This is round, isn’t it?” They readily responded positively to that question. She then engaged them in the discussion of roundness and introduced the concept of “sphere” and the term “spherical” to them, and then she asked if they would also define it as a ball. They then rejected that classification on the basis of the fact that the world globe did not bounce. However, they soon learned that the bowling ball and the marbles didn’t bounce. In this way, they subdivided spheres according to whether or not they bounced. The teacher also engaged them in a discussion of what they thought might be inside the balls and introduced the concepts of solid, hollow, empty, full, and so forth. A brief example of a few of their questions is offered below.

The class then divided into subgroups of four or five per group to examine various characteristics of the balls in the collection. One group measured the circumference of each of the balls with string and displayed the strings by hanging them on a beam suspended from the ceiling. Another group made rubbings of the surface textures of each ball in the collection. Another group predicted their weight and tested their predictions. Another group predicted and tested the height of bounce. Another group constructed a slope using a large block and a plank and measured the length the balls rolled depending on the steepness of the plank and whether they had it on the carpet, the wooden floor, on the gravel outside, and so on and so forth. The children created a question table in a discussion with their teacher as seen below.

Question Table about the Balls

| Questions | Predictions | Findings |
|---|---|---|
| Which ball will bounce the highest? | The beach ball<br>The tennis ball<br>etc. | |
| Which ball is the heaviest? | The beach ball<br>The bowling ball<br>etc. | |
| Which ball will roll the farthest? | The billiard ball | |

When the teacher engaged the children in making predictions about what the answers to their questions might be, she occasionally asked, “What makes you think so?”, thereby launching and strengthening the important disposition to examine the basis of one’s opinions, an important basis for scientific thinking and research.

## Problems with Standards

The discussions about standards seem to continue to grow more and more intensely. However, the term is far from a simple one, though it seems to have a kind of cliché value these days. Today, the answer to the question "What should be learned?" is most likely to be stated in terms of performance standards, benchmarks, and other types of outcomes. Early childhood educators are pressured to get children “ready” for school, ready to “succeed” in school, and ready to perform well on tests of academic skills. All of these goals and outcomes are frequently cited as the end products or outcomes of the curricula “delivered” to young children. Frequent reference to the “delivery” of a curriculum, as in delivering the mail or the milk, is noted. However, a curriculum, that is, a plan for learning, cannot be delivered; it must be provided.

These concerns with outcomes and end products are based on a corporate, industrial, or factory model of education. Indeed, some commentators even refer to child care and other early education provisions as an “industry” instead of as a service. Such an industrial model implies that once the raw materials have been placed on the right kind of assembly line and then subjected to a fixed series of processes, “out” will “come” identical products—identical shoes, chairs, cell phones, or test scores, or whatever else is being manufactured. This industrial model is not completely successful for corporations and factories; periodically there are bankruptcies and large-scale recalls of manufactured products (e.g., Toyota cars) because of faulty design or errors in production processes. The industrial model is not foolproof for industries or banks or corporations; I suggest that it is a highly inappropriate basis for thinking about the education of young children. In fact, it is most likely to be seriously misleading for the design of provisions for young children, especially as they are related to the basic goals of STEM education.

I am suggesting that a more appropriate approach to a plan for learning might be to ask ourselves: What are the *standards of experience* that we want all of our children to have? Rather than “delivering” education, we are most likely to help children by “providing” experiences known to benefit young children. Thus when we decide to evaluate or assess a provision for young children, we might ask: What kinds of *experiences* is each child having much of the time? Or perhaps we should ask: What does it *feel* like to be a child in this environment day after day after day? To use these questions as a basis for assessing the appropriateness of provisions for young children requires coming to agreement on what experiences are considered and known to be essential to yield the kinds of short-term *and* long-term *effects* (vs. products) we want to cause. Below is a very preliminary list of some important “standards of experiences” that I suggest should be “standard” in all programs for young children.

Young children should *frequently* have the following experiences:

- Being intellectually engaged and absorbed.
- Being intellectually challenged.
- Being engaged in extended interactions (e.g., conversations, discussions, exchanges of views, arguments, participation in planning of work).
- Being involved in sustained investigations of aspects of their own environment and experiences worthy of their interest, knowledge, and understanding.
- Taking initiative in a range of activities and accepting responsibility for what is accomplished.
- Experiencing the satisfaction that can come from overcoming obstacles and setbacks and solving problems.
- Having confidence in their own intellectual powers and their own questions.
- Helping others to find out things and to understand them better.
- Making suggestions to others and expressing appreciation of others’ efforts and accomplishments.
- Applying their developing basic literacy and numeracy skills in purposeful ways.

- Feeling that they belong to a group of their peers.

The list is derived from general consideration of the kinds of experiences that all children should have much of the time that they spend in our educational settings. It is based on philosophical commitments as well as the best available empirical evidence about young children's learning and development.

If the focus of program evaluation and assessment is on "outcomes" such as those indicated by test scores, then children's experiences of interest to evaluators and assessors would very likely be "drill and practice" of phonemics, or rhyming, or various kinds of counting, or introductory arithmetic. While in and of themselves such experiences are not necessarily harmful, they overlook the kinds of experiences that are most likely to strengthen and support young children's *intellectual* dispositions and their innate thirst for better, fuller, and deeper understanding of their experiences. A curriculum or teaching method focused on academic goals overlooks the centrality of *understanding* as an educational goal. After all, literacy and numeracy skills are not ends in themselves but basic *tools* that can and should be applied in the lifelong quest for fuller, deeper, and more accurate understanding of significant phenomena. In other words, children should be helped to acquire academic skills *in the service of their intellectual dispositions* and not at their expense.

Extensive experience of working with young children and their teachers confirms the supposition that all children are innately curious and eager to explore their environments and learn about a wide variety of causes and effects. In this sense, our early education pedagogical methods should support these basic dispositions and provide a wide range of contexts for young children to use them.

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