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Developmentally Appropriate STEM: It's STREAM!

(Science, Technology, Relationships, Engineering, Arts, and Math)*

by Dan Gartrell

**Thanks to Thea Blair for sharing the term "STREAM." Thanks also to Lilian Katz, who back in the "Academic Eighties" famously said that the 3 Rs need a fourth, "Relationships."*

From time to time in American education there occurs a nationwide push for a new teaching emphasis or a new curriculum approach. Those who initiate are usually well-intended educators, policy makers, and politicians who grab an idea 'whose time has come' and decide that, yes, this is what American students need! Business interests tied to the education world are glad for any new push, of course, because they can then produce new curriculum guides, activity books, and textbooks relating to the trend. STEM education (education in and for Science, Technology, Engineering, and Mathematics) is now such a push. Another continuing and long overdue national push is for high-quality preschool education.

Many early childhood colleagues and I are concerned about the current trend regarding STEM. The reason has nothing to do with a primary and laudatory intent of STEM: to help more girls become competent in and committed to professions in the sciences. We know that the potential of young children, both girls and boys, has no bounds. We are passionate in our efforts to support and nurture the potential of every child — including for girls to go into the sciences and boys of color to go further in their educations than tenth or twelve grade!

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The concern ECE colleagues have conveyed to me about STEM is this: Similar to other 'reform' trends in the past that have a content/curriculum focus, STEM may perhaps be appropriate in subject-focused schooling at the upper grade levels. However, in holistic early childhood education, STEM might morph into a developmentally inappropriate academic pushdown of curriculum and teaching methods, to be mis-used with infants, toddlers, preschoolers, and indeed, primary grade children.

The father of all pushes gone wrong, of course, is the wholesale intent to improve education by making teaching and learning accountable through standardized tests (Gartrell, 2012). While models of authentic assessment document that 'minimally invasive' practices work just fine, political accountability rather than more rational educational accountability has taken hold. Nationwide, at all education levels, an undue emphasis has grown up around single number scores on high-stakes standardized tests. As a consequence 'education' at all levels is being reduced to teaching for the test. The general attitude seems to be no child should go untested and no teacher ungraded by children's test scores. It is my observation that stress levels have never been so high in American education. No wonder ECE teachers are wary about the prospect of another new 'academic' push.

STEM in the Context of DAP

To many of us in the field, Developmentally Appropriate Practice is NAEYC's most fundamental stock-in-trade. DAP is NAEYC's macaroni and cheese (now made with gluten-free macaroni and low-fat cheese); its ants-on-a-log (now made with non-dairy 'cheese spread' and raisins for those with peanut and dairy allergies). In fact, more so than for

any other professional association, the brand behind DAP is NAEYC. My position is that STEM must happen within the context of DAP. The message of this viewpoint piece is that early childhood professionals will be accepting of, and should be enthusiastic toward, STEM if content and methods surrounding the approach remain true to, and in fact sustain, developmentally appropriate practice.

Some readers may know that I sprinkle my writings and presentations with illustrative vignettes (all based on real events in real classrooms) in order to make ideas accessible and worth reflecting about. (My more 'scholarly' pieces also provide frequent references to make them more ... scholarly.) This Viewpoint uses vignettes (with source information provided) in order to provide one answer to the question: What do developmentally appropriate STEM (Science, Technology, Engineering, Mathematics) applications in EC programs look like?

Science

DA science in ECE goes beyond the stereotypical 'lab setting' with a teacher doing a demonstration and children watching — think a baking soda and vinegar 'volcano' here (which kids from Hawaii's Big Island know is totally bogus). But the direction in which DA science has moved may surprise some people. During the 1980s the term 'sciencing' captured well the active and interactive dimensions of what many of us know to be DA science experiences. In such experiences, there may not be a structured science lesson at all. Instead, teachers motivate children to use (if informally) the scientific method: carefully observe situations, act intentionally (often with open-ended materials), reach independent conclusions, and interact with others about their discoveries. Teachers use the interactions as teachable moments relative to science ideas.

Why is this good science? In the largest, purest sense, Karen was practicing scientific thinking. She observed the conventional Rudolph and sensed what millions of adults over many years had missed or ignored: the misplaced physics of light. Tail lights belong in the back; headlights belong in the front. Through the experimental expression of her hypothesis, Karen improved on society's conventional wisdom. Along the way she gave herself an anatomy lesson concerning deer, used mathematical sets — four legs, two ears, one nose — and experimented with the chemistry of markers interacting with paper. Significantly, she codified her findings and conclusions in a 'science journal' — the story-picture. To me this is sciencing at its best. You go, Karen!

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Teacher Natisha organized a cluster of activities around Rudolph the Red-Nosed Reindeer. The group read the book, learned the song, and discussed how Rudolph was a deer that overcame a disability. One of the follow-up activities was in the art area, where Natisha did not have a model of Rudolph for the children to copy. Instead, she used spoken motivation, inviting the children to do their own unique 'story-pictures' (pictures that tell stories) of any idea they wanted relating to Rudolph.

Karen, aged four, decided to draw her own Rudolph using markers. She worked carefully, got the anatomy just right, and then gave Rudolph a yellow nose. Using personal script (which some call scribble writing) she wrote two lines with a big 'R' in the middle. She wrote her name at the end.

When Natisha complimented details in her story picture, Karen pointed to the two lines, "This says my Rudolph's got a yellow nose. That's so Santa can see better." The teacher's reaction was an amazed grin, a nod of the head, and this acknowledgement: "Karen, you know that Santa needs a headlight up front, don't you? You drew that and you wrote it in your story picture!" Karen smiled and nodded.

(Source: Dan's Head Start Classroom in Red Lake, Minnesota, 1968. Teacher's name changed.)

Note that the adult response to Karen's creative scientific thinking means everything here. For Karen's experiment to be a success, the interaction with Natisha had to be reflective of Karen's intent, and be positive. Notice also that if the activity had been reduced to 'non-art' by having the children copy a pre-made Rudolph, Karen would have done the activity 'wrong.' With pre-cursive young children, theme-related open-ended art serves as the child's first science journal. DA science needs opportunities for children to act using open-ended materials, along with supportive interactions involving caring adults (with whom the child develops and maintains a trusting relationship.)

Technology

Along with Diane Levin (2013), I think that a legitimate worry in this media age is a widespread faulty self-identity process. Some young individuals are coming to prefer virtual relationships with remote (sometimes animated) others, over real relationships in the here-and-now. Face-to-face relationships come with responsibilities and frustrations. If real relationships become too challenging, they can pressure young individuals into this risky, electronic escape mode. So much technology use today is individual in orientation and seems to be contributing to this skewing of identity formation.

Perhaps in ECE at least, socializing children in the use of media should often have a real human, relational component. When they become adults, today's children will certainly be more ethical with technology (and probably more intelligent with it) if they are able to use 'Big T' cooperatively, together with real and present others.

Technology comes so naturally to today's children. But humane, productive, and socially enriching ways of using technology do not come so naturally. Adults need to guide children in forming pro-social kinds of connections around media devices, connections that start with learning communities that are humane, productive, and enriching — where children feel included and are encouraged to be inclusive toward others.

Kabir and his family have moved to a rural Minnesota community, and the almost five year old has just begun Head Start. Kabir sits on a large beanbag chair next to Wesley and Anna. He watches them play a game on an iPad. After a short time Anna says, "It's your turn now, Kabir." Wesley agrees, hands the iPad to Kabir, and moves to sit on the other side of him. Anna and Wesley coach Kabir on how to play the game. Austin walks over and asks if he can have a turn. "Kabir's using it," Anna tells him. "You have to wait." After Kabir catches onto the game, Anna and Wesley sit back and watch. Elissa, the teacher of these four year olds, observes the whole thing. She causally asks the children what they are doing, and Anna explains. After about 10 minutes with the iPad, Kabir gives it to Austin. Elissa can't stop beaming.

(Source, author observation of videotaping: Elissa Braaten's Head Start classroom, Detroit Lakes, Minnesota 2012.)

Engineering

A definition of engineering (from my Microsoft Word system dictionary) is: "The branch of science and technology concerned with the design, building, and use of engines, machines, and structures." Children become nascent engineers every time they use hands-on materials during the classroom day. Everything from beads and puzzles to Legos®, blocks, and carpentry constitute valid, developmentally appropriate engineering experiences (meaningful practice at designing, building, and using objects). A child who draws a

The teachers at a child care center wanted to have a carpentry center. They found an old solid workbench-sized table and cut the legs short. They got soft pinewood scraps, sturdy nails, and 8-ounce 'household' hammers from a building center. At a class meeting they explained the center would only be open when an adult could supervise; only two children would use the center at a time; children would need to wear safety glasses; and there would be a sign-up sheet.

It was Senouri's turn at the table. She whispered to the teacher she was going to make 'a plane.' She got two pine pieces and began to nail them together criss-cross. One nail was mostly in. She was starting on the second when she hit her thumb. Tearing up, she put her thumb in her mouth and turned around to look for the teacher. She saw two children waiting to take their turns at the table, turned back around, and kept hammering! Senouri got her plane nailed together and asked the teacher if she could paint it orange like her brother's remote control airplane. When mom picked her up, Senouri proudly showed her the creation. The teacher was there, too, and told mom how Senouri had showed real grit in finishing her project. Senouri took home her own orange plane with quiet pride. This anecdote is from many years ago; bet she still has the orange plane she made.

(Source, author observation: Kristin Anderson's First Learning Circle Preschool, Bemidji Minnesota, 1982.)

map from her home to the school is engaging in prototype engineering activity. So is a three and a half-year-old who uses a hammer and nail at a carpentry table.

Since having a carpentry table in my Head Start classroom back in 1967, I have been encouraging ECE teachers to include carpentry (this most fundamental form of engineering) in their classrooms ever since. Taking the precautions mentioned here, I have never heard of a serious injury.

The reality is that too many adults have had limited opportunities to use building tools, especially hammers and nails, during their formative years. If we want girls and boys to think of themselves as potential engineers, or at least as handy at building and repairing things, we need to provide them with repeated, practical building experiences as they are growing up. If STEM means that modern education focuses a bit less on two-dimensional test preparation and a bit more on practical three-dimensional engineering experiences, we should be all for it! In the arena of prototype engineering, ECE should continue to lead the way.

Math

Long-time kindergarten teacher Pat once told me that she often used 'a fish cracker math curriculum' and did a lot with subtraction!

One day Pat is doing an individual math activity with Chris. The teacher and Chris have put four fish crackers on a napkin and Pat asks, "Chris, can you count them and tell me how many there are?" "Don't need to count them, Pat," says Chris. "There are four."

"Now eat two," says Pat, which Chris happily does. "Now how many do you have?" "Four," says Chris. Pat frowns, and kindly tries to scaffold, "No, you had four, Chris, but you ate two. So how many do you have?"

Chris, now scaffolding for the teacher: "Four, Pat. Two here," Chris points to the table, "And two here!" he points to his stomach. Pat laughs out loud and says to Chris, "You are right. You have two on the table, two in your tummy, and that makes four. I couldn't fool you, could I?" Chris says, "No way," and asks if he can eat the other two crackers. A doctoral student at the time, Pat nods and may have muttered, "Piaget's got nothing on you, kid!"

(Source, author interview with Pat Sanford, now retired kindergarten teacher, Bemidji, Minnesota, circa 2000.)

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Piaget held that as children transition from the magic and charm of the preoperational mental stage to the 'crackers-on-the table' concrete operations stage, they begin to perform a key cognitive operation called 'conservation of quantity' (Gartrell, 2012b). The idea is that as children become more sophisticated in their thinking, they realize that quantities can remain the same when their appearances change. Chris indeed gave a sophisticated, developmentally advanced response to Pat's question, an answer that another teacher might have concluded was naively simple and wrong.

After many years of observing young children, my perception (different than the conventional wisdom on the topic) is that they move fully into the concrete operations stage at any time between about age five and eight. Until they do, young children can think perceptively and intelligently about quantities as long as they have objects before them that they can manipulate and group together (such as eight counters next to the numeral eight).

A widespread concern about math curricula for young children is that teachers too often force them into numeral-based exercises before they have progressed from needing hands-on materials to think mathematically. The archetype example is the 'power test' — requiring young children to complete numerous problems of addition and subtraction 'on the clock.' Especially if used before children have made the transition in their numerical thinking — and most especially if a teacher makes the stakes high by publicly

comparing children's scores — power test type mathematics seems a sure way to teach not basic math concepts, but basic math anxiety. The case of Chris teaches us that effective mathematical teaching and learning starts with the teacher-child relationship: the teacher knowing the individual child and being open to understanding how the child thinks.

Developmentally Appropriate STEM

The key to DA STEM is not the efficient instruction of teacher-led, pre-set science lessons. In John Dewey's hallowed words, it is the teacher's ability to "psychologize the curriculum" (Gartrell, 2012). As I see it, this means the ability to use trust-based relationships with children to nudge them into perceiving openly, acting with materials creatively, and interacting with others cooperatively about their efforts and discoveries.

DA STEM cannot happen by itself. To effectively implement STEM, teachers need to bring intentional openness to new teaching and learning opportunities. They need to work at organizing intriguing learning opportunities. They need to nurture and celebrate children's amazing responses while doing activities. Energy, organization, and reflective enthusiasm are required on the teacher's part.

Developmentally appropriate STEM is holistic. For the child, scientific problem-solving, artistic creative expression, and building and using meaningful structures all take similar self-affirming, brain building exploratory processes. Interaction with others about these experiences is natural, and positive interaction, especially with adults, is vital. Some of us consider STEM in early childhood education to be better thought of as STREAM: science, technology, relationships, engineering, arts, and mathematics.* But let's give the STEM proponents their due. Girls as well as boys benefit in lasting ways from ongoing science- and math-oriented experiences that involve hands-on materials — as well as regular shoes-in-the-woods encounters with the outdoors. If DA STEM helps children to open their senses to the world around them and to more fully interact with and learn about that world, this is a trend we, in early childhood education, should embrace.

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