CHAPTER 2

Methodological Approaches to STEM/STEAM Learning

What methods and approaches will schools use to train teachers to implement STEM and STEAM learning? The answer unfortunately is: The same methods we have been using for everything else! We can investigate why this is so by looking at how methods and ideas for organizing classroom learning become available to teachers. For the purpose of this discussion, a teaching method is a tool that can be reused to achieve a planned result or outcome. Teacher-preparation programs typically provide new teachers with many opportunities to try out different established teaching methods. The variety of teaching methods available to the profession is beyond the scope of this discussion, but it is safe to say that there is no shortage of access to methods thanks to the Internet. Teachers also benefit from professional development (PD) opportunities provided by schools and school districts. The PD provided by schools figures prominently in how new methods are integrated into teacher practices. School administrators can provide motivation for teachers to take PD classes/seminars/training in the new methods and ideas that a school or school district has decided to budget for. The other way that teachers learn new methods is through additional state-certified professional licensing or through non-degree certificate programs. I can often tell where certain school districts are focusing professional development budgets by the phrases and acronyms teachers use when talking about teaching. One very prominent phrase I've heard over the last 10 years is "student-centeredness."

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Thoughts on Centeredness

A "teacher-centered" methodological approach to creating learning environments features the teacher as the prime motivator of what happens in the classroom. Teacher-centered methods include the lecture, using the blackboard or electronic whiteboard, reading to students, demonstrations, and questioning students. The teacher also decides (as far as the students are concerned) what topics will be learned and how students will learn them. The progressive movement in education and curriculum design has trended away from teacher-centered approaches to student-centered approaches. Student-centered approaches have been proposed as a way to organize teaching in school systems since the late 1890s to address the specific learning needs of students (differentiation) and to respond to low student achievement in schools (Franklin 2005). Most student-centered approaches to teaching allocate the majority of time in a lesson for students to be engaged in cooperative or collaborative activities with peers.

"Centeredness" in learning environments means that there is a focal point around which instruction revolves. In my opinion, talking about whether classroom instruction is teacher-centered or student-centered obscures or oversimplifies the complex cognitive, social, and emotional interactions that teachers and students are having in the classroom. I have heard many educators claim that practice in the classroom is student-centered. However, it is impossible to determine what exactly is going on in the classroom simply because it has been labeled "student-centered."

I see "student-centered" as being a kind of shortcut phrase for describing what happens in the classroom. This shortcut to communicating may be helpful when we do not want to or need to take the time to provide the specifics of student-centered activities. The shortcut does not help when we are trying to find new ways of thinking or innovating in the classroom. What I do think will help is teacher narratives. I've noticed that teachers tend to tell stories about what goes on in classrooms. The stories contain rich descriptions of social interactions in the classroom. Sometimes there are interesting digressions to provide listeners with historical background, and there is often a point being made about teaching in that particular circumstance. These narratives are a genuine and powerful means of engaging adult and youthful learners. To create developmental STEAM learning environments, we are going

to have to tell each other stories. In the next section, I will tell an ironic story about learning to use project-based learning (PBL) as a methodology in the classroom. Training in project-based learning has emerged as a popular method for preparing teachers to use student projects as a way to make STEM and STEAM interdisciplinary learning fit into the existing curriculum. PBL training comes with a system of forms and instructions to produce a documented process (unit plans and lesson plans) that will ultimately result in descriptions of student learning outcomes that are tied to explicit learning goals, standards, and products that demonstrate evidence of learning. What follows is an experience in observing and participating in teacher professional development that features project-based learning.

Project-Based Learning Professional Development

During the summer of July 2014, I was invited to attend three all-day professional development sessions with approximately forty teachers in an elementary school. The focus of the professional development was to initiate the creation of PBL unit plans for the upcoming school year. The PD implemented the PBL methodology of the Buck Institute, widely considered the gold standard in PBL training. The trainers were educators who had received Buck Institute training and were very familiar with the schools and school districts the teachers came from. The training was typical of other PBL workshops I have attended. The trainers were knowledgeable and were able to bring computer technology and lesson planning resources to bear that have been shown to be useful in a variety of schools in the district.

Typically, at the beginning of a PD workshop, attendance is taken, teachers drink coffee, eat bagels, and workshop organizers hold off on starting the day until they get close to the expected number of attendees. When that happens, the workshop organizers start making introductions and remind teachers to sign attendance sheets so they can receive what is known as "per-session" training pay. On this occasion, the workshop leaders introduced me as a researcher and a university-based partner. I had an opportunity to introduce myself and speak to some of my priorities, and I took a few minutes to teach and play an improvisation game. The game, "Yes, and" creates a collective story and is designed to help players listen to, accept, and build upon the conversational "offers" that others may contribute in the telling of a collective story. I find that this

is a useful game to play when I anticipate being in environments where many people will begin their comments with "No, but" or "Yes, but," which work to negate what has been said and brings conversations to a halt or initiates a dispute. The "Yes, and" collective story is one of my methodological tools for creating developmental learning environments.

The workshop plan was for the participants, all pre-K–5 teachers from three different elementary schools, to work in groups and use instructional technologies, such as laptop computers, the Internet, Google Apps for Education™, to develop STEM-based PBL unit plans. Their PBL plans required identifying a problem and developing a curricular unit that resulted in solutions to the problem. They were required to produce documents using PBL management templates and Web-based resources set up by the school district to provide teachers with easy access. In addition to the materials listed above, teachers also had curriculum maps (a schedule of the content to be taught each month) for the grades they taught and the appropriate Common Core State Standards.

As teachers began to work, I became aware of some resistance to the new ideas and some of the work. Some teachers rejected offers of help. Some teachers seemed to be working on using the PBL framework to retrofit classroom projects. Others appeared to be continuing work started in an earlier workshop. Many of the teachers I worked with had chosen their individual comfort zones as a starting point for a PBL-integrated lesson and were trying to identify a relevant problem to associate with the project unit they were developing. Over the course of the 3 days, even as the teachers became increasingly comfortable with the PBL framework, they struggled to align the standards, curriculum, and ideas. Many teachers experienced frustration at trying to "make it all fit" into their existing understandings of their teaching contexts. I hoped people would remember the "Yes, and" performance when they wanted to say "but," however, many sentences started with the word *but*.

Disequilibrium

According to some of the research literature on teacher professional development, disequilibrium is a necessary component of teacher learning (Opfer and Peder 2011; Wilson and Berne 1999). Existing practices and beliefs need to be challenged for teachers to learn something new. Teachers' responses to the PD were consistent with the research literature. Some teachers demonstrated "resistance" to the experience; I

interpreted the failure of participants to make eye contact with the lecturer, their reluctance to ask questions, and their tendency to make statements that began with "but" to be an indicator of this.

Another phenomenon that is identified in teacher professional learning research is that teachers will not adopt new approaches unless they see the benefits regarding improved student achievement (Adey et al. 2004). During the workshop, some of the teachers I interacted with expressed concerns about making PBL structured projects fit within the realities of a school day, meeting the expectations of administrators, aligning projects with standardized testing, and teaching the students. Many teachers who made references to standardized testing said that they could not see how PBL prepared students for the test. Given these conditions, it was reasonable to expect that teachers would continue to resist adoption of new technologies and new methods until they saw the benefits.

Interdisciplinary connections across content areas are part of the natural progression in a PBL unit plan. Teachers with more experience and subject-matter expertise had less difficulty seeing interdisciplinary connections than less experienced teachers. One group of less experienced teachers admitted that they needed to do more research for their interdisciplinary unit on the migrations of native North American peoples. I thought, if the goal of a PBL unit is to generate a process of inquiry, why did teachers feel they had to know the answers in advance? Why could not students and teachers discover things together?

The relevance of instruction to the lives of students is another key feature of PBL instructional units and is one of the objectives of the U.S. Department of Education Magnet Schools grant that funded the teacher professional development at the school I was visiting. In these types of workshops, teachers make decisions about what students will learn based on the curriculum and standards. It was not clear to me how much input students or the community were expected to have in these units. In my interactions with some teachers, it was unclear whether they had an understanding of the socioeconomic realities of the community they worked in or how their social class biases might lead them to take certain things for granted about the lives of their students when making decisions about the relevance of PBL units. For example, one group was planning on having third-grade students create a travel brochure for visiting the Galapagos Islands. I couldn't see how the lesson plan related to the lives of the children in that community, and those

connections would still need to be made in the lesson plan, if indeed they could be made.

I observed that experienced teachers seemed to be able to increase pedagogical options in the PBL plans of less experienced teachers, and they seemed willing to share and provide guidance. The beneficial impact of experienced teachers on novice teachers is consistent with some research findings (Adey et al. 2004).

PBL is process oriented, inquiry driven, and presumes an iterative development cycle. The tendency of some traditional approaches to teaching is toward facilitating knowledge acquisition by explaining and motivating students to complete the task. Some units ended with a final assessment of whether or not student-created products met the criteria established by standards. Workshop leaders noted during the workshop that starting the actual hands-on project work at the end of the unit as the assessment instrument was an indicator of teachers' thinking in more traditional terms. The PBL process uses hands-on activities to raise questions throughout inquiry learning units. Based on my observations, it was evident to me that many teachers in the room did experience disequilibrium and were struggling with new ideas. At one point in the workshop, one facilitator did remind teachers of the "Yes, and" story in response to a series of statements where different teachers were saying, "but." It is not the first time I observed someone reaching for an improv method in a moment of frustration.

Dispositions

During the lecture portion of each day, I observed many teachers with "eyes on screens" or who refused to make eye contact with the speaker. That this was frustrating for the trainer was evidenced by the phrase, "You need to pay attention to this." One possible explanation for this behavior is that the teachers were multitasking. I am sure that many workshop participants would claim to have been multitasking. I did see some laptop screens showing e-mails, the PBL forms, and other relevant looking materials. Another explanation, as previously noted, is "resistance," which may be due to indifference, embarrassment at not knowing the material, being unprepared, or being bored. Alternatively, trainers may have mistaken lack of eye contact for lack of teacher understanding. Teacher resistance is a source of frustration in PD environments for trainers and workshop participants alike. The professional development

literature helps explain and diagnose teacher resistance, its forms, and possible treatments. But getting to the root causes of the symptoms is not one of the things that can easily be accomplished in a PD workshop.

I engaged in conversations with several teachers and was heartened by their enthusiasm and willingness to plan to take risks with the material. Several of these teachers had already been given formal leadership roles as Magnet school specialists. These were senior teachers who self-selected and interviewed for teaching positions that would be funded through the Magnet Schools grant. These teachers were highly motivated and willing to take on significant challenges, and their performance at the workshop was different from many of the participants. Other teachers were being paid by the hour during the summer to be in the workshop, but their performances told different stories about their reasons for and comfort with being there. I felt that this was a clue to moving beyond describing and diagnosing teacher resistance and toward understanding it.

There are many approaches to providing teachers with support in examining their expectations for students and their beliefs about learning. The best type of support comes from peers and opportunities to reflect openly on teaching practices. In this professional development workshop, there was a plan to provide opportunities for reflection and to use the Critical Friends protocol for feedback. The Critical Friends protocol originated from work at the Annenberg Institute for School Reform at Brown University. It is a type of professional learning community that is designed to structure peer interactions to improve teaching (Moore and Carter-Hicks 2014). The Critical Friends process has a set of protocols, including as a first step the implementation of a "tuning" protocol that provides the group with practice in going through each of the steps in the process together. The outline described by Moore and Carter-Hicks specifies 68 min from introductory activity to closing debriefing (Moore and Carter-Hicks 2014, p. 7). However, circumstances drove workshop facilitators to cut short the feedback and reflection portions (20 min) to cover PBL curriculum development issues. Time for reflection and feedback was traded away for covering the curriculum. I have participated in the Critical Friends protocol and have observed others using it. I view the protocol as a highly scripted ensemble performance. On this occasion, I was an observer, and the interactions seemed a bit rushed. It was hard for me to determine how anyone felt about the process. I do think that the reflection portion is as important or almost as important as the content/curriculum of the workshop.

I think understanding how people felt about the process would (1) help improve the process and (2) probably provide insight into what the take-away for teachers was.

In my opinion, the 3-day PBL workshops proceeded along familiar patterns and would be recognizable as being of high quality despite the varied levels of enthusiasm. The teachers responded along the lines predicted in the literature on teacher professional development. A few days after the workshop, I provided workshop organizers with feedback on the training. The specific feedback is not relevant here; I responded to them with suggestions coming from a best practices perspective. My goal was to continue to build my relationship with these teachers and schools, and that meant I had to work with what they offered, which was an opportunity to provide useful feedback on their terms.

Many teachers feel like they do not have a choice when it comes to professional development, and choices are difficult for PD trainers to create. Empowered teachers, such as those identified leaders (the Magnet school specialists) in a PD workshop environment, will exhibit enthusiasm. The Critical Friends protocols can work when they are routinely part of teacher practices in schools. In my experience, in schools where new ideas take hold, teachers believe there are opportunities for choice making and risk taking. Teachers are also receptive to new ideas if they think that administrators trust them and that they can trust their colleagues. A suggestion I would offer is that schools invest the same effort in creating trusting environments as they do in developing professional knowledge and other professional practices.

Systematic Approaches

Based on my observations of efforts in STEM education, I think that PBL will be the approach that many schools will take toward STEAM education. Collaboration and creativity in classrooms will also be encouraged in STEAM teaching and learning. However, it is still unclear whether creativity and collaboration will be central to STEAM education practices or be viewed as add-ons to what I regard as a systematic approach to learning in schools. Systematic approaches to learning in school sequence and coordinate learning activities. A measurable outcome can be described when the learning process is broken down into distinct steps. For example, “the student will be able to write her name,” is a measurable outcome.

When we compare early childhood learning, such as the type that toddlers are engaged in, to formal school-based learning, the differences become apparent. The developmental performatory learning of children outside of school may include, for example, a child's exploration of a living room. The exploration of a room by a child has many possible outcomes, some that are observable and many that are not. The outcomes of an exploration may not be measurable. What a child learns in the exploration of the room may not have direct, causal relationships to what develops and is not predictable.

In a learning activity that is systematic, for instance in a kindergarten classroom, a morning routine might involve children signing into the class by writing their names in crayon on a large sheet of paper. Name writing is re-enforced through the systematic instruction of the alphabet, posting the children's names on personal items, and having them practice writing their names on worksheets and other items. As the school year progresses, teachers will have documented the progress of each child's ability to write her name and form the letters of the alphabet. The expected outcome of instruction and immersion in the production of text is a child who can write her name, recognize letters, and form and space the letters to create words. There is no doubt that a system of learning helps with measuring learning and ensuring that students have opportunities to learn the things that are a priority. However, a systematic approach to learning only recognizes or values the expected outcomes. We cannot discover other important things about children if we only use systematic methods. Fortunately, kindergarten and other elementary school teachers do many things that are, in my view, performatory.

Performing With(in) a System—A Slight Digression

The morning sign-in activity is a non-threatening, formative assessment strategy that is also fun for the students. Elementary school teachers also perform many unsystematic formative assessments of children and their families in daily interactions. For instance, elementary school teachers note how parents and children perform the morning routine. They consciously and unconsciously track changes in the routine, making note of troubling drop-off incidents, children who look sick, or changes in the drop-off caregiver. Any change to the routine may trigger an improvisational response from the teacher. I've known many excellent elementary

school teachers who are great improvisers and astute observers of children and families. Those skills and approaches to assessment are performatory and vital to creating welcoming and safe environments for children. In less happy circumstances, where teachers have much less autonomy and do not perform, bureaucratic (systematic) responses prevail, and there is little evidence of development, improvisation, or good conditions for learning. I have worked in hard-to-staff schools, failing schools where the systematic approach to learning dominates, and there are many unpleasant trips to the principal's office. I have had many conversations with teachers about "the system," where they tell me that the system does not allow them to teach much less perform in the ways that I suggest. I encourage them to perform within the system and play with the system. I further remind them that teaching is a political act, and they have a civic responsibility to be advocates for children and families.

Irony and the PBL Workshop

A pedagogical approach like PBL prioritizes what is to be learned and documents it. A PBL may involve many well-defined tasks to produce one or more expected STEAM learning outcomes. However, if PBL outcomes must be predetermined, how will the possibilities associated with unplanned learning be recognized and valued? More important, if PBL and other recently used methods in progressive education are reused for STEAM, would there be justification for expecting different results than those for STEM or other initiatives to improve math and science learning?

I think it is ironic that the PBL method was not the method used to teach teachers in the professional development session described earlier in the chapter. Professional development workshops are product oriented. Teachers must produce unit plans for teaching, and the workshop is a process for production, not a process that prioritizes inquiry or facilitates the involvement of stakeholders (members of the community, students, etc.) in the development of the unit plans. For teachers, learning the PBL method can get disconnected from practicing the method. To be sure, many teachers do produce PBL units that are engaging and efficient in this manner. However, I question the sustainability of this approach. The PBL system generates a significant amount of documentation that details what students need to do, how activities will meet standards, and how student performance will be assessed. Unit plans

also include listings of required materials, interdisciplinary connections, differentiated strategies, and expected outcomes. Teachers will tend to reuse and perhaps revise units, but what will occur when there is a change in the curriculum or the standards? What will happen when a second-grade teacher is reassigned to teach the fourth grade and her PBL units are no longer relevant? Will she be offered someone else's fourth-grade PBL units? Will she find them appropriate for how she envisions teaching the fourth grade? What will happen when funding for teacher PD and new curriculum development efforts ends? A challenge of having any system is that it needs to be maintained and moreover that it can break when conditions or assumptions change. Another challenge of systems is that they encourage more systems, which can lead to fewer opportunities for creativity and autonomy.

Despite my questions about the PBL approach, I believe it is possible to use systematic approaches in creative ways. We can play and perform with the system and within the system if we need to. The value of project-based learning is that it does provide students with hands-on learning experiences. When a PBL unit is ambitious and well-designed, there are opportunities for collaborative learning experiences inside and outside of the classroom with peers and adults.

Experiential Approaches

Project-based learning provides a type of experiential learning. Experiential learning can include but is not limited to field trips, collaborative research projects, internships, service-learning, and study abroad experiences. Descriptions of experiential learning do not usually include imaginative play, rule-based play, team sports, improvisational performance, theatrical performance, and organizing public exhibitions. I believe the play and performance activities that I've added to the list are all forms of experiential learning that should be part of any approach to developmental STEAM education. Experiential approaches to learning provide students with opportunities to reflect on what they are doing and learning. The reflective process of experiential learning can be about more than generating a piece of writing that will be submitted at the end of a lesson. Reflection can be a part of an ongoing process that informs creative development. What I find most powerful about experiential approaches to learning is that they often take place in a "real world" context. When the outcomes are not overly predictable or predetermined, students must bring the

entirety of their being to bear on figuring out what they need to do, not just report on some knowledge they acquired. However, even experiential approaches to learning can be made to be as systematic as any other kind of approach. What makes one approach to learning systematic and another unsystematic or performatory?

The Math Video Project discussed earlier was designed as a developmental, performatory approach to learning. I could not predict the outcomes, and I did not predetermine what learning standards would be met. Furthermore, I couldn't claim that I "knew what I was doing" because I had never done it before. I was confident, however, that something positive would come out if it because students were being supported to collaborate, they were using new tools, and they had complex challenges that were relevant to their lives.

If I were to make the Math Video Project systematic, I would determine specific content knowledge to be covered by all videos. For example, using seventh-grade math content, the theme of the videos might be to understand the concept of pi. Each video would have to meet criteria that aligned with learning standards in mathematics and presentation skills. Each team member would be assigned specific roles in the project and would be responsible for specific tasks. There would be a test at the end of the production of videos to confirm that everyone learned something about pi. I would still expect to get a variety of videos, but they would all be about pi. The students would still have opportunities for choices, and they might still have fun and be engaged because they are using technology.

I do know that the overall experience would be different because I have done projects with students using performatory developmental approaches and systematic approaches. Students and teachers can become very comfortable with systematic approaches to learning because they know what to expect and what is required. Knowledge is acquired incrementally, and as long as a student does not fall behind, progress is predictable and measurable.

When I have used performatory approaches with middle school students, I upset the order of things. Students will ask questions about the requirements when they do not see many. They will express uncertainty about whether they are doing their projects correctly. Students will often discover that certain approaches to a project can lead to dead ends. Students tap into their personal areas of strength, and some discover things about themselves that they would like to improve. Many

students are often more self-critical about their performances than I would ever be of them. A performatory approach to teaching is more fun and interesting, and it creates opportunities for different kinds of wonderful conversations with students. The conversations that I have with students contain feedback that they can use to continue to develop their performances. I also build better relationships with students when I use performatory approaches. Experiential learning, especially when there are opportunities for "real world" interactions, creates development in many of the same ways that a performatory approach would. Experiential approaches to learning help create stages for performatory approaches to learning and development.

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