
AC 2012-4900: DEVELOPING ELEMENTARY ENGINEERING SCHOOLS: FROM PLANNING TO PRACTICE AND RESULTS

Elizabeth A. Parry, North Carolina State University

Elizabeth Parry is an engineer and consultant in K-12 STEM (science, technology, engineering, and mathematics) Curriculum and Professional Development and the Coordinator of K-20 STEM Partnership Development at the College of Engineering at North Carolina State University. For the past 15 years, she has worked extensively with students from kindergarten to graduate school, parents, and pre-service and in-service teachers to both educate and excite them about engineering. As the Co-PI and Project Director of a National Science Foundation GK-12 grant, Parry developed a highly effective tiered mentoring model for graduate and undergraduate engineering and education teams, as well as a popular Family STEM event offering for both elementary and middle school communities. Current projects include providing comprehensive professional development and program consulting for multiple K-8 STEM using engineering schools, serving as a regional partner for the Museum of Science, Boston's Engineering is Elementary curriculum program, and participating in the Family Engineering project. She currently serves as the Chair of the American Society for Engineering Education K-12 and Pre-college Division. Other professional affiliations include the International Technology Education Association, the National Council of Teachers of Mathematics and the National Science Teachers Association and serving on the Board of Directors for the Triangle Coalition for STEM Education. Prior to joining NCSU, Parry worked in engineering and management positions at IBM Corporation for ten years and co-owned an informal science education business.

Mrs. Emily George Hardee, Brentwood Magnet Elementary School of Engineering

WCPSS

Mrs. Lizette D. Day, Rachel Freeman School of Engineering

Lizette Day is the STEM Coordinator at Rachel Freeman School of Engineering in Wilmington, N.C. She has more than 17 years of experience working with at-risk students in K-12 public education.

Developing Elementary Engineering Schools: From Planning to Practice and Results

Introduction

The need for schools to try new and innovative ways to reach diverse groups of students is growing rapidly in K-12 schools. Traditional teaching methods and approaches have not proven to be consistently effective in addressing stubborn achievement gaps among students from different ethnic and socioeconomic groups (Reardon). Since the advent of standardized test scores under No Child Left Behind ten years ago, schools with large numbers of minority and/or economically disadvantaged children not only deal with the challenges of reaching all students but having their progress, or lack thereof, published. School leaders are constantly looking for new and more effective ways to engage their students in their own learning (and be able to demonstrate it), and in high poverty/high minority schools in general, both the need for out of the box and innovative approaches and the presence of federal and state funds under programs such as Title 1 provide a vehicle to try new things.

It's into this environment that the elementary engineering approach was introduced in our state. Six years ago in New Hanover County, North Carolina a high poverty and high minority magnet school was created when the district went to a neighborhood school assignment policy. The administrative team was allowed to choose a focus program to implement at the school. The principal and lead teacher, after investigating various models, decided to implement engineering, using a new curriculum from the Museum of Science Boston as a way to engage all students. At the same time, Elizabeth Parry at North Carolina State University (NCSU) had been working in K-12 classrooms directing a large National Science Foundation GK-12 project. Engineering is Elementary (EiE) was one of the tools her team used in both in and out of classroom settings, so she had been trained in the curriculum. The Museum of Science connected the two and the team formed a plan for a school that would use engineering as the integrator of all subjects, with every teacher and student participating. The genesis of the school was documented in a paper presented at the ASEE Annual Conference in 2008. (Parry, et al.)

Presently, five schools are implementing the model developed. All have diverse student populations in terms of race/culture and socioeconomic levels and they represent urban, rural and suburban areas in two states.

Table 1: Partner school profiles

School Name (Location)	Number of students	Student demographic profile (all grades K-5)		Current Year of implementation of engineering
		Racial Breakdown	% Economically Disadvantaged	
Rachel Freeman School of Engineering (Wilmington, NC)	321	White = 7% Black = 85% Other = 8%	91%	5

Brentwood Magnet School of Engineering (Raleigh, NC)	483	Asian = 3% White = 11% Black = 40% Hispanic = 43% Multiracial = 3%	79%	3*
Clarke STEM Elementary (Henderson, NC)	500	White = 13% Black = 69% Hispanic = 13% Multiracial = 5%	92%	2
Brunson STEM Elementary (Winston-Salem, NC)	500	Asian = 6% White = 36% Black = 17% Hispanic = 37% Multi-Racial = 4%	56%	1
Hephzibah STEM Elementary (Hephzibah, GA)	458	White = 59% Black = 39% Other = 2%	64%	1

*Brentwood was named a district priority school during year two based on several years of performance. All but 4 staff was transferred and a new administrative team was brought in. The new team underwent training in summer, 2011.

Developing the Model: Initial Professional Development

In late summer of 2007, the staff of Rachel Freeman returned to school a week earlier than their peers in the county to undergo five days of staff development to implement the engineering theme. The district funded both teacher stipends and professional development fees. Since the school had made the decision with Ms. Parry to use Engineering is Elementary (EiE) as a primary tool of the implementation; the schedule was structured around two and one half days of EiE training using the same format as the Teacher Educator Institutes run by the Museum of Science (Cunningham). This was preceded by a session about what engineering is and one on project/problem based learning. The Engineering is Elementary training session begins with a discussion and activities to help teachers understand the differences between science, engineering and technology. Elementary school teachers are often not confident of their knowledge of science content, so this is an important part of establishing foundational knowledge (Carson and Campbell). An overview of the curriculum structure is next, and the rest of the time is spent working through a kit or kits to give teachers insight into the student experience of the curriculum. The teachers, in this way, move between the “teacher” and “student” roles to get a broad perspective.

It is not unusual for children from economically disadvantaged homes to enter kindergarten with fewer experiences and early childhood education than their more affluent peers (Reardon). Because of this, the team decided to not use the EiE kits in grades K-1, but rather to focus the establishment of foundational skills the children would use throughout their elementary years at Rachel Freeman, enabling them to participate in the engineering implementation fully as they moved up (these are discussed later in this paper). To implement engineering principles, the K-1 teachers, the school’s STEM coordinator and Ms. Parry devised smaller engineering projects that were tied to the literacy program the school used. For the first two years of the engineering implementation, the school was a “Reading First” (Department of Education) school, which

meant that the lower grades had a 90 minute uninterrupted block of reading time each day. The reading program was thematic, so the team began to develop small projects that tied to a story that was read during a three week theme. For example, when first graders read “Caps for Sale”, the students were asked to design a hat that would stay on their heads for 30 seconds in front of a fan on medium speed. In this way, engineering could be introduced in a content area the K-1 teachers felt competent in. Another way engineering was integrated into the day for the youngest students was to re-examine projects and activities, typically arts and crafts, the teachers had already been doing to “engineerize” them, or look for ways to add constraints and criteria on the front end and a way to evaluate or test those on the back. For example, if in November a teacher’s habit had been to have his/her children color a drawing of a turkey for Thanksgiving, the project was modified to add the criteria that the turkey lived in a certain climate (i.e. snowy or desert or one that has trees who leaves turn bright colors in the fall) and that they did not want to be “caught” for Thanksgiving. The “test” becomes an evaluation of how the children disguised their turkeys based on where they live. For example, if a student had a turkey who lived in a snowy area then “camouflaging” it by coloring it with brightly colored crayons would indicate the student did not meet the criteria. This is also a way of assessing understanding of the weather/climate science they cover that year.

In addition to using engineering and the Engineering Design Process as defined by EiE (Ask-Imagine-Plan-Create-Improve), Ms. Parry introduced the staff to the idea of using STEM notebooks in their classrooms as each student’s record of his/her own learning. Very little was available at the time about STEM note booking but as an engineer, Ms. Parry knew the professional practice of engineers keeping documentation of their work. This combined with the then available research on science notebooks in elementary schools (Ruiz-Primo and Li) provided the basis for training. To model the process, Ms. Parry gave each participant their own STEM notebook and gave feedback each evening on the day’s prompts and reflections. Further information on STEM notebooks is provided later in this paper.

Teamwork was another topic of the training. One of the most important aspects of working and thinking like engineers is working in teams. Initially, both the team and the teachers felt this would be fairly simple for them to implement, given their experience in grouping for academic reasons, such as ability grouping for reading or math. However, the reality was that these children were exposed to a significant amount of stress and tension in their daily lives, and that was brought to school with them. While instruction in language arts and math can be effective in small groups, it is still an individualized instructional approach based on the child’s benchmark testing against competency expectations. Structured engineering design challenges require a multiple person effort to be successful in meeting the constraints and criteria. The ability to work together for a common goal was not prevalent in the first few years at Rachel Freeman, particularly in fourth and fifth grade, and this was a focus of several half day professional development sessions and ongoing work by the staff and administrative team.

One of the key sessions of the week focused on the culture change necessary for a successful implementation. Ms. Parry facilitated a long discussion to develop the school’s new mission and vision statement to reflect the change in focus. The teachers were highly invested in this activity, as it had become clear this was a very different and new way to do things at their school, and they took this responsibility to articulate it very seriously. The vision developed by the staff

simply states:

“We will achieve social and academic excellence utilizing the engineering design process.” The mission statement was also carefully crafted and states: “We are a community of student engineers who use team work, communication, and creative thinking to solve problems as we build dreams and become lifelong learners in a global society.” One of the more interesting discussions about this statement was the need to include teachers in the “student” category both to indicate their own recent introduction to engineering principles but also to reinforce the tenet of lifelong learning. The final activity for setting the tone was for the group to take an in-school field trip. During this session, we walked through each part of the school building, stopping along the way in key areas to determine what changes we could make to “Scream the Theme” of engineering. The goal was to establish, immediately upon entering the facility, that Rachel Freeman was a different kind of school, a student centered learning environment that taught problem solving through engineering. In the main lobby, staff decided to move in existing display cabinets from other parts of the building to show student work. They devised a large poster with the new mission and vision statement on it, together with their new gear oriented logo. A brightly colored Hoberman sphere was hung from the ceiling, as was a model of the space shuttle. The lobby was transformed into a bright welcoming place where engineering was front and center. Other changes the staff made were to install street signs on each of the hallways using engineering related terms as Innovation Way and Problem Solving Parkway. Inspirational posters about engineers and engineering were hung from the ceiling so children could see and read them while moving to encore (specials) classes or the cafeteria. This exercise proved to be extremely valuable for all stakeholders in the school as they assumed the mantle of engineering.

Developing the Model: Ongoing Professional Development

The professional development commitment and investment for both the schools and Ms. Parry was understood from the beginning to be long term. In year one at Rachel Freeman, the plan for monthly visits was developed prior to the start of school. On these visits, Ms. Parry might model an engineering lesson in a classroom. For example, when fifth grade studied technological design, she did an activity in which the student teams design a snack package to protect a S’mores sandwich from water, heat and dropping (WEPAN). In fourth grade, learning about volume in math led to a Diaper Dissection activity where the volume of yellow water it takes to saturate a brand name diaper vs. a store brand diaper was collected, compared and analyzed. Whole group sessions were held on early release professional training days. In these sessions, the focus was on particular aspects of the implementation, such as effective teaming, STEM notebooks, integration, science content and assessment.

On bi-monthly visits starting in year two, Ms. Parry met with grade level teams during their planning time to discuss issues specific to that grade. When the physics of sound was being taught in second grade, she held a session on the science content behind waves and vibration, and pitch and frequency. This type of session has proven to be most effective for professional development time during the school year, because it provides grade level specific dynamic feedback in that it can be structured to provide immediately address issues and concerns in real time vs. reviewing it later. The STEM coordinator at the school is essential to a sustainable implementation, as she/he is the onsite expert and resource for teachers, students and administrators. At Rachel Freeman, the STEM coordinator (who had been the school’s

technology teacher) was a driving force in the implementation, providing teachers with expertise, ideas and materials for engineering, coordinating and later co-presenting with Ms. Parry in staff development, and serving as a liaison to not only Ms. Parry but to parents and community and industry resources. At Rachel Freeman, the STEM coordinator and Ms. Parry decided together how to structure each visit to the school based on the needs of the teachers.

Schools specialists participated in all professional development sessions. Meeting with them during the school day when grade levels met proved to be problematic in that they typically have the students during teacher planning time so their own planning time is staggered. Specialists were expected to use STEM notebooks as well, so the children carry those when they go to art, PE and music. When the school was changed to engineering, the district funded the installation of Smart Boards, document cameras and other instructional technology in each classroom. Each teacher received a laptop, and all classrooms had five computers. There was, therefore, no “computer” or “technology” special, although there is a computer room where teachers bring classes for whole class instructional technology activities and some assessments. The installation of these took place over the course of the first year, and since then the teachers have received voice magnifiers to wear during instruction as well. It is important to note that the implementation of the engineering plan did not depend on the instructional technology; i.e. a school does not need an extensive array of technology to effectively implement engineering.

One of the most important tenets of the model is the commitment from the administrative team and the staff that every teacher and every child will participate in the engineering instruction. This is essential to creating a community of practice utilizing the foundational skills of the engineering design process, working intentionally and productively in teams and documenting learning through STEM notebooks. The end goal is a culture change in the entire school community and wholesale adoption, while it can be intimidating to some, is the most efficient way to accomplish this.

Subsequent Implementations: Using Lessons Learned

During the first two years at Rachel, we were able to refine aspects of the model we implemented in our quest to have a repeatable and sustainable offering for other schools, while at the same time leaving space for local adjustments. During this time, a second school district visited Rachel Freeman and made the decision to implement a similar school at an existing under enrolled building in their county. In this case the existing staff was assimilated into the new theme and they began training in the spring prior to implementation, with a three day summer session just prior to school starting. The interest in the idea was growing both within and out of state, and through advocacy; a small grant from the Department of Education funded Ms. Parry’s efforts to replicate the model elsewhere in the state. Since then, two other schools have implemented in North Carolina, with two additional schools starting in fall 2012. Similar efforts are being implemented in Georgia and Louisiana, and Ms. Parry has coached schools seeking a similar program implementation in other states. With each implementation, the model is more finely tuned toward a goal of a sustainable and replicable model for other schools and universities to adapt.

Defining the Model

While each individual school maintains some unique aspects of their implementation, the process has allowed us to define—and refine—many core aspects of the model. In November, 2011, teams of four from each of the partner schools came to NCSU to network and begin to establish a baseline for what this implementation strategy looks like initially, several years in and long term. All partner schools share the challenge of student populations that are high poverty and/or high minority. All professional development has been done by Ms. Parry. All implementations at partner schools share foundational practices, although their implementations of these may vary:

- *A committed administrative team with high expectations for all teachers and all students, plus an ability to navigate the “system” to allow for exceptions or flexibility on district pacing guides and reporting tools which still stressing the absolute of teaching the Standard Course of Study effectively.*
- *Understanding and commitment through schedule manipulation of the importance of including engineering in the day.* For example, one school combined math and science instruction into a 2-2 ¼ hour STEM block of instruction each day. Through weekly planning with the STEM coordinator, teacher grade level teams decide how to divide that time to include direct instruction in math, assessments, science and engineering. Some weeks there is no engineering while science is being taught, some weeks it is the opposite. Other schools schedule blocks of instructional time for engineering in the STEM lab.
- *STEM coordinator on staff.* Some schools use the STEM coordinator as more of a teacher resource, or one who plans with the teachers how the integration of STEM using engineering will be implemented and when, provides materials and resources and coordinates/conducts training alone or with Ms. Parry. Others have dedicated STEM “labs” where teachers bring their students for integrated STEM using engineering lessons and activities. The two coordinate the lessons and share co-teaching (Perdue) responsibilities.
- *Sufficient curriculum and materials access and support.* Since engineering projects in these schools is correlated to the science standards, typically teachers will teach the science goals for a quarter for about seven weeks and then spend two weeks on an engineering project or unit. This is accomplished primarily in grades 2-5 through implementation of the *Engineering is Elementary* curriculum correlated with grade level science goals. In fifth grade, for example, students learn the science of ecosystems. The engineering kit is “Cleaning up an Oil Spill” based on the work of environmental engineers. A successful implementation requires not only that science instructional kits are available and ready to use, but that EiE teacher guides and materials kits are also available. Additional materials to support the K-1 small projects and additional integrated projects in other grades and specials must also be readily available. These are typically commonly found and inexpensive (many are simply recycled materials sent in from home) but a storage room and organized storage plan removes many teacher trepidations about doing the activities.
- *A focus on the development of three foundational skills in grades K-1: Learning the engineering design process of Ask-Imagine-Plan-Create-Improve; how to work productively and intentionally (with a purpose) in teams; and how to document their learning through the use of STEM notebooks. These skills are reinforced in grades 2-5.*

- *Involvement of the staff in the school's direction.* This is accomplished through professional development sessions, professional learning communities (PLCs)-vertical and horizontal, school improvement teams and the school improvement plan.
- *A commitment to involve both parents and the community, including industry, in the school's mission of educating students to be problem solvers.* This is accomplished through several vehicles. Family STEM events, using materials developed by Ms. Parry under an NSF GK-12 grant (Parry, et al.) and other materials such as the Family Engineering resource as well as teacher suggested additions, are held several times a year by partner schools. This gives parents an opportunity to not only participate in simple yet engaging integrated STEM using engineering projects and activities alongside their children, but also to showcase the unique approach taken on by the school and it's staff. These events regularly draw in several hundred parents. Community partners are also sought. At Rachel Freeman, GE Nuclear engineers serve as classroom mentors for teachers. They help teachers to understand some of the science and engineering content but primarily they serve as mentors for special projects such as the Fifth Grade LEGO Mindstorms competition and Engineering Week activities. The schools have implemented STEM instead of Science Fairs, STEM Career Days and Engineering Week whole school activity days with community volunteers.

The November meeting presented a unique opportunity to access a wide variety of perspectives on the model to date. Present were administrators, STEM coordinators and classroom teachers from each school. The challenge was to use a short amount of time to capture a wide variety of aspects of the project from widely varying perspectives. The opening session was spent familiarizing the attendees with the partner schools and their progress in integrated STEM using engineering. Then Ms. Parry, serving as facilitator, led the group through the development of the day's agenda, using the Open Space facilitation technique (Stadler). In Open Space, participants are presented with a blank agenda subdivided into multiple sessions per time period. Paper and markers are placed in the center of a circle of chairs where participant sit. The facilitator describes the process and the agenda is developed over the following 30-45 minutes. Each participant is invited to consider those topics of great interest or importance to them that would support the goal of developing a replicable and sustainable model of an integrated STEM using engineering elementary school AND that they would be willing to lead a discussion on. They then write that topic on a piece of paper, hold it up in front of the group, state their topic and affix it to one of the available session blocks on the board. Once all the blocks are full, the agenda is complete. The facilitator reviews the topics with participants, combining similar or related discussions based on group consensus. The objective was to structure an agenda that met the needs of the schools to further the implementation of the program. Through the discussion, Ms. Parry could achieve her goals of documenting the common practices, challenges and barriers and remaining issues for a sustainable model.

Table 2: Day One Agenda developed by group

Opening Session 9 am-11:45	Introductions, School Overviews, Meeting Goals, Explanation of Open Space Facilitation Technique			
Session A 12:40-1:35	K-1 STEM (non EiE	EiE/EDP Integration in all	School wide Events	Creating Teacher buy in

	activities)	subjects (combined with STEM and Literacy)		
Session B 1:35-2:30	Implementing a STEM Lab (combined with Materials)	Screaming the Theme on a budget (Combined with Fundraising and Materials)	Defining the IMPROVEMENT stage of the engineering process and how to facilitate and guide the intrinsic factor needed amongst students (combined with Ownership, Plan, Time Management)	Continuing Momentum
Break				
Session C 2:45-3:40	Parent and Community Partnership	Business and Community Partnerships (added Materials)	Extension beyond Elementary (K-12 and beyond)	How do we know we are implementing with a level of fidelity? What IS fidelity for STEM ed?
Closing Session 3:40-4:30	Progress Report/goal Check/Tuesday Plan			

During each session block, participants self-divided into groups based on their interest in the discussion. They could also choose to change discussion tables during the block. Notes were kept on each discussion and results of the discussion were reported out at the end of the day. In the last whole group session, the agenda for the second day, a four hour session, was developed.

The second day began with the group divided into teachers, STEM coordinators and administration. We asked them to discuss in detail the aspects of professional development and materials support from their particular standpoint. The goal was to broadly examine the two most critical components of enabling a staff to implement integrated STEM using engineering. The information gathered on both days of the meeting is still being compiled and analyzed and will be included in the conference presentation.

Assessment/Results

Assessment in a program that introduces a non-standard subject into the already packed school day is challenging. While some principals of high needs (and other) schools are willing to allow some leeway for their teachers to incorporate an innovation, the truth is they often don't have

much leeway themselves. The school may be under local or state sanctions for consecutive years of inadequate student growth, or it may be incorporated in a cohort of “focus” schools due to achievement levels or student demographic challenges. The “currency” in K-12 is test scores, and in our experience the ability to potentially impact those measures with any program brought in is a necessity. The administrative team may be able to reshape the school’s schedule, planning practices and professional development, but in the end the scores of the students in grades 3-5 on end of year standardized testing in reading, writing, mathematics and science are what determines whether they are deemed “successful.”

Therefore, the approach taken in this project is that by having the same high expectations for every child to actively learn through the engineering “lens” where application of skills in and out of context is expected, the test scores will reflect these abilities. At this point in the project, only two of the partner schools have been implementing long enough to have valid available comparison data.

Table 3: Summary of XX End of Grade Test Scores (Grades 3-5)

	% Overall Reading*	% Overall Math*	% Science**
Rachel Freeman¹			
Year 1 of Implementation	34.4	43.9	14.3
Year 2 of Implementation	51.1	69.1	45.8
Year 3 of Implementation	62.1	74.6	80.0
Year 4 of Implementation	56.2	70.2	67.9
Brentwood²			
Year Prior to Implementation	50.0	62.6	57.1
Year 1 of Implementation	47.3	71.5	36.9
Year 2 of Implementation	52.0	73.0	60.3

*% of students who tested at or above grade level in these subjects (3-5 grade overall)

**% of 5th grade students who tested at or above grade level in science

¹ At the start of the implementation, Rachel Freeman’s student body was 95% new to the school; therefore year one data serves as baseline

² Brentwood implemented the model with the existing student body therefore the year prior to one is baseline.

Another measure being monitored is the teacher turnover rate, since research has shown a correlation between the poverty level of a school and the rate teachers leave it. As noted by Ingersoll in a 2004 report, “The data show that high-poverty public schools, especially those in urban communities, lose, on average, over one fifth of their faculty each year.” (Ingersoll, 2004) The reasons are myriad and range from common reasons such as job satisfaction, pursuit of other jobs and compensation. However, a significant number of teachers who leave jobs in high poverty schools do so because of a lack of support from administration, too many interruptions in teaching time, discipline problems and limited involvement in school decision making. (Ingersoll, 2004). Half of the schools currently implementing this model of integrated STEM through engineering had flexibility in staffing; i.e. these schools were granted extended transfer option periods and/or expanded staffing to hire teachers who chose to come to the school because of the integrated STEM through engineering implementation. In those schools where the option to leave was granted, several sessions on the implementation plan were presented to the staff prior to the decision date. In one school where the transfer rate was extended, the first

year's effective turnover rate was 22%, or about twice the district's average. In subsequent years since implementation, the rate has ranged from 3-4%, or less than one half the district's average. At a school where the staff in place was expected to implement, i.e. they did not make the decision to become an engineering magnet, the turnover rate went from 21% the prior year (vs. a district average of 11%) to 12% the first two years of implementation (vs. 10% and 11% respectively in the district). At the end of year two, as one of the four highest poverty schools in its district, the school was named a "Renaissance" school and was reconstituted from the principal down. Only four staff members returned, including the STEM coordinator. The new staff came to the school from all over the country and committed to the job knowing the challenges and the curricular approach of integrated STEM using engineering. That staff underwent training prior to school starting in August, 2011.

As a part of a grant from the National Institutes of Health, Ms. Parry and colleagues from the College of Engineering and the College of Education have been conducting research on the efficacy of implementing engineering in elementary schools. Pre and post tests on teacher and student attitudes toward STEM and student competency and self-efficacy in engineering design and science were administered and an analysis of student STEM notebooks was done. Results of that work have been or are in process of being disseminated (Ernst, et al); pilot and field test data indicate statistically significant gains in both science content knowledge (field test) and engineering design content knowledge (pilot test) as well as in student STEM self-efficacy.

STEM notebooks are used by teachers for formative assessment. At all five schools, students keep STEM notebooks as a record of their learning. Initially, the STEM notebook was presented to teachers as the practice of real life STEM professionals, a way to document thinking and progress. This was a new idea for most of the teachers, and the combination of beginning note booking and deviating from their established routine regarding mathematics notes and papers was a challenge. Interestingly, the format of a notebook itself was a point of much discussion. In year one at Rachel Freeman, all students in K-2 used a marble composition book with the top half of the page blank and the bottom half in primary spaced lines. The upper grades had the same upper half but graph paper on the bottom. Notebook implementation in year one was inconsistent. For the kindergarten and first grade teams who have their students sit at shared tables with bins of supplies in the middle, the transition time for pre-reading and writing children to find their own notebook and get ready to do a reflection or writing activity was a problem. In the upper grades, use varied by grade level. In October of the first year, Ms. Parry came to the school for a half day professional development session. One month prior to the session, she notified the staff that they would be bringing their students' notebooks to the meeting to do a notebook share. The idea was to let them see what other teachers were doing to elicit student responses; however, it became a stressor for those teachers struggling with the implementation. At the session, the teachers had the opportunity to sit with non-grade level colleagues and really examine what their peers were doing. At the end of the session, each group reported out a few ideas they had learned. For example, one of the fifth grade teachers had taken pictures of her students participating in an engineering activity. The following week, she printed them out in black and white on copy paper. She gave each student their picture and asked them to do a reflection on how they felt when the picture was taken. The students were able to recall and reflect on the activity and their role in it given some perspective via time. Others shared their

ideas for how to structure, organize and elicit writing. The staff development session was the highest rated one of the year for the teachers.

The following year, grade level teams decided what form their notebooks would take. In the lower grades, binders were chosen by some grades due to the ability to personalize (making transition time easier), remove and add papers, and establish one source for all subjects. In one school, the fourth grade team reported in the first quarter review with Ms. Parry their frustration with the “one size fits all” STEM notebooks they had been given. We developed a plan for them to make the creation of the notebook a student design challenge. Teachers would provide a binder and a variety of materials for students to use to personalize and organize the notebook. The criteria were that a table of contents must be included, math and language arts had to be separated and a student must be able to retrieve any requested item within one minute of being asked. At the year-end review session, one of the fourth grade teachers gave an emotional testimonial about how she had not really believed in the engineering design process because she was the type of teacher who liked to maintain complete control over her classroom. However, her teammates convinced her to try the new notebook strategy with her kids. She was taken aback at how they assumed ownership of their work and notebook, and cited a particular child who had often been written up for not being able to find work. She said he’d divided his notebook, after the table of contents, into sections labeled “math”, “language arts” and “miscellaneous” but in the many times she’d challenged him to find a particular paper to try to point out the pitfalls of his system, he’d never once failed to meet the one minute limit. She became a believer, she said, and now used the notebooks in parent conferences to demonstrate student learning progression. Further research into the STEM notebooks being used in partner schools is ongoing, with results to be disseminated at a later date.

Finally, we monitor to what degree the engineering design process has been incorporated into areas of the school community outside of the STEM instructional time. In these schools, the EDP is used as a problem solving process in and out of the context in which it was introduced. The process hangs in the hallway and in the common areas, in the cafeteria and in every classroom. One school has adapted the process for a parent recruiting flyer and for discipline referrals. When a child is referred to the office, he/she completes the ASK (why am I here?), IMAGINE (how I could’ve handled myself differently) and PLAN (how I will handle it next time) steps prior to seeing the administrator. Teachers have guided their classes through the design process when they are struggling with a classroom behavior or other problem. The process is goal oriented so is a powerful tool for general use. Teachers report the engagement of students is markedly higher during engineering activities and that behavior has improved overall. Losing time with your team while planning your design is a compelling motivator to be a good classroom citizen and stay on task. Further study of these outcomes is planned.

Conclusion

The need for schools to try new and innovative teaching methods and approaches is increasing as traditional approaches have not proven to be consistently effective in addressing stubborn achievement gaps among students from different ethnic and socioeconomic groups. Elementary school is a prime time to introduce engineering through STEM integration, given that children make up their minds early about their abilities and feelings about math and science; elementary

teachers have more time with the same group of students during the day and elementary teachers are typically responsible for teaching all core subjects. In our project, we are well on the way to establishing an effective, affordable and sustainable model for integrated STEM through engineering.

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