Science Review Committee, Weston Schools, 2012

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Executive Summary

Goal:
Eight scientists and engineers met with teachers, parents, administrators, and students, read curriculum, and visited classes over the course of three days to provide the school system feedback on how well the Weston Public Schools are teaching their students science and engineering.

Definition of Science and Engineering:
We asked all constituent groups to define what science is and what engineering is. The students, teachers, and parents almost unanimously agreed that science *is the understanding of the rules of the natural world around us through observation and evidence, from individual organisms to large complex systems.* There was far less agreement when it came to defining engineering, with some proposing *the development of the designed world,* to *the application of science to help mankind,* to *I do not know.*

Commendations:
The committee was impressed with many aspects of the Weston School science programs, from the self-reflection that resulted in this committee work to the pockets of teacher innovation and scientific thinking in the students, to a talented and passionate faculty, to an enthusiastic and engaged student population, to a successful and popular middle school engineering program. We saw excellent teaching with a clear rapport between teachers and students, an atmosphere that promoted pedagogical innovation, high quality facilities (except middle school science classrooms) and strong computer/technology support, and a department aware of the challenges it faces and actively addressing them. We also saw evidence of a strong community outside the school that is supportive of the school and are starting to integrate more with the classroom (e.g. science fairs, Land's Sake Farm, science advisors for student research).

Recommendations:
While the overall report presents a number of suggestions and ideas at all levels, we had three primary recommendations. Through these recommendations, we hope that Weston Public Schools can become a "thought-leader" in 21st Century STEM skills.

1. **Construct and implement an over-arching K-12 plan to enable all students to become scientists.** Our suggestion is to set aside substantial resources (money, people, and time) to develop a coherent, research-based scope and sequence for the development of effective science practice and content knowledge by all students from kindergarten through grade 12. In part this will require cross-school leadership, involve piloting and testing new ideas, will involve communication between educators

at all grades, and will involve professional development for faculty and administrators alike. It will be a dynamic and continually growing document. It will also require more time for the faculty to assess and reflect on their practices and innovations.

2. **Construct and implement an over-arching K-12 plan to enable students to become engineers.** In a similar vein, we propose the construction of a well-articulated scope and sequence for the development of effective engineering practice and content knowledge for all students from kindergarten through grade 12. It is important that the differences between science practice and engineering practice be considered and emphasized. This should begin in all of the elementary grades and be a required part of the curriculum in the Middle School and High School to meet the growing demands of STEM (science, technology, engineering, and math) knowledge of all citizens.

3. **Emphasize elementary school science and engineering.** Students should engage with science and engineering every day in elementary school to ensure competency in all students. We propose that the two plans listed above ensure that significant emphasis is placed on raising the amount and quality of elementary science and engineering, helping all students understand the scientific process to make sense of the world around them (developing their own mental models supported by evidence) and the application of their knowledge to design and create new solutions to authentic engineering problems. We recommend that teachers help students defend and build off of their own mental models, rather than memorize generally accepted models.

Full Summary of the Review Committee Thoughts

Over the course of the three days, the committee took extensive notes and combined/organized the notes below. It is organized in the following way:

Definition of Science and Engineering

Science is understanding how the natural world around us functions through evidence, such as observation, measurements, and discussion. Exploring and determining the rules of patterns of the natural world to facilitate prediction.

Engineering is changing the world around us by inventing, designing and building technology.

Commendations

1. A talented and enthusiastic faculty with a demonstrated interest in improving their practice of science teaching.
2. A department with a willingness to experiment and innovate at all levels.
3. A community that is supportive of the department and its goals.
4. Excellent teaching characterized by an evident rapport between teachers and students and among faculty colleagues.
5. A student population that is enthusiastic, interested, engaged, and polite.
6. Strong technology support for curricular programs.
7. An atmosphere in which teachers feel free to innovate in the classroom.
8. Quality facilities that support the program well (with the exception of the Middle-School science classrooms).
9. Use of community resources such as Land's Sake Farm and local scientist volunteer advisors in the Biology Independent Research Project.
10. A department that is aware of the challenges it faces and is actively seeking to address them.
11. Examples of authentic inquiry learning that exist within the current curriculum.
12. An existing engineering program in the Middle School that is innovative and successful.

Recommendations

Construction of a well-articulated scope and sequence for the development of effective science practice and content knowledge by all students from kindergarten through grade 12. This must involve dedication of sufficient resources and faculty and administrative time to developing leadership in this area, to piloting and testing ideas in the classroom and to reflecting upon and developing assessments of the effectiveness of these programs.

Construction of a well-articulated scope and sequence for the development of effective engineering practice and content knowledge for all students from kindergarten through grade 12. It is important that the differences between science practice and engineering practice be considered and emphasized. This should begin in the elementary grades and become a required part of the curriculum in the Middle School and High School.

Construction of a well-articulated template for time on learning, particularly at the elementary level, balancing the time spent on disciplines by increasing science and engineering instruction time to reflect a 21st century curriculum. Students should engage in some aspect of the scientific or engineering process every day, particularly in the K-5 grades. Resources should be dedicated to help administrators to become instructional leaders for good science and engineering teaching. It is critical for teachers to understand the motivation for these changes so they can see how their efforts contribute to overall goals for students.

Observations and Evidence

Learning Progression

1. Evidence & observation from the committee review of the curriculum provided (K-12)

- Learning goals for disciplines don't exist at the discipline and teacher level. (Exceptions: exists in K-5 and in biology where work of Janet Kresl-Moffat has created more common learning goals)
- Transition to grade 6 "Integrated science" overview - engineering approach is central, focus, litany of projects (build-a-boat, windmill project,) - stage of implementation is not clear. Very broad content coverage listed but sequence of coverage is not explicit. Goals and standards that it meets are not articulated.
- HS learning goals are primarily subject and teacher based. Very little evidence of consistency between courses and between grades.
- Good example of curricular alignment in biology. Clearly articulated learning goals that provide consistency within levels.
- Examples of final exams provided were primarily multiple choice, with focus on content.
- Overall science goals for 4 years in high school are not well articulated (incorporate hands on activities).
- Elementary curriculum that's not built in-house tends to lack consistent principles to be revisited year to year.
- Clarity on what is to be taught and a pacing guide/ curriculum map for each grade level would be helpful. (Exceptions: exists in K-5)
- Engineering is connected to physical science rather than looking for opportunites to connect to life or earth and space science.

2. Evidence and observations from the committee discussion with parents

Parent Comments:

- Lack of transparency of progress/self-study of Science Curriculum to parent community.
- Concerned about lack of feedback on HS assignments.
- Transitions between HS and MS and MS and Elem are hard, needs to be smoother.
- Gap between expectations in college prep Physics and Honors Physics.
- Recalled little communication of science/engineering learning at the elementary levels.

- Narrow curriculum, cited need for greater connection to real world and innovation in thinking about teaching and learning science in the HS.
- Robotics success in Middle School, why not continued in High School or as a Middle School required course.
- Communication about intent of science program needs to improve between faculty and students and faculty and parents.
- Perception that getting into High School is the first exposure into science.

3. Evidence and observations from committee discussion with teachers

Teacher Comments:

- Elementary teachers want to do the right thing for their students, are interested in how to assess student learning in science and engineering (formative/ qualitative and quantitative).
- Need more elective science courses.
    - could be one semester long instead of year long
    - now there are three, but all in biology
- Big concern at elementary level of how to implement progress-monitoring of students as scientists rather than content, particularly as they integrate more inquiry based instruction.
- Coverage of Discipline Core Ideas is spotty and inconsistent across grade levels and students based on observations and anecdotal evidence. Early Middle School students appear to be significantly varied in their inquiry experiences and content knowledge.
- Significant variation in science experiences and expectations of students when they enter Middle School. Different classes in 5th grade have substantially different amounts of preparation. Lack of communication between these groups of teachers and lack of clarity about what students can be expected to have mastered in science by the end of elementary school is evident.
- In Middle School, loss of thematic continuity of new courses, since they are no longer organized by content type. What will hold the material together for the students? There is a strong desire for more PD time to be dedicated to this curricular shift, especially by those teaching new content areas in their courses.
- Most core learning progression was skill-based -- constructing data analysis from testing data, lab methods, and concepts of measurement, scale, magnitude.
- The scientific method was also stressed.
- Fifth grade has MCAS in STE, and testing covers learning K - 5, how can we ensure students are prepared through each grade so fifth grade is not solely responsible.

4. Evidence and observations from committee discussion with students

Student Comments:

- Large gap between Honors and CP in terms of difficulty.
- Connections to real world applications make it relevant.
- Non-AP science electives are all biology based, no chemistry or physics offerings.
- Elementary students recall activities completed, as did the High School students, rather than the big ideas not cited.
- Science is part of Social Studies (elementary).

5. Evidence and observations from committee observations in classrooms

- Little connection across subject areas, often lead to missed opportunities to bridge the connections across to improve students learning - examples: are there informational text reading units at each grade level that tie to science units or engineering units?
- Limited classroom time in K-5 on science.
- In addition, connections between both classes and grades need reinforcement at all levels.
- Students were able to articulate the activity they were doing but unable to cite the purpose for the activity and how it connected to prior learning of a core idea.
- Some K-2 teachers have clear expectations in a progression for observing and recording evidence in notebooks.
- SUGGESTION: begin student notebooks in K and continue adding each year in the same notebook to grade 3, then pass to next school so it operates as a reference for learning, continue in next grades and pass to Middle School to continue.
- There appeared to be consistent progression between 1st and 2nd grade science programs, ie 1st grade discussing leaves and seed differences, then 2nd grade diving further into the parts of plants.
- Consistent revisiting across K-2 grade levels of students using their journals for recording.

6. Evidence and observations from committee discussions with principals

- Peer observation is rarely used to improve teacher practice.
- Staff adapting to hands-on science, staff wants more project based curriculum, making learning organic with teachers assisting students.
- Grade 5 switching means that 4 teachers can work together to plan lessons in science/ engineering.
- Incoming from the preK-3 schools “seems good” for our teachers to build on.

Science/Engineering Practice and Independent Thinking

I. Evidence & observations from committee review of the curriculum provided (K-12)

- K-5 curriculum
  - well-rounded material carefully selected from a variety of curricular resources.
  - in-house designed units are high quality.
  - thoughtful focus questions to anchor lessons.
  - good integration of hands-on projects and recording of the projects through notebooks, etc.
  - very limited classroom time for science.
- 6-8 curriculum
  - transition to grade 6 "integrated science" overview - engineering approach is central, focus, litany of projects (build-a-boat, windmill project,) - at what stage is implementation? Very broad content coverage listed too - links to engineering side not all clear (how is course integrated/unified?)
  - 6th grade labs: Baking soda experiment, candle experiment - how open ended? Student design seems evident... degree of guidance of from teachers?
  - 7th grade projects: students picking projects/approach within defined range (PSA, creature feature, cell model, little jars of crud).
  - 8th grade labs: convection/continental drift highly proscribed/directed, chemical weathering seems more open, can crush not clear.
  - MS lab report rubric weighted towards hypothesis, observations and conclusion sections - student design of approach seems to be a regular feature of most lab materials shared.
- 9-12 curriculum
  - HS curriculum has varying degrees of independent thinking. Some labs give students a large amount of freedom to design experiments and question results, but most contain some degree of structure and guidance.

II. Evidence & observations from committee discussion with parents (K-12)

Parent Comments:

- Not bringing out natural questions in kids / not listening to kids ideas.
- Homework is not always graded, students don't get feedback.
- Too hung up on "hitting the scores' rather than awaking student interest.
- Not enough hands-on.
- Need to get kids excited about science class as early as possible.

- Students not always engaged at the high school level, often dependent on teacher.
- “Safe science” - teachers stick to simple memorization rather than authentic investigation.
- Ensure a strong hands-on approach which allows students to remember and conceptualize.
- Integrate disciplines as far into age groupings as possible - especially through Middle School.
- Need more science fairs - where kids are communicating science.
- Should do more internal development rather than “buying science education” with traveling exhibits etc.
- What about a “scientist in residence” program?
- The strongest students tend to lose interest in the Middle School program. Students often do too much listening and not do enough lab work to keep them engaged.
- Find ways to provide additional challenges to bright and motivated students in the “non-leveled” classes in the Middle School.
    - More electives in other domains, specifically mentioned engineering, robotics/technology.
    - Having engineering electives was a better alternative to integrating into classes.
- More integrated interaction between math and science (and art, etc).

III. Evidence & observations from committee discussion with teachers (K-12)

Teacher Comments:

- The strongest students lose interest in the Middle School program.
- Additional challenges are needed for the strongest students in “non-leveled” classes in the Middle School.
- The need to get students to question.
- Start with questions and let them frame the activity.
- Allow them to fail and try again.
- Lack of support for Middle-School science field trips--most are social-studies based.
- Need more elective science courses.
    - should be one semester long instead of year long.
    - now there are 3, but all in biology.
- Develop inquiry-based learning in tandem with direct instruction.
- Evolve with the technology.
- Teach students to ask better questions and make better observations.

- Teach/model independent learning strategies for students.
- Develop better questioning skills.
- Middle School--thematic continuity of new courses no longer organized by content type. What will hold the material together for the students?
- Inquiry labs have been moved “to put the hardest stuff closest to the MCAS” and coverage of topics ranging from plate tectonics to human body systems in the new eighth grade year are examples. Conflict between time required for more open-ended experiences and the need for MCAS-related content coverage.
- High School--increased content demand in the more advanced courses is denying the inquiry experience to the kids who might get the most out of it.
- Independent Research Project (IRP) an example of truly independent student thinking. Students doing the IRP supported by intermediate deadlines as well as community members volunteering time to review and fine-tune the final design with students.
    - Also mentioned was another IRP based on a body system in Anatomy (an elective course), and a new (and not yet started) project in environmental science (another elective course) where the class will be given great independence in answering broad questions about the town’s plastic-reducing program -- Is it succeeding? How can it be promoted? Is it saving money?
    - One project leading up to the IRP in 10th grade is the enzyme lab. Students are given a variety of materials and must design and implement the process of determining which enzymes are in unlabeled test tubes.
- The difficulty of trying not to grade based on the success of the experiment (so long as it was well designed/executed) to allow students to fail -- this is much harder to place in a rubric.

IV. Evidence & observations from committee discussion with students (4&5 + HS)

Student Comments:

- Allow students to have ideas and answer questions - not just follow directions.
- Need to care more about students and learning than about test scores.
- Connections to real world applications make it relevant.
- Have too much technology--wrong place to invest.

V. Evidence & observations from committee observations in classrooms

K-5

- Highly engaging fourth-grade class had kids designing devices for dropping pigs safely using the engineering design process, collaborating, planning, testing, redesigning.

- First-grade celery and food coloring activity included careful observation and encouragement of student questions and explorations.

6-8

- Open inquiry and engineering projects currently exist. Examples include rocket design project and “air circus” labs in eighth grade, little jars of crud in seventh grade. These are seen as a highlight by teachers. They provide models to build upon. These are the exception rather than the rule. I observed highly proscribed teacher directed lab and talked to students about teacher directed lab they were left to interpret for themselves.
- Students in one sixth grade carried out a structured measurement lab, but were helped by the teacher to ask good questions and figure out answers for themselves.

9-12

- Authentic inquiry/data analysis appears to play a part in the courses I observed to varying degrees:
- A very strong model of inquiry based learning exists in the Independent Research Project done by all Biology students in 10th grade. Teachers are enthusiastic and committed to this feature of the program. The involvement of volunteer scientists, who come to campus for a day of consultation with student groups is an exciting feature.
- Honors biology students beginning a “composting competition” project. On-line discussions have just been begun about how composter design/location.
- AP bio students using “Evolution Megalab” data collected by “citizen scientists” to analyze snail evolution.
- Anatomy and Physiology lab observed was teacher directed, but loosely structured. Students made measurements and observations of their reflexes and reaction times.
- I also observed a more traditional teacher-directed lab in Chemistry. The CP Chemistry course teacher reported student-designed approaches to the labs in her course (not observed in action). The teacher of this course said that the freedom from extrinsic test-driven demands in the CP course compared to Honors gave the flexibility that made this approach possible.
- Both observed classes started with a more teacher focused discussion section, where vocabulary, core concepts were discussed and reinforced. Following this, students were sent with instructions to actually do the lab.
- Students immitated instructor in doing lab -- combining food particles with indicators to determine what was in each type of food. Some of their results were certainly formed by their opinions “I think celery should have protein -- it makes

sense that it should have protein, right?" -- despite getting a negative sample for protein.

- Students were split up into groups of four, with three different roles (groups were responsible for picking a person for each role). Two people filled out a handout on the environment they were studying while observing the two other students. One student would stir up the bottom of the river with their boots and another would stand slightly downstream to catch what they stirred up in a net and deposit into a bucket.

VI. Evidence & observations from committee discussion with administrators

Administrative Support and Leadership

I. Evidence & observations from committee review of the curriculum provided (K-12)

- More professional development for elementary school teachers.
- Accountability on how much time is really spent on science in the lower school.
- Elementary school teachers are very eager to improve their science knowledge - so continuous PD to take advantage of that.
- PD in science and engineering practices for teachers AND administrators - what does good science teaching look like?
- Safety needs to be emphasized systematically at all levels and clearly communicated to students.
- At High School - planning and decision of what gets taught occurs at the teacher level - making it up to the teacher to integrate and execute hands-on experimentation.
- Department has to define "we want to do hands-on learning" - when students graduate, we want them to be able to do X. Then get teams of teachers together to plan out what they will do in each year (and draw from pre-high school) to get them there and what is the assessment to demonstrate that they have gotten there.
- Teachers need time to come up with shared understandings, assessments, and then to reflect on the success of what they do.
- Need for overarching plan - that includes ALL grades. Middle School needs to be part of the High School discussion.
- Need a clear articulation of goals from the administration (scope and sequence) - and being able to count on what science is being learned in other grades so that they can build off of it.
- Realize there are things that have to happen and in a certain way (MCAS etc) then admit it and plan for it.

- Arrange an accountability structure to reduce inconsistencies between teachers - this is the administrator job and they should be fully versed in science.
- As move to integrated approach to discipline -visit other schools, conferences, etc.
- Increase more time for coordinator - more of an administrator role and include developing a scope and sequence - for example what Pam is doing in the elementary school.
- Elementary school science needs to happen daily - and needs to be making sense of the world around you.
- Administrations may not give accurate picture of science teaching and learning within the school and at each grade level.
- Little connection across subject areas, often lead to missed opportunities to bridge the connections across to improve students learning - examples: are there informational text reading units at each grade level that tie to science units or engineering units.

II. Evidence & observations from committee discussion with parents (K-12)
Parent Comments:

- MCAS should not be a concern, but AP/SAT/ACT need to be.

III. Evidence & observations from committee discussion with teachers (K-12)
Teacher Comments:

- Transitions between HS and MS and MS and Elem are hard, needs to be smoother.
- Lack of support for Middle School science field trips--most are social-studies based.
- Provide more Professional Development.
- Promote visiting other schools.

Technology and Facilities

- Middle School facilities: Facilities have severe limitations and need to be updated.
    - Current rooms are in poor repair—electrical outlets that do not work, storage cabinets that don’t close, counters that leach chemicals, sinks that do not drain.
    - Rooms lack space and storage to support a project-based curriculum. One room in particular, a converted storage room, was crowded with 24 lab seats in tight formation (and the class had 25 students). Even the simple measurement lab we observed was problematic because the students had so little room to work with their meter sticks. Cabinet doors are broken and lab bench tops are unsealed and leach chemicals. Lack of a refrigerator for laboratory materials was also raised.

- High School facilities: Generally *very* strong -- teachers highly approve of and appreciate new facilities. Lack of shop/space for engineering was mentioned. The Middle School has a shop -- perhaps an opportunity for cross-school collaboration?
- iPad Program: still uncertain - does it really help the science learning? possible release time for the teachers to play/learn/reflect. One of the questions to ask is: Do the iPads help the students create material, or just consume? (Consume is fine, but if we're moving towards more open-ended material, then creation should also be key).
- Technology courses should be part of science not art and should incorporate engineering design (but does this take time away from science?). NGSS expects engineering to be merged into science.
- Robotics/technology/design and construction -- how do we extend these outside the Middle School?
- Use of technology appropriate but not forced -- sharing through google docs, using online search to shore up student knowledge in areas around lab reports.

Committee Thoughts

Tensions

- Tension between expectations (parents, community) and what science really is.
    - parental and community education.
- Tension between science and engineering.
    - engineering uses science, but also ELA, math, etc.
    - engineering could come at the cost of science.
- Tension in balance between students discovering and teachers telling.
    - “making sure they have heard of it” (lecture) and “making sure they can do it” (hands-on).
    - “talking knowledgeably about science” versus “understanding/doing science”.
    - investigating and finding the answer in the back of the book.
- Tension between MCAS and “real science”.
- Tension between current incentives (grading the outcome) and real science (process and outcome).
- Tension between the standards, which are focused on content, and process skills / higher order thinking / creative problem solving.

Questions to ponder

- Will a better understanding of the world around you get you into a better college? Help you do better in college?
- How do you “fix the plane while it is still flying?”
- How do you teach students to “Know what you do not know?”
- How can a school bridge the world of education research and the classroom implementation?
- How can teachers become education researchers?
    - iPad as an example - how does this benefiting the learning?
    - brainstorming phase - play with the tool.
    - structured research phase - schedule reflection time for teachers - what differences happen?
- How can teachers become education researchers in their practice?