Where's the math?

A proposal to redesign the Middle-school Math through Applications (MMAP) project curriculum

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“The value of a problem is not so much coming up with the answer as in the ideas and attempted ideas it forces on the would be solver.”

I.N. HERSTEIN

“I do not teach, I relate.”

MONTAIGNE

Introduction
The Institute for Research and Learning at Stanford University designed a program to re-conceptualize math learning for middle-school students. The program was designed to shift from traditional teaching methods such as memorization of abstract formulas toward understanding math through applied situations. This shift was to happen through the math classes only, and state and federal standards for learning still applied. This program was called Middle-school Math through Applications Project (MMAP).

The design of MMAP seems to be based on the following principles, based on the Greeno et al article “Cognition and learning”:

– S1 Environments of participation and social practices of inquiry and learning
– C1 Interactive environments for construction of understanding
– B3 Individualizations with technologies
– S4 Curricula must provide opportunities to learn practices of formulating and solving realistic problems.
Learning problem
Before the MMAP solution, students were not meeting math standards. They were not engaged in mathematical problem solving, and were going through the motions of solving equations and exercises without a larger understanding of how math was relevant to their lives.

The goals of MMAP were to address these learning problems by making math accessible and engaging for all students, and helping them see its relevance beyond the classroom, while getting students to meet and exceed math standards. Upon observation of the implementation of the curriculum in the classroom, the researchers realized their original design was not producing successful quantifiable results. In addition, teachers, students and parents, are not able to identify whether math is actually being learned through the new curriculum.

The new learning problem for the students is that they are enjoying themselves by solving “real-world” problems, but not developing their own procedural or device knowledge as a result. In this situation, strategic knowledge is the only type of information available. However, it is left undeveloped because they are not being taught the processes or facts to build and develop their ability to reason in different situations.

The teachers also have a new learning problem. They are being asked to teach in a way that is different from their previous experience and training. Instead of teaching formulas and methods in an abstract and symbolic way, teachers will need to work with each student individually to understand where they are and intuitively lead the student into their next stage of development, taking full advantage of every “teachable moment”. The program also requires that the teachers be actively engaged at all times in the classroom, and have an authentic understanding of the subject matter in order to convey the information fluidly.

Design objectives
As a result of our design solution, we would like the learners to:

Meet federal and state math standards
The overarching concern with the new curriculum is captured in our title “Where is the math?” Students, teachers and parents were puzzled about which state standards were being followed in the MMAP curriculum. The pedagogy made it difficult for the teachers to ensure that the students actually learned enough for the standardized tests. We address this issue by explicitly calling out the state standards for each project, so that going in the teacher knows what has to be covered in terms of math concepts.

Enjoy math and see opportunities to think mathematically outside of the classroom
Learning by doing fosters a feeling of control in the students. It puts them in the class of people who reason and talk math. Their group activities are confidence building. We
hope that they can transfer this math speak into other areas of study like science and geography.

*Eliminate the “mystery” from problem solving*

Traditional problem solving is often associated with brilliance in math and has a certain aura of mystery around how the solution was crafted. By introducing activities and making the math processes explicit, we hope to make problem solving a natural extension of the students thinking rather than a separate activity.

**Design rationale**

We use a mix of three perspectives (Behaviorist, Cognitive, and Situative) in designing learning materials that facilitate the students’ ability to understand new information apply it in different situations. We concentrate on redesigning the curriculum for the students, and the training for the teachers conducting this program.

**NOTE:** In the following section, we will refer to the principles by number. Please refer to the appendix for more detail.

**Design solution**

Our solution includes a modification to the experience for both the teacher and the student.

**Teachers**

As stated earlier, the learning problem for the teachers stems from the fact that they are being asked to perform a role that is quite different from what their training and experience prepares them to do. Since their understanding of the possibilities of the classroom environment needs to expand, we propose that the teachers be required to attend training workshops where they would themselves be students in a situative environment.

**Training workshops**

The workshops will be held three times during the school year: one during the summer before school begins, and two during the winter and spring. The summer session would be to orient new teachers to the curriculum and the coming year, and allow teachers who have already implemented the curriculum to share their success stories and challenges with the entire teacher group. [S1, S2, C5]

The workshops would contain formal discussions of the curriculum and software used in the projects, in addition to hands-on activities [C1] where the teachers become the students and go through the projects they are teaching at an accelerated pace. Also, in the workshops, the teachers would take part in discussing the curricular intentions and developing their own solutions and customizations for their classrooms. There will be a focus on common vocabulary and development stage of the middle-school student within the math discourse. [S4]
A key opportunity for learning for the teacher is the act of identifying and taking advantage of the “teachable moments”. The work session will infuse this idea throughout all discussions, and key individuals will be identified to share their experiences, both positive and negative. [S1, S2, C5]

Central web site [S1, S2, C1, B2, C5]
As part of a developing community of enthusiastic teachers, a web site would be developed to store resources and provide a forum for discussion. The site would include case studies of how the curriculum has been implemented in different schools, containing information on projects, how they’ve been modified, successful teaching practices, new understandings, and student results. In addition, the site would include a gallery of successful projects accompanied by a short narrative presenting the background.

The web site will also contain a message board space which enables the teachers to continue their discussions throughout the year. One essential category in this space is the “teachable moment”, where teachers can share their excitement and experiences in identifying when a student is ready to learn, and how the teacher facilitated the “ah-ha”.

In addition to being handed out at the training session, the web site will also store information on the basic framework and learning goal of each project/lesson and an index of how the lessons align with state and federal standards. Suggested quiz and test questions, along with the framework for student self-evaluation will also be available.

Software modifications
The software tools provided through this project will be modified slightly to allow for customization. The teacher may want to modify the context, to allow or disallow certain features or to imbed key information in the application, and there would be an authoring tool for the teacher to make these changes.

Mentoring
An ideal yet impractical situation would be to pair novice teachers with an experienced teacher in the new curriculum as a mentor. Their classes could be combined while doing the projects so that the novice teacher can experiment with how they teach while getting feedback from an experienced observer. The novice will also learn from techniques the mentor models through her teaching.

Students / Curriculum
Our proposal maintains the MMAP defined project of teaching math through architecture, although we suggest modifying the content to be a subject more relevant to middle school students. Instead of one continuous project of designing an Antarctic
research station, our project will be designed in sequences of conceptual and tactical development [B4] as follows:

*Stage 1 Project:* Students begin by naming their team and establishing a product-based company. They will decide what they are going to sell, and will prepare a budget for production (costs to make item, sales prices, salaries, profit goals, etc.)

*Stage 2 Project:* Students will continue to define and refine their company plans with more complex math. This will include sales forecasting, loans and interest, etc.

*Stage 3 Project:* They will need to make a plan for a warehouse/storage facility, identifying the space needed, building costs, materials, and operational concerns like heating/cooling, building maintenance, etc., along with designing the floor plan for the building. They will use ArchiTech software to design the facility while building physical models and measuring physical space for studies.

As each project is being assigned, the teacher will orient the students into the activities they are doing with a brief math lesson and introduction to terminology, tools and processes. [C3]

Along the way, the teacher will interact with each group of students, giving them feedback into their math discoveries. There will be incremental discussions as well as quizzes of increased complexity as the students go through the projects.

At the end of each project, the students will present their solutions to the class, pointing out the applied math concepts. [S2, B1] This will enable them to practice articulating their concepts for others to understand in addition to explicitly identifying the math skills they acquired through the project.

The students will also do a self-evaluation paper [S5, S6] answering questions such as:
- What did you learn with this project? [S6]
- How do you see your role in the team? What will you improve on next time? [S5, S6]
- What math concepts did you use? [B5]
- What other situations can you imagine using those math concepts? [B5]
- Solve given symbolic problems relating to math topics covered in project. [B5]

**Assessment**

**Testing**

Students will be evaluated on the basis of their performance in the standardized tests held periodically throughout the school year. These tests will provide the much needed validation that the students are learning the material required to meet the state standards. A feeling of achievement is very important to motivate the students.

Grading will be done the standard way.
Evaluating the process of learning

Since this learning occurs in-situ while the students are engaged in hands-on activities, it is important that the assessment also reflect the process of learning. Teachers would look at the interaction logs generated by the software. They would also be non-participative observers at pre-determined locations in time. They would use a 5-point scale to evaluate the students on the following criteria, and this would influence their final grade in the course.

- Teamwork
- Articulating ideas/Presenting
- Level of engagement
- Level of focus
- Overall investment

Self assessment paper

Students will be asked to write a self-assessment paper in not just their math class but in other subjects where math is used. This would test not only their understanding of math concepts but also their ability to transfer these understandings into other areas of learning. It helps the students to develop a mathematical consciousness and an awareness that mathematics pervades through all subjects. This assessment will have a structured format at first to help the students to structure their thoughts. Gradually they will move onto writing more free-form documents. The teachers can then evaluate the papers based on:

- Appropriateness of ideas
- Clarity of articulation
- Completeness
- Concept maps

Presentation

Students will prepare a presentation conveying to a larger audience what they have been working on all year long. This gives them a chance to:

- Show off their work and understanding
- Receive feedback and validation form an external source

Conclusion

Our main design goals were to make the math more visible to the students and to help the teachers transition into a new way of teaching. Through explicit reinforcement in the form of lectures, tests and self-reflection for the students, and workshops and tools for the teachers, we feel that this will lead to a coherent community engaging in explicit math practices.
Appendix: Principles from Greeno, et al.

Learning Environment

S1 Environments of participation and social practices of inquiry and learning
S2 The learning environment provides support for development of positive epistemic identities.
C1 Interactive environments for construction of understanding
B1 Routines of activity for effective transmission of knowledge
B2 Clear goals, feedback, reinforcement
B3 Individualizations with technologies

Curriculum

S3 Curricula must support the development of disciplinary practices of discourse and representation.
S4 Curricula must provide opportunities to learn practices of formulating and solving realistic problems.
C2 Sequences of conceptual development
C3 Explicit attention to generality
B4 Sequences of component to composite skills

Assessment

S5 Assessments must focus on the learner’s participation in inquiry and social practices.
S6 Learners need to participate in constructing their own assessments.
S7 Design of assessment systems must take into account not only the outcome of the learning process, but also the process of learning practices (e.g. curricula and teaching practices within meaningful activities), and the dynamics of the learning environment.
C4 Assessments of extended performance
C5 Crediting varieties of excellence
B5 Assessment of knowledge components

References