Playful Math World

A Solution to MMAP

Design Proposal

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Learning Environment

The R & D team designed and developed an experimental, application-based middle-school math curriculum that, they believed, would support activities in which math could emerge and teacher could notice and capitalized on these emerged math opportunities to teach math. By doing so, students could learn math in the context of “application.” One unit of this curriculum was called the Antarctica Project. It was implemented in Martin Luther King Jr. Middle School and other schools. The students were engaged in research activities, design activities, and analysis activities involved in building a research station. Software containing a scale icon and a simple spreadsheet was provided as a tool. A math opportunity chart was offered to orient teachers toward noticing and capitalizing on math teaching opportunities. The teacher was excited about how the curriculum was going, the computer software was holding up under the assault of real classrooms and kids.

Learning Problems

However, engagement, excitement, and the use of computer software did not necessarily mean the learning result would be satisfactory. On the contrary, the curriculum was problematic. Based on MMAP research team’s filed test findings on the Antarctica Project, we identified the following learning problems.

Problems in MMAP

- Many math teaching opportunities were missed because
  - teachers were able to capitalize on just some of the mathematical opportunities covered by the math opportunity chart
  - the math opportunity chart was not sufficient
  - most teachers failed to create their own new activities responding to the emerged mathematical opportunities
- It was subject to not covering all math topics
- Because Students weren’t seeing the connections between the activities they were doing and the formal mathematics.
- Many of the real world “Applications” in Antarctica Project, such as bathroom architecture and heating cost of a room, are not easy to understand or not interesting enough for these middle school students, because they are the activities for professionals and adults, not for these young teenagers.
- The in-depth mathematical conversations, activities, and arguments were inconsistent across groups and classrooms.

Problems in General Math Teaching

- Math is seen as difficult, boring, and irrelevant
- Students are passive recipients of mathematical knowledge and symbols and not motivated in learning
- Students cannot apply math principles to the real world problems

Design Objectives

After having identified the learning problems, our design objectives are straightforward. We are seeking to achieve the following goals.
• Ensure that teachers cover all math topics and content set by national and state standards through easily teachable curriculum
• Motivate students and improve sense-making in learning by making math learning interesting and relevant to the real world practices with the subjects more related to their interest parts in daily life.
• Improve problem-solving skills which are tailored to solve comprehensive real world problems
• Develop in-depth mathematical communication and argument ability

Design Rationale

Based on the learning environment, participants, and the client’s goals, we situate our proposed design of learning solution in cognitive and situative approaches. Specifically, we will employ the following principles.

1. Cognitive
   (c1) Interactive environments for construction of understanding: learning environments should be designed to provide students with opportunities to construct conceptual understandings and abilities in activities of problem solving and reasoning. The activities of constructing understanding have two main aspects: interactions with material systems and concepts in the domain that understanding is about and social interactions in which learners discuss their understanding of those systems and concepts. It recommends teaching concepts initially with exemplification and teaching students to solve applications problem later.
   (c4) Assessments of extended performance: it suggests assessments be based on more complex performances. For example, assessing writing should be based on performance of students in writing tasks. Similarly, the assessments in our case should be based on students’ performance on solving the real world problems using mathematical principles.

2. Situative
   (s1) Environments of participation in social practices of inquiry and learning: it believes that an important part of learning the concepts of a domain is learning to participate in the discourse of a community in which those concepts are used. This principle recommends students work in group so that they can discuss how to solve problems and understand each other’s ideas.
   (s4) Practices of formulating and solving realistic problems: it suggests that the subject concepts and principles be embedded in the contexts of the learning activities.

Design Solution

Guided by the design principles we think appropriate, we came out the following solution to address the identified learning problems and achieve our learning objectives.

Redesign of the Curriculum

Class organization and Instructional Methods
The redesigned curriculum is still application-based, but the sequence and organization of the content are reorganized. Mathematical concepts will be taught before any application so that students have acquired basics which can scaffold their understanding and problem solving. Math topics and concepts are chunked into each lesson and sequenced from simple to complex to ensure that all math topics are covered in a teachable and learnable manner. The idea is that teaching and learning are sequenced from a single or a few concepts to the application of concepts in the simple real world problems (understanding of concepts and sense-making) and then proceed to solving the comprehensive real world problems and developing metacognitive skills (problem-solving).

Since the math concepts and topics are clearly and explicitly presented in each lesson teachers won’t miss any of them. Teachers do not need to identify the mathematical opportunities because they are already there. It largely reduced their planning work so that they can more concentrate on the real teaching. In addition, the new curriculum doesn’t need to retrain teachers to be capable for identifying mathematical opportunities as this may be needed in the MMAP curriculum.

Another emphasis in the redesigned curriculum is making learners aware of their problem-solving processes. According to cognitive approach, success in problem-solving requires both cognitive and metacognitive skills. Metacognition is the skill that sets goals, monitors progress, and makes adjustments as needed. People with good metacognitive skills focus not only on the outcome of the job, but on the steps and decisions they make to achieve that outcome. When working in a team, the person with high metacognitive skills will be the one to say: “Wait—let’s stop and see if we are making progress. Will our individual efforts work well together?” When working on a problem alone they might say: “This approach is not really getting me anywhere—what else might I consider?” In other words, they are mindful of their mental work. When they don’t see progress toward a goal, they shift gears and try another approach.

Accordingly, the instructional methods need to be modified.

- Using worked examples and demonstrating expert thinking process
  A worked example is a step-by-step demonstration of how to solve a real world problem or perform a task by using math concepts and principles – understanding of concepts, and sense-making
- Practice exercises mirroring the real world situation – motivation, sense-making and problem-solving and application
- Group work to solve the comprehensive real world problems – motivation, sense-making, in-depth mathematical communication, and problem solving and application
- Student work presentation and think aloud – in-depth mathematical communication and argument ability

Based on the design ideas we formed, each class will be structured in the following sequence.

1. Student work (group or individual) presentation and think aloud
   One group or a individual work (homework or work in previous class) will be
presented in class. They also need to talk about how they have reached the solution (their thinking process). Other students can ask questions and challenge their solution. The presenters need to either defense, if challenge unjustifiable, or revise, if justifiable, their solution. By doing so, students can develop in-depth mathematical communication and argument ability and metacognitive skills.

2. Teach basic math concepts principles. For example, area, perimeter, and their relationship

3. Demonstrate the application of these math concepts and principles in real world problems using worked examples. Provide several diverse examples (worked examples) of expert problem-solving actions and thinking (not only problem solutions but also of the thinking processes behind them). Worked examples are more efficient for learning new tasks because they reduce the load in working memory, thereby allowing the learner to learn the steps in problem solving.

4. Practice exercises mirroring the real world situation: Students are required to work out a few simple practice problems by using math concepts and principles covered in class and write out problem-solving plans. It can promote learner awareness of and reflection on their problem-solving process by making learners document their plans and by showing maps of student and expert problem-solving paths.

5. Group work (homework or in class depending on time) to solve the comprehensive real world problems: Students are divided in groups, each group working on a same comprehensive real world problem by using math concepts and principles covered in class and in previous classes. By being involved in real world problem-solving process and documenting their solution plans, students are motivated and their in-depth mathematical communication and problem solving ability are enhanced.

Learning Materials

Based on the above design, we also redesign the learning materials of “Math in Design Units” with Real World applications for the math practice and group work. The redesign has three major advantages over the old one.

- Expending learning capability with mantel development process: One design unit will target a main math topic, and then it can be expend to the different math problems, such as, from algebra, binomials, to equivalent expressions.
- Providing simple, easy-to–understand real world problem with explanations to give student the connection from basic math concepts to the real world situation.
- Fun and playful. It is designed to be more related to the youngsters’ world and life to increase their interesting, motivation, and imagination, which provided math-learning opportunities whining activities: ratio, scale, proportions, algebra, and functions.

Here is an example for a fun and expandable group project – Chick Egg Incubation Project: The eggs take 21-22 days at 98 degrees to start hatching. Students need to build an incubator with heating devices. Following are some sample practices in the project:
1. Space Design: 20 eggs need 1 cubic feet for hatching. We have total 80 eggs, how big the incubator we need?
2. Electricity Heating Design: A 100 W heating lamp can heat 0.8 cubic feet space for 98 degree. How many 100w heating lamps we need for 2.5 cubic feet incubator?
3. Energy Costs: Two 100 W heating lamps for 22 day continues heating.
4. Different eggs hatching exchange in one incubator: The space for 6 chick eggs is equal to 4 duck eggs and 3 turkey eggs. How many duck eggs we can hatch in an incubator for 20 chick eggs?
5. Temperature reading: Fraction concepts.
6. Percent of successful hatched eggs at day 21.

From one project, we can have students to excise many different math problems.

Redesign of Software

To help the performance of this curriculum design and to increase the quality and effectiveness of the learning, we propose a new interactive software tool with today’s technology to help the math study program. This software has two main screens:

1. Teacher’s Screen. The software will help teacher to perform the measurement of the student learning with NCTM Standards requirements.
   - The NCTM data installed
   - Review function
   - Analysis function.
   - New project generation function

2. Student’s Screen—Playful Math Wizard. The software design should stimulate the students to develop the mantel model for math with many playful functions and improve the learning process with the learning from participation, conceptual understanding or strategic thinking, and skill or routine knowledge.

The software is used for students’ homework and preparing the project within the curriculum. This new software shall be fun and playful when students are learning real world math problem. It will be just like a student playing a computer game when he/she plays with this software.

The following features of the system will be designed:

- Interactive function for math problem solving with step-by-step guide by “charting” with a animated “Math Wizard”.
- Basic math formula and sample database with key words search capability.
- Design Units and Solution Database with optimized solutions calculation function.
- Systematic and User-Friendly design to enable students to using this tool easily.
- Intelligence math “hint” suggestion capability.
- Smart Performance Analysis function with NCTM Standards.
- An explanation and description for the real world situation background.
- Tests composition capability with automatic score function.
- Group or individual “Math Game” function. The person who get the most of points is
the winner.

Here is an example of an interactive conversation design:

S: Student.
W: Math Wizard

Start Project:
“Electricity Heating Design for Incubator”. Total Score 100 points.
W: Welcome to the Playful Math Wizard. A 100 W heating lamp can heat 0.8 cubic feet space for 98 degree.
S: I have an incubator with 1.2 feet wide, 1.8 feet long and 1 foot tall.
W: Then how much is the cubic feet?
S: I forgot the formula.
W: Hint…. Remember a rectangular formula? Cubic has 3 dimensions.
S: Oh, WxLxH…
W: Right! You got 2 points! Then, how much?
S: 216 cubic feet
W: Wrong! Hint: Fraction…
S: Whoops! 2.16 CF.
W: Right! You got 1 point! Then, how many 100W lamps you need?
S: Mhhhh….
W: Hint: Algebra.
S: X=2.16/0.8!
W: Great! You got 5 points! Then, how many 100W lamps you need?
S: 2.7.
W: How can you get a 0.7 lamp? Hint: One lamp is 100W.
S: I will use two 100W lamp and one 70W lamp!
W: Smart boy! You got 10 points!

The game can be continued with different setting, such as energy costs, different eggs, and different incubator sizes. It also can provide the simulation results. For example:

S: I want use four 75W lamps in the incubator.
W: Sorry, your chicks are dead after 15 days.
S: I put two 1,000W lamps in this incubator!
W: Congratulations! Your eggs are fully cooked after 10 minutes. Enjoy your meal!
   Hint: Your designed an inferred oven!

Assessment

We determine the follow assessment methods to examine our design solution. We expect that the assessment results show some evidence on how our design solution is on solving the existing learning problem and on reaching our design objectives.

- **Math background test**: we believe that the various level of math background impacts the learning results of our design solution. Hence the Math background test will find the missing or mistaken concepts in their understanding. As a consequence we can on the one hand help students to catch up through our designed curriculum, on
the other hand gain a coordinator to show whether our solution reaches our design goals. The test will be half standardized math problem and some open-ended questions on measuring students’ conceptual understanding on background math topics.

• **Class observations**: we focus on how students build their understanding on the new math concepts. We will answer questions such as Do students properly build connection between the real life problems and the mathematical principles behind the problems? How students think and communicate mathematically and how the newly taught concepts are used in their communications?

• **Students and Teachers Survey**: The survey aims at motivation and engagement of students and teachers in implementing the design curriculum. We will ask question such as how do you like the class activities? Is the connection between the practices and the mathematical principles behind clear to you? What math do you think they learn though a specified class and how well they grasp it? How the software motivates students and facilitates learning?

• **Achievement Test**: we will finally have an achievement test. Half problem of the test will standardized math problems, through which we can see how well the curriculum reach the national or state math teaching standards by comparing with the results from the math background test. Based on our design rationale (c4) **Assessments of extended performance** and (s4) **Practices of formulating and solving realistic problems**: The other half will test on students’ understanding and using of the learning math concepts. We will have students solve similar real life problems applying the learned math principles. We will also give students a real life scenario such as painting the classroom under some budget and time constraints. Students are asked to find the mathematical opportunities in the activity and using these principles to solving problems such as how much they will spend on painting materials and how long they can finish the jobs ideally? We expect that students can employ their learned math concepts such as area, perimeter in thinking, communicating and working.

Conclusion

Based on above solution and assessments, we expect the Playful Math World project can make math to be accessible, fun, interesting and motivating for all students. The curriculum design will improve the math thinking process by using math concepts and principles with fully understanding, and sense-making. The utilization of new software technology shall enhance learning opportunities with playful and mantle stimulation features for all students. We expect the result of the student performance will not only meet NCTM math standards, but also exceed the math standards.

Reference: