After-School Mathematics Program Skeleton

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Classroom Structure: *One instructor per 10–15 students. 60 or 90 (depending on age) minute lessons, twice weekly.*

The Program will supply instructors with training in a non-lecturing, Socratic method of teaching. This style has been selected to encourage verbal, social interaction between the students and instructor as well as among the students themselves. The students are then the arbiters of their own discovery. Self-discovery enhances a sense of ownership over the material and engenders social cooperation among students to achieve a unifying goal. Moreover, feeling one is contributing something to others is especially motivating.[1] Lastly, the Socratic method has a built-in assessment scheme that is not readily identifiable by students. The questions used in this style are themselves graduated prompts. Counting the number of prompts necessary before students are able to transfer knowledge to new contexts is an especially sensitive way to test students' learning.[2]

Individual verbal feedback will be supplemented by group responses communicated through hand signals, chorus responses, and quick surveys of written work. Diverse methods mixing public and private, individual and group, urge participation even from shy students in a non-pressuring way. Lessons can therefore be tailored to the specific needs presented on a class-by-class basis. Unlike programs which follow a book whose curriculum is blind to the needs of the students, the structure of this Program takes into account the students' individual preconceptions of mathematics and respond accordingly and dynamically. If it does not, many students would come to an incorrect understanding of the material.[3]

I will enlist instructor candidates from the math and science departments in local colleges, though all volunteers will certainly be welcome. After passing CORI or SORI screening, they will complete a training program before entering the classroom. The training will include an introduction and review of both content knowledge (of the material) and pedagogical content knowledge (to teach the material) apropos to their classroom. After training, teachers will have continued support throughout their stay in the program. This support may come in the form of one-on-one meetings with administrators, staff meetings, and social events. The administrators should also observe each class a few times over the course of the semester. Teachers will be in routine contact with the director, or if they exist, certified specialists to discuss any concerns they may have. At first, the Program may contract specialists to visit for staff meetings only, rather than employ them fully (to cut down on initial costs of the program).

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[1] Schwartz, D. L., X. Lin, S. Brophy, and J. D. Bransford, 1999. "Toward the development of flexibly adaptive instructional designs." p. 183–213 in *Instructional Design Theories and Models: Volume* II, C. M. Reigelut, ed. Hillsdale, NJ: Erlbaum.

[2] Campione, J., and A. L. Brown, 1987. "Linking dynamic assessment with school achievement." p. 82–114 in *Dynamic Assessment: An Interactional Approach to Evaluating Learning Potential*, C. S. Lidz, ed. New York: Guilford.; Newmannet al., 1989

[3] Mestre, J.P., 1994. "Cognitive aspects of learning and teaching science." p. 31–353 in *Teacher Enhancement for Elementary and Secondary Science and Mathematics: Status, Issues, and Problems*, S. J. Fitzsimmons and L. C. Kerpelman, eds. NSF 9480. Arlington, VA: National Science Foundation.

Curriculum: *Topics will be carefully drawn from areas of advanced mathematics, potentially including (but not limited to): Cantorian set theory, group theory, number theory, geometry, calculus, and complex analysis.*

If chosen correctly, advanced mathematics need not be out of the reach of elementary learning. The present national curriculum exists as it does largely for historical reasons and has not changed radically in over a century.[4] [If anything, it has been watered down.] Yet there has been much development in mathematics and in our understanding of learning and teaching. Very simple investigations have led professional researchers to discover whole branches of new mathematics. Likewise, with proper guidance newcomers to the field can do the same.

Mastery over a topic in advanced mathematics gives students an increased sense of accomplishment improving mathematical intuition and reasoning skills. Because of the learner-centered environment, students lead the discovery process. As noted previously, self-discovery activates a sense of their individual capabilities, which makes them more receptive to the regular mathematics curriculum. Indeed, because of the way society views mathematical ability, a stronger, demonstrated understanding of mathematics enhances a child's general self-esteem.

Because students will lack previous exposure to subjects in the curriculum, these topics will provide a level playing field for all of the students. Furthermore, these topics will not suffer from failures incurred during previous experience with them, nor will they place this program in competition with the children's middle and high schools.

I will need to speak with prospective students and their teachers so that I may select topics that will address areas that need improvement. I imagine that I will need to work on basic arithmetic, functional visualization (graphing, etc.), operations with negative numbers, axiomatic systems, variables, exponents, polynomials, decimals, and fractions.

I plan to develop several classes, divided by age [grades 3–12]. Each will focus on a few skills (such as those listed above) for the entire semester (or year). Such extended attention will allow the students not only to memorize facts and formulae but to cultivate relationships which exist within the mathematics. Attempts to cover too many topics too quickly impede learning and understanding for a few reasons. Due to general time constraints, students learn only isolated facts that are not organized or connected. And if the curriculum does explicitly address organizing principles, students cannot grasp them because they lack enough specific factual knowledge to populate such relational structures in a meaningful way.[5] Abstracted representations do not remain as isolated instances of events but become components of larger, related events and schemata.[6] Thus the power of mathematics lies in its argumentative procedure. Despite difference in surface appearance

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[4]Papert, S., *Mindstorms: Children, Computers, and Powerful Ideas.* New York: Basic Books, 1980. p. 66.

[5]Bransford, J. D. (Editor). *How People Learn : Brain, Mind, Experience and School* (Expanded Edition). Washington, DC, USA: National Academies Press, 2000. p 58.

[6]Holyoak, K. J., 1984. "Analogical thinking and human intelligence." p. 199–230 in *Advances in the Psychology of Human Intelligence (Vol. 2)*, R. J. Sternberg, ed. Hillsdale, NJ: Erlbaum.; Novick, L. R., and K. J. Holyoak, 1991. "Mathematical problem solving by analogy." *Journal of Experimental Psychology: Learning, Memory, and Cognition* 17 (3) (May): 398–415.

of information, mathematical competance transfers across multiple domains which share cognitive elements.[7,8]

Acknowledgments:

I have modeled my proposal largely after three successful programs: AmeriCorps for Community Engagement and Education (ACEE), a comprehensive bilingual literacy tutoring program; Project SEED, a nationally run after-school math program designed to serve poor students with special emphasis on the Socratic method; and the Math Circle of Boston[9], a program which aims to provide a friendly and relaxed atmosphere for the open and rigorous discussion of advanced mathematics.

Also, I have relied on my personal experience as an instructor in the Theory and Practice of Teaching Mathematics masters degree program offered through the Harvard Extension School and run by the Harvard Department of Mathematics.

Literature that has influenced me most include *Mind in Society*, Vygotsky; *How People Learn: Brain, Mind, Experience and School*, National Academies Press; *How Students Learn: History, Mathematics, and Science in the Classroom*, National Academies Press; and *Mindstorms: Children, Computers, and Powerful Ideas*, Papert.

[7]Singley, K., and J. R. Anderson. *The Transfer of Cognitive Skill.* Cambridge, MA: Harvard University Press, 1989.

[8]Not all skills transfer to activities which appear to be similar. The ability to memorize long strings of numbers does not transfer to strings of letters, for example. Cf., Ericsson, K., W. Chase, and S. Faloon, 1980. "Acquisition of a memory skill." *Science* 208: 1181–1182.

[9]The Math Circle, `http://themathcircle.org`.