Re-Thinking 'Integration' in Science and Mathematics Education

Larry Flick
Oregon State University

Vexation

This vexation is a branch of the last year's vexation concerning to what extent one learns from hands-on activity. Last year I thought about the problem from inside the learner. This year I am thinking about the problem from inside the classroom. My vexation is about the fact that we tend to teach from a discipline-structured perspective but seem to reach an understanding of the material from within a context or multi-discipline perspective.

I will give you an idea of the direction I would like to go. When we talk about racial integrating, we do not mean using one race to solve problems for another race. Integration does not mean merely to house multiple races in the same neighborhood or in the same schools. Racial integration means learning from one another, finding a multi-cultural synergy, and reaching a deeper understanding of our selves and our own culture. Educators have not applied these principles to the integration of disciplines especially when applied to school-age learners. The problem that vexes me is how to meaningfully combine disciplines in an educational setting for adolescents and while at the same time helping students learn discipline-based concepts. Meaning seems to come from combining yet knowledge seems to require some separating - of disciplines.

A common approach that, to me, ignores the problem is to claim that by simply engaging in a task (e.g. PBL or hands-on activity), the student demonstrates the application of integrated knowledge. Certainly, integration is more complex than that and most certainly requires sequenced activity and instructional scaffolding over a significant period. A claim that "word problems" integrate mathematics with other concepts similarly obscures attempts to confront the challenge. Problems expressed in word form typically strip most of the interesting detail and leave only the words that code for arithmetic operations. An interesting example in science comes from a physics text that asks, How many candy bars does it take for a mountain climber to climb to the top of a 5,000 m peak from sea level? When examining the requirements of the problem it has nothing to do with nutrition, human physiology, or for that matter mountain climbing. The problem only requires the use of energy conversions.

Specifically I am interested in examining the vexation from two curricular perspectives (1) what we mean by integrating science and mathematics in the context of laboratory-type or project-based activities and (2) what we mean by integrating mathematics and/or science into career technical education (CTE) courses. The first case asks; can a single project meaningfully use both disciplines and at the same time help teach something in each discipline that complements the other? The second case asks; can a problem derived from a career-related context also teach something fundamental about one or both of the disciplines?

Integration therefore is more than just finding new words with which to state the problem. Integration is more than juxtaposing concepts form multiple disciplines. My vexation would approach resolution if, as a result of integration, we know something more about mathematics having used it in science and vice versa.

Return for a moment to hands-on activity. Hands-on activity makes thinking visible. It is one way to operationalize what we mean when we say; "I understand". For example, we can see how a skilled craftsman uses proportions to scale a pattern and position and cut the pieces so that they result in a whole garment as designed. If we observe a student doing the same task, can we infer understanding of mathematical ideas? What kind and how much scaffolding is appropriate for bridging the zone of proximal development but still maintain the need for true mathematical thinking by the novice to accomplish the task?

To use the garment itself as a metaphor for my vexation, the garment maker fits the pattern pieces (disciplines) to the fabric to make a product (integrated understanding) that is more than the sum of its original parts. That is what we are after when integrating the curriculum. The integrated ideas attain a meaning that is greater than the sum of the separate ideas each from different disciplines.

Venture

The two types of integration mentioned above come about because they are elements of a project that will take place in a high school as part of a mathematics and science partnership grant under *ESEA Title IIB*. The problem the grant is trying to solve is how to increase the passing rate of freshmen in Algebra I. The approach is to integrate ideas in algebraic reasoning into other classes that freshmen will take. The classes are Science & Society and Design & Engineering (metals, woods, nutrition, and fabric arts). The first class will integrate science and algebraic reasoning. The latter will integrate algebraic reasoning with career-related (CTE) skills and concepts. The high school provides a good fit for examining the integration of algebra in context because the curricular model of the school a model of project-based curriculum. Therefore, the plan will be to design projects so that elements of algebraic reasoning can be highlighted and reinforced in class projects. These same elements of algebraic reasoning will also be taught in the Algebra I class. Note that I did not say that algebraic reasoning will only be "applied" in the courses. That would suggest a continuation of the *status quo* to invoke "integration" as the use of one discipline merely in the service of another.

How do we prosecute this venture? What are the project design elements? What are teaching strategies that facilitate thinking both about the subject matter of the class while at the same time being aware of how elements of algebraic reasoning are being developed? What temporal issues are involved in considering ideas separately then together or vice versa? How can projects be designed (curriculum) such that teachers can facilitate thinking (instruction) about the right ideas at the optimum time? How can student knowledge (and interest) in one domain support construction of knowledge (and interest) in another domain?

The venture as I see it now, will rely heavily on research on teaching algebra that focuses on algebraic reasoning not on symbol manipulation for the solution of equations. It will also rely on research in understanding science as inquiry. Projects will require generating and interpreting data, making arguments based on these data, and formulating conclusions. The glue that will bind these classes in different disciplines together will be concocted from the ingredients of teaching students about problem representation, proportional reasoning, balance, meaning and use of variables, patterns and functions, inductive and deductive reasoning. Each class will design projects that incorporate the use of active exploration, conjecture, and deliberate generalization. The theory is that these forms of thinking, when taught in coherent manner and presented in different situations, will lead to a meaningful (connected? integrated?) understanding of algebra, science, and other technological content (e.g., making a garment).

Teachers will work with science and mathematics education faculty to modify and/or embellish projects. The garment example is one project under modification. Students will receive a pattern for an athletic bag that is too small to be of much value. Students will scale up the pattern to fit their chosen specifications. In making the bag, students employ skills on the sewing machine that involve visualizing shape and proportion. In the metals class, students learn to use a torque wrench. Students learn the physics of torque, physics of threads on the bolt (inclined plane), and reading the gauge to calculate the load on the bolt. The load on the bolt translates into how much the bolt stretches and its tensile strength. These results have implications for design and structure.

Implications if Unresolved

I do not think that vexations actually get resolved. They become less vexing. We learn more so that we are able to make progress toward improved understanding. The risk we run by not attending to how integration can work is to continue claiming that we are doing something that we are not. Sooner or later, and usually sooner, a smart reporter, or teacher, or researcher, or government official, or student blows the whistle and says, Wait a minute, and here is test data, or attendance data, or survey data, or personal experience that shows you are not accomplishing what you claim.