Industrial Arts/Technology: What Are We Doing?

The push to prepare all students for college has resulted in the near disappearance of high school industrial arts courses. Mr. Howlett and Mr. Huff warn that this unfortunate trend endangers the future of both non-college-bound students and the U.S. as a whole.

BY JAMES HOWLETT AND BRAD HUFF

HE WAS late! It was the first day of school, a class he didn’t know anything about and had not asked to take, and it was taught by a “hard-nosed” teacher who he knew made an issue of students being late.

Not a good start! But he needed to stay in school only until his 16th birthday. Then he planned to drop out and work in the vineyards with his father. Who needed English, history, and math to pick grapes and prune vines?

He entered the classroom, found an empty seat, and followed along as the other students were asked to get out materials, drawing boards, T-squares, triangles, and scales. Over the next few days he began to learn new things, and he used his hands. He got immediate feedback on his learning, positive comments when what he did was correct, and suggestions on what to do when it was not quite right. He found that he wasn’t really conscious of what he was learning; he just did the work. Gradually he realized this class was interesting. It was hard, but he learned to do the drawings. Soon he began to do them really well. Roberto, for the first time, was learning a skill.

Roberto was lucky. He was lucky for two reasons. First, he was attending one of the few remaining high schools in California that has an industrial arts program; and second, he would be able to make a connection between his skill training and the academic classes he needed to graduate.

California lost 75% of its high school industrial arts programs and nearly 90% of its junior high exploratory industrial arts programs between 1950 and 2004.

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Today the state needs 1,500 industrial arts teachers, but only three California State University campuses offer a teaching credential in industrial arts.

We use the term industrial arts in this article because that is really what the subject comprises. Although many educators now call it industrial technology, the art is still there, and we need to keep it there. You can have self-taught “shade tree welders” in any garage, but it takes a welding artist to do the job correctly.

The University of California and California State University systems prescribe courses students must take successfully to qualify for admission. These are called the “A to G” requirements. No “skill training” class meets the A to G college entrance requirements. However, among the students in California’s 2004 high school graduating class (the latest for which data have been published), only 14% entered a four-year college or university. Why were 86% of these graduates forced into a curriculum of college entrance courses? Why are we pushing students who come in all shapes through the same round hole?

We have, in one California assemblyman’s words, “denigrated the vocational worker.” Vocational workers are no longer viewed as making valued contributions to society, yet this year in the U.S. we are short 35,000 machinists, 48,000 construction workers, and, in California alone, 2,500 automobile technicians.

The U.S. is desperate for the skills Roberto has gained. These skills used to be taught to some degree in every high school. The need for manual skills was recognized for decades as something that should be taught in secondary schools. To be a trained machinist, auto mechanic, welder, ship fitter, or other skilled laborer was viewed in a different light from what it is today.

In the year 2002, the average age of all mold makers in the U.S. was 58. The Department of Defense is concerned that, should we have a major military conflict, we could not build the necessary war equipment within the U.S. We would have to “outsource” the manufacturing of vital components. Not a reassuring picture.

In addition to the dominance of university entrance requirements in the curriculum, another factor destroying the industrial arts is the No Child Left Behind Act. Unenlightened administrators are quick to point out that many industrial arts teachers do not hold a bachelor’s degree. NCLB requires all teachers to be “highly qualified” and, because there are so few people with four-year degrees in industrial arts in California, many administrators eliminate these departments and convert the space into study areas for reading or math review. We have seen this in the Silicon Valley at San Leandro High School, in San Jose, and in other locales.

INDUSTRIAL ARTS AND MATH SKILLS

Industrial arts courses support the academic core subjects of math and reading. First, every industrial arts class requires measuring. While a multiple-choice test can’t assess a student’s ability to machine a part to within a thousandth of an inch or to program a computer numerical machine, it can assess a mastery of knowing how to measure. In addition, students have to know what to do with those measurements, how to manipulate them, and how to add, subtract, multiply, and divide fractions and decimals, all of which are testable. But that is the simple stuff.

Students in a drafting course must master the concepts of perpendicular, radius and diameter, tangential relationships between circles and straight lines, and angular measurements and must develop the ability to read and measure using architectural, mechanical, and metric scales.

Because the U.S. has yet to adopt the metric system for measurement, much of the work students do is in fractional parts of an inch. Then the students must convert fractions to decimals because machinists work in decimals. The students become fluent in the language of drafting and adept in the use of drafting tools because they have to finish project drawings. And they have to be able to mentally “picture” what they draw in three-dimensional space without the aid of a computer.

Also in drafting, students have to apply the Pythagorean theorem and solve quadratic equations to find the radius of an arc, which are practical applications of some fairly complex thinking. In spite of this, drafting does not qualify for the university “A to G” entrance requirements.

Now, what about something like “Outdoor Power Mechanics”? That’s educationese for learning how to repair lawn mower engines. How many of us remember Bernoulli’s principle from science class? That is what makes carburetors work. Industrial arts students have to know this. When they see it on a test, they will already have seen it work and know what it is.

How about the effect of magnetic lines of flux and magnetic fields on a copper wire? Lawn mowers do not require a battery-operated ignition system; they use magneto. The ignition points have to be set to within the correct gap measured in thousandths of an inch, or the ignition system will not operate correctly. We teach compression ratios, and students have to calculate engine dis-
placements, which involves volumetric measurements of cylinders. Finding the volumes of cylinders is taught in first-year algebra, but algebra doesn’t include finding compression ratios.

Industrial arts students need to learn air-to-fuel ratios so that proper combustion is achieved, why a capacitor is needed across the points, why there is a gap in the laminations of a magneto coil to ensure proper changes in magnetic flux, and what ratio of turns in a magneto coil is needed to achieve a 10,000-volt spark to jump across the .035-inch gap of a spark plug. Why do we need 10,000 volts in an engine when we can get a spark of 1,000 volts to jump an inch in dry air? What does compression have to do with voltage requirements?

Let us supply a little statistical information. The best-known manufacturer of small engines, Briggs and Stratton, produces 12 million engines each year and has about 60,000 dealers nationwide, each with a trained technician. From where do those technicians come?

Do we need some solid science in our discussion of small engines? We think so. However, “power mechanics” doesn’t meet the “A to G” college entrance requirements.

How about something really mundane, such as woodworking or cabinetmaking? Even in beginning woodshop, students like to build something that looks good and that is made of something other than pine, birch, or wood salvaged from discarded shipping pallets.

Now we get into the area of cost/benefit analysis. At $5 a board foot for some of the more common woods used, it might be a good idea to be able to calculate the number of board feet to be used in a proposed project and then get a cost estimate before you plow ahead with your plans to make a stereo cabinet out of solid Brazilian walnut.

And what in the world is meant by “board feet” anyway? Well, a piece of wood that is 1 foot square and 1 inch thick makes up a board foot. Oh yes, and if your wood is called 1 inch thick, it is really ⅞ of an inch thick. So here we are back to measuring and calculating using fractional inches, having to think about how long the shelf will be if we want a bookcase that’s 4 feet long and the inside shelves are to fit into a dado cut that is ⅞ inch deep. And while we are thinking of a dado cut, how many shims are required to set the blade to make a ¾-inch dado? Measuring and calculating are happening all the time.

Woodshop students also have to learn about different woods and how grain affects the fit and potential warping of a board. What is grain? How do we look at wood and find a piece that will do what we want it to do without splitting a year after the project is finished? In many quarters this is called materials science.

If we include house construction under a broad category of woodworking or construction, then we have a whole host of additional mathematical problems: studs on 16-inch centers and stub wall stud lengths for windows that have to be placed according to the local building code.

How many steps will you put in and what rise and run will you use to match the building specs for that staircase to the second floor on the custom-built house that has 12-foot ceilings on the first floor? What will be the angle of cut on the roof stringers so they match at the peak, what should the roof pitch be, and how do we calculate that?

How many units of shingles will be needed for the roof? What size HVAC unit do you need to heat and cool the volume of a house that has a floor area of 3,650 square feet with half of the floor space having a 12-foot ceiling and the other half a 10-foot ceiling?

How many square feet of insulation do we need for the attic to achieve an insulation level of R-24? Is it cheaper to use fiberglass batting or blown insulation? If we use blown insulation, what is the volume of 12 inches of insulation for the attic? Now we need to compare the cost of that volume of blown insulation to the square footage of fiberglass batting. And while we are on insulation, how many square feet of batting do we need for the walls? How many board feet of 2x4s and 2x6s do we need?

What is the square footage of the outside “wrap” of moisture barrier; how many linear feet of water pipe, copper tubing, sewer pipes, and wiring are needed; what is the required number of light fixtures, outlet boxes, fuse panels, etc.? Square footage problems must be solved to determine the areas covered by flooring, shingles, wall-board, and finishes. Is there a need for math skills here? Critical thinking skills? Planning?

Welding presents another set of problems that need math skills. There may also be design problems for jobs that come into a welding shop lacking diagrams or specs.

Recently a young welding teacher asked Jim Howlett what kinds of math and reading skills he had to teach his classes. We kicked around those skills and concepts that are taught in all the shop areas, and then he talked about a discussion he had had with the school’s physics teacher. The physics teacher is a very bright fellow. He received a perfect score on the math portion of the SAT when he was in high school and teaches AP physics and calculus. He was bragging about his math abilities, and the welding teacher told him that, though
the physics teacher was really sharp on theoretical math, he was not nearly as fast on practical problems. The challenge was made and accepted. The physics teacher lost the challenge, and it was a fairly straightforward welding problem . . . nuff said.

Is there a need for welders in America? A 15 August 2006 Wall Street Journal Online article by Ilan Brat states, “The ranks of welders, brazers, and solderers — whose jobs all are essentially to join pieces of metal — dropped to 576,000 in 2005, a 10% decline compared with 2000, according to the federal Bureau of Labor Statistics. The American Welding Society, an industry group, predicts that by 2010 demand for skilled welders may outstrip supply by about 200,000.”

And then we have machine shop. Right off the bat students must learn to think in decimals. In the commercial machine shop, “125” is immediately understood to be $\frac{125}{1000}$ of an inch. We have to teach our students to read vernier and micrometer scales so that they can accurately measure to $\frac{1}{100}$ of an inch. This is because we expect our students to be able to machine a part to this tight a tolerance, about a quarter of the thickness of a human hair.

When we start to teach machine tool cutting speeds and feed rates, we have to be concerned about rotating diameters and the surface speed of the material being worked by the tool bit. On a lathe, how does the surface speed change as the diameter of the material we are working on decreases?

For a milling machine, students need to know the rotational speed of the bit, its diameter, and how many cutters it has. All that information must be used to calculate the proper feed rate of the material past the cutter. Show me a math class that teaches that or that motivates a student to learn the math he or she must know to be able to machine a part to the required tolerances.

We also have to include instruction on different metals and what the characteristics of each are for machining. We don’t expect our students, or anyone else for that matter, to remember all the information necessary for a machinist to do a competent job. That information is found in the Machinists Handbook, which has been in print for more than a hundred years, is updated annually, and is now a tome of more than 4,000 pages in several volumes. Yes, we expect our students to be able to access that book, find the section they need, read it with understanding, and use what they have read.

Machinists must be as facile with angular measurement as are draftsmen. In cutting threads on a nut or bolt, the standard V thread that we are all familiar with (because that is what we see used on the nuts and bolts in our local hardware store) uses a 60-degree V that is split along the centerline of the V. We have to grind a tool bit that is in that shape and then cut the threads, making repeated measurements to ensure the proper depth as measured from the crest to the root of the thread.

Inside threads are another interesting challenge. Threads are an example of artistry in machining. Well-cut threads are beautiful to behold!

INDUSTRIAL ARTS AND LANGUAGE ARTS SKILLS

Within California’s STAR (State Testing And Reporting) test of English/language arts, 50% of the questions deal with reading and following directions. All classes in the industrial arts require students to read and follow directions.

Jim Howlett asked the head of the English Department at his high school how he and his colleagues teach reading and following directions. “We don’t,” was his response. Lab science classes require students to read and follow directions, but how many labs do most science classes hold during a school year? Perhaps one a week. Reading and following directions are a daily occurrence in industrial arts classes.

What we really need the teachers of academic core subjects to understand — and we don’t mean to insult anyone’s intelligence — is that industrial arts and any hands-on training we can give our students can be as important to them as any English or math class. There is a tremendous amount of research showing how working with one’s hands improves one’s mental abilities.

Roberto enjoyed his drafting class! In that class he started to see connections to math, and the confidence he gained in drafting, computer-assisted drafting, and computer numerical machining quickly spread to his other classes. Roberto graduated from high school and received a four-year college scholarship. Roberto’s story is true. He did not become one of the 120,000 students from his class who dropped out of high school. He is not working in the vineyards. But Roberto was lucky. He went to the right high school — one that offered industrial arts classes.

For the remaining students attending the high schools throughout California with “A to G” college requirements and no industrial arts program, we feel compelled to ask, What are we doing?

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