Using Old Antique Tools to Solve a Modern Problem - The Introduction of the Slide Rule to the Classroom

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In education there is a continual need to look for 'new' ideas to affect or solve problem areas in the access to success for learning. The problem to explore today is rooted in mathematics and moves through science and technology courses as well.

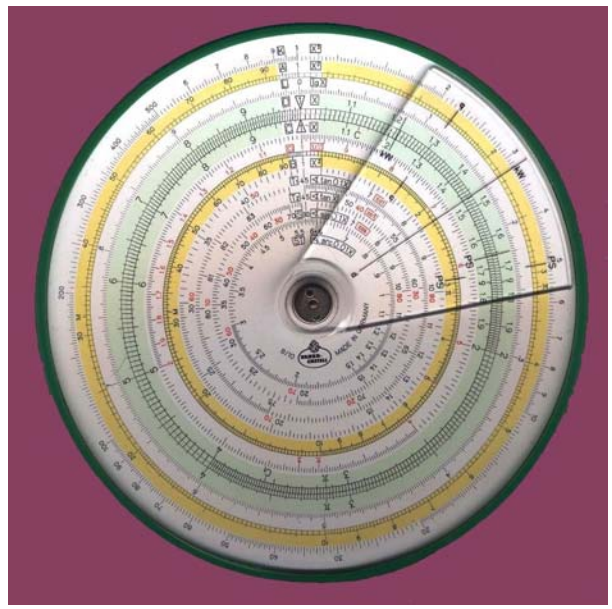
First a side note on the importance of math and science education so as to assert its necessity. Few would argue that education beyond high school today is not required and that the primary access to the employment market is through math and science related fields. In fact one could argue that one's math skills will determine the primary economic layer that one ascends to in society. The greater one's math skills are, often they have greater mastery of related science concepts if needed and between the first and with the second here it grants one the adaptability in the world today.

The primary problem seems to be the barriers for learners to grasping, conceptualizing, and finally mastering some level of proficiency in various math skills which are found throughout most math courses and are necessities in science classrooms as well.

The first solution area has been simply to have more technology in the classroom. In the 1970s students were introduced to calculators. One of the stated reasons by the manufacturers as a selling point was that it could engage those who were not inclined for math, though no studies were done to reveal this claim. As time went on, there has been smaller yet more powerful calculators and there are now graphing ones that can store more information than a NASA computer system in the 1960s. Despite the technology, the problems persist.

To explore options we need to look at the problems though. The problem I identify is a growing trend in society's students to have little to no what I call computing skills. These skills are the foundation for all of the mathematical and logical reasoning needed in the fields of math and science as a student progresses through education.

The following details these skills, the rationale as to why they are important, why the calculator may not be able to meet this need, and where looking at a historic device in the form of the slide rule could actually hold the solution to this puzzle.



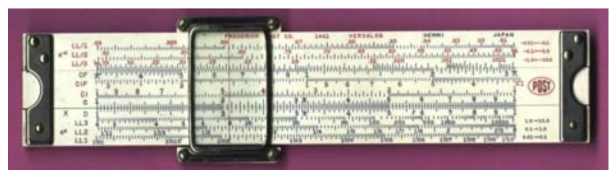
What are these computing skills?

1) Basic Operation Calculations – These are the basics: adding, subtracting, multiplying, and dividing. – How many teachers can note that when asked a basic calculation task, a student does not know the answer, gets it wrong, or needs a calculator. Even those with some skills seem slower than students of yesteryear. Many teachers can note the number of times that students have difficulty in multiplying two numbers together in class. When asked, the students do not know the answer, where the answer should fall nor have any strategies for solving such a problem.
2) Little to No ability to Estimate an Answer (noted in number 1) but is a skill unto itself. Even the best calculator user is known to make mistakes. How often do we hear of the wrong values punched into machines by

workers? We let the machines do our calculations and not us. Calculators, in fact, do not promote estimation as a skill. Simply type in the values and the answer magically appears in the window. Without estimation there is an over-reliance on the magic machine. We have shifted the definition of computer of yesteryear, which was when we did the actual computing to that of the machine today. To illustrate how far this has gone, consider today's work environment, where pictures are used on cash registers to make the task easier so little to no math skill is needed for that layer of society's workforce. Thus the place to begin in Estimation with Basic Math Computation Skills in place. These are found in early Elementary School and extend all the way unto college.

3) Inadequate skills at Simple Formula Manipulation along with Computation- Simple Formulae here are ones of the form A = B * C (or B/C). This is noted not only for Math but Science as well. Note that most ideas conveyed in school involve just such a formula. Take for example the formulae for speed (v = d/t), force (F=m*a), pressure (P=F/A), density (p = m/V), Ohm's Law (V=I*R), Area of a Rectangle or Square (A=L*W), Work (W=F*d) , and even everyday calculations like miles per gallon (mpg=mi/gal), and computed costs C=R*t (cost=rate*time)
4) Often unable to realize the effects of one variable in a simple equation on another as it is changed by some factor in a given situation. (direct and inverse relations). This is due to not being able to visualize the problem.
5) Poor skills at using Scientific Notation computations (tied to both basic computational skills and estimation skills (here magnitude)).
6) Poor skills in using fractions and converting back and forth to decimal equivalents. The trouble with fractions has been noted in numerous studies. This is also connected to converting values from one measurement form to another (metric to English units, time units, and so on), as well as the critical skill of Solving Proportions which appears in many formulae and can be employed with all 3-variable functions noted above and others as well as with Similar Triangles, Geometric Parallax Measurements, and so on.
7) Poor Significant Figures skills. This can also be attributed to the calculator since it provides us with a flood of decimal places, virtually all of which are unnecessary.

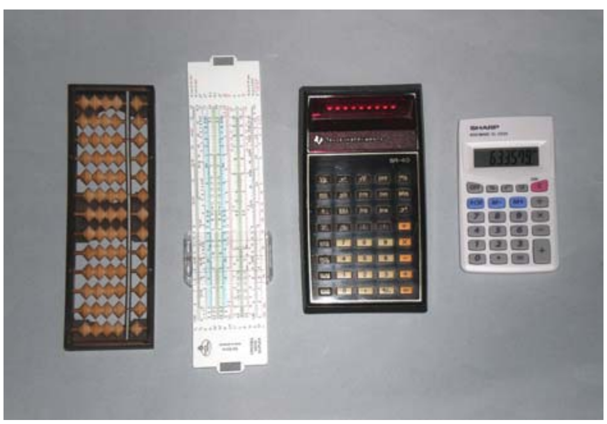
The above list is not to say that all students lack these skills. Instead there is a very broad spectrum of students and hence skill levels. However, this is important to note. What we do with this spectrum of students is to create natural segregations. The top percentages, those with the sharpest of these skills often are enrolled in what is traditionally referred to as the 'college-track' classes and the others are labeled as 'regular education'. I use these too in my discussion. Clearly, it is the regular education students who have the most troubles in these areas noted above, and are now being places in the college-track system since that is the wave of the future.



Are the problems serious? Certainly. *It is primarily Math and Science which are the main determinants of where a person's occupation and income levels will fall*. Realize the necessity of math in the workplace today at jobs of higher needed skills, since going to college is not a luxury anymore and most if not all degrees necessitate some level of math competency. There are a number of studies that note the need for math in the workplace and for success. Lacking or being weak in these skills will result in many doors closed. Society is reflecting the problem. Today in many fast food places they use pictures instead of numbers. And when was the last time a teen counted back your change to you? Clearly too, the problems noted do exist. All the data proves this (teacher's grades, teacher's anecdotes, national and state test scores, and the like). So what are the solution possibilities?

To find a solution we need a common thread in all of these elements. That thread is the fact that we have transferred the skill of computation from ourselves to our tools. We rely too much on the calculator and not on ourselves for determining the outcome of a problem. Also recognize that many other solutions have been explored, from repackaged books, motivational exercises in the class, and all sorts of other materials. The following explores and explains my hypothesis for helping to solve the computation problem by using the slide rule as the tool. The slide rule is a logarithmic scale system that can be called a visual analog computer which promotes mental computation and is analogous to the number line which is still in use in school to promote foundation math skills. In fact, the slide rule can be seen at the next step since 2 number lines can be placed adjacently to illustrate addition and subtraction, the basic form of the slide rule is two adjacent logarithmically-spaced number lines for use in multiplication and division.

The first place to explore the reason is found in the goals of math and science. What is the goal of both Math and Science education? Is it only having an answer to a math problem or knowing a definition of an idea in science? Obviously not. In both disciplines *it is the process of solving the problem that is the goal*. As with all good goals, the process of solving a path to it begins and is worked out in one place – the mind. Calculators do not require us to think about what is being done with the numbers or even why we type them in. How many times has a student asked what do you type in when asked a problem?



Let's look at the value of the SLIDE RULE in each of the Computation Skills areas and other critical ideas to use the slide rule in the classroom as a visual tool for acquiring math skills:

1. The Calculator does not promote the knowledge of Estimation, Basic Operation calculations and the like. In order to even properly use a Slide Rule, one must know: Decimal Points and their placement. They must have a good working knowledge of Value Estimation and have sharp memory of the Basic Times Table to even use the device. Unlike the calculator where you press buttons and answers are flashed back at you (we often give it to the student and want only the answer), the slide rule user must interact with the device to find the answer and then compare it to your knowledge, your expectations. One might say then why use it if I have to approach it with skills in place? In the class, even in the elementary school level students could be presented a simple two-scale slide rule to perform basic calculations involving multiplication and division. The tool is visual – one sees the answer as compared to many of the present-day tools in the classroom such as plastic blocks, sticks and other assorted colorful items. They may help too, but the slide rule has the answer directly on it and only required basic skills to operate it. Also one sees the changes in variables as one reads it (see following arguments concerning 3-variable functions). The device encourages mental math with a direct answer (unlike other manipulatives)– unlike the calculator which merely reaches the answer and flashes it at the user. Though one cannot see the value of the slide rule here, with guided practice from a teacher the visual tool in the student's hands can act as the bridge from the tangible world to the conceptual world.
2. The value of estimation cannot be emphasized enough. One cannot use a slide rule without estimating the answer unlike the calculator which totally erases the process of estimation. When computing the area of a floor, walls and the like for tiling, carpeting, painting, and wall papering we round values to no more than 3 significant figures and can mentally estimate where the answer falls. Even in cooking, we estimate costs. When employing the slide rule we have to keep track of the decimal place, we need to have reasonable skills in multiplication through practice so that we can read it and determine the answer, and develop deeper computational skills.
3. A slide rule has the numbers from 1 to 10 only, yet because of scientific notion we can find any and all numbers that exist on it! Imagine showing a student that power. Regardless of the number one thinks of and multiplying or dividing it, one can find both values on their independent of magnitude and discover the answer in one's mind and

reinforced by the slipstick, the stick with numbers on it.

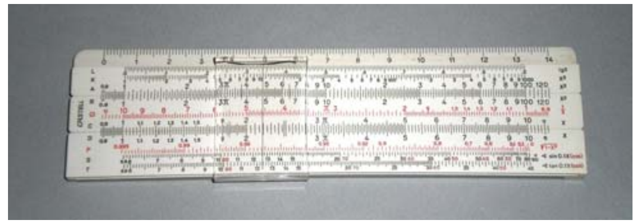
4. The Slide Rule is designed to fully illustrate the world of simple ratios and multiplying factors – both of which come from Simple Formulae (A=B/C). One scale is one variable, the other scale is the other variable and the answer (the third variable) is the relation of the two found easily. This makes visualizing the relationship all the more tangible. With this tool, the variables are there in hand. A calculator does not provide this at all. Even as an aside Teachers can use it to construct tables as needed for data and graphing too! Plus now students can do the same and examine data tables for relations. Take a given speed problem. Place this speed over the index value of 1 on the slide rule. Now all values on that upper scale are distances while the lower scale represents time – just like the equation itself! This works not just for whole numbers, but any decimal value too. A teacher can ask how long did it take to travel some given distance or how far did one travel in x amount of time. The student reads along the scale, the greater the distance along the scale represents a greater amount of time at a given speed. Notice how this reflects the number line and its use to promote number placement. In fact, like one could use two rulers as number lines and place one over the other and it behaves in a slide rule manner. Instead of multiplying and dividing, the rulers can be used to teach adding and subtracting. This extension then takes Elementary school education to the Middle School and the High School.
5. Since #2, then the Slide Rule is a natural tool for examining the effect of the change of one variable with respect to another very easily. One could look along the scale for changes with respect to other variables that a number might be multiplied for example. With a C1 scale (inverse) one could then look at dividing too! One would have to retype the problem time and again to examine the possibilities on a calculator.
6. The idea of one variable over another is especially true when placing a value over '1' and looking along the scale at 9, 8, 7, et al – which are now 90%, 80%, 70%, and the like. This is not only useful for math and science, but also business and everyday life calculations. Other calculations, such as increases in percentage on an item and calculating tax on an item are easily done too.
7. This idea extends to the fact that most formulae can be seen as proportions – even 3 variable ones! Take v=d/t. Once we place d over t on the side rule look over the index '1' to find v. Hence it is v over 1 equals d over t. The same is true for all conversions, say 1 ft = 12 inches. Place 1 over 12 and look along the latter scale – this is now the inches and look above to find the feet or vice versa! All conversion scales are really slide rules. Imagine seeing all answers to every question simultaneously when converting. Place 1 representing inches over 2.54 representing centimeters. The upper scale is any and all inch values while all numbers on the lower scale are centimeters. It can be read back and forth for any value. Try that with a calculator!
8. In the realm of fractions, their equivalents, and decimal conversions this idea of the proportion is critical. Take any fraction, say 7/8 and place it on a slide rule. Look along and find all other equivalents to it – 14/16 and the like. On the scale of '8' look for the index '1' that has a value above it (the one to your right) and find 87.5 or 0.875 the decimal equivalent of the fraction! Again notice the visual power of the slide rule. It would reflect how it is written in a text book (with one number over another) and makes a good picture when a teacher is discussing this verbally with the class.
9. Another critical area that is related to fractions is proportions. Virtually all formulae, conversions, and the like are proportions. One can solve a proportion on a slide rule as fast if not faster, plus as accurately as anyone using even a scientific calculator. This is because all one has to do is set up the known ratio in the proportion and then find the other known variable so that the value either above or below it is the answer.
10. One might quickly object and say that a Slide Rule gives typically about 3 figures for an answer normally. Clearly a calculator gives many more numbers. This is the fallacy of the calculator. All Science Teachers know this. How many figures are in the answer depends on how many numbers are in the values in the question. Typically this is no more than 3! Think

about it, Reality itself is often this number! What do I mean? When measuring a room or anything for than matter (7ft 9 in, 688 cm, 14 gal, so many dollars and cents, time on a clock, and the like). We rely on 3 figures at most in our daily lives. This is all that is needed. Realize that it is the process of calculation and not just the answer than matters. Think of how often the students when using calculators want to write all the decimal places. Please someone show me with your standard ruler how to measure that 6^{th} or 7^{th} decimal place sometime. This may be needed when I purchase paint, tiles, or wall paper when working on my home. (all sarcasm intended).

11. Since a person using a Slide Rule must keep track of the decimal place, it becomes easier to then discuss the Powers of 10 Math Rules. How. Go grab two ordinary rulers. When you place the rulers alongside each other so that you can read both scales (either English or metric – I recommend the metric) you already have the means to Add and Subtract. Place a number in line with the '0' of the other ruler. Say, for example, 4. Now looking along the ruler with the '0' go to 7 and look back on the ruler with the '4'. It is on '11'. Obviously this can be read in reverse. But wait. I promised exponents, not simple math. Bear in mind that the rulers allows a simple means to teach slide rule use. What if these numbers were Powers of 10 instead of regular numbers and not added but are multiplied. $10^4 * 10^7$ is 10^{11}. This means that all of the multiplication and division rules for exponents are at your fingertips. Side Note: This makes the Slide Rule the natural extension of the Number Line, which is the idea expressed here.
12. Other added features of the Slide Rule: the Slide Rules require no batteries! Interestingly, despite the fact that Slide Rules may be short or long, or even circular, they have all the same operating rules and employ the same scales – given names like: A,B,C,D,L,S,T. This means there is little adaptation needed as compared to calculators with different keys and the like.
13. Unlike calculators there are no games on slide rules, such as graphing calculators. It is a focused device. Plus it would be harder to cheat with a slide rule as compared to a shared calculator.
14. A basic 9 scale slide rule can perform virtually any and all calculations that a scientific calculator can. (Persons such as Einstein and von Braun relied on the same type of slide rule). Students can start with a basic instruction of 2 scales in elementary school and move on to more scales in middle school and high school using the same 9 scale form they started with. Notice the lack of training needed, the reduction in costs of materials, and the easing of tension to acquire new skills.
15. In the Elementary and Middle Schools there are two points to be made. First, ask yourself what is used for all students in many if not all cases to teach counting, addition, and subtraction. Simple – the Number Line. All of us have used one. Most of us would argue that it is a very useful and tangible way to learn the process. Guess what? The Slide Rule is a Number Line only in a different scale (logarithmic) and can be used for multiplication and division. Why then not use a number line here too? Imagine making the transition from Elementary to Middle to High School and having to only go from the number line to the logarithmic number line and learn any and all functions that are necessary to master all of the ideas in math and science.
16. The second point when discussing school and tools used, do we need technology simply make the learning faster and easier? If technology is always the answer why do people still use wood and charcoal burning grills instead of microwaves for cooking? Technology does not necessitate usefulness. Also in Elementary and Middle Schools there is a trend to have physical manipulative tools to help the student grasp the idea. The slide rule is the next logical extension of this idea. Perhaps it can even find its way into those arenas. There are even books on paper ones to teach these ideas. A company, TOPS, even wrote a 3 book series involving math and sciences. It is useful for the high school, but some of the simpler ideas could be used in the middle school environment. One book, Far Out Math, is only about Slide Rules and logarithm use. One may think this is an outdated source. It was written with NASA and published in 2006. It uses the idea of a number line and extends to the world of the slide rule (more on number lines next). It is

interesting to note that education provided the number line to all then separated the groups later on and provided a different number line for one group and none for the other. Did the slide rule make the others ‘smarter’? By no means. But did it grant access to promoting the use of ‘mental math’ which is the chief argument presented here. Yes it did. Look at any text of the 1960s in physics. Are the problems that more complex and requiring a slide rule? Rarely. Also have the problems changed so significantly that the slide rule would be displaced? The obvious answer is no – the rules of science and math have not changed.

17. Students can even make their own slide rules when given a template and glue them on wood or plastic pieces. These may become projects that tie the science and math departments to art and shop departments in a school. Realize that a personal tool may have less of a tendency to be forgotten, broken, and the like, plus imagine the excitement and power one feels holding such a tool in their hands and accomplishing mathematical prowess with it. (A list of web sites follows at the end of this discussion).
18. Unlike the calculator, the slide rule was a part of history in terms of effecting science (in the areas of astronomy, geology, chemistry, and physics), math, engineering, and the like for nearly 350 years. In fact it can be said that it is the most powerful device for math per unit volume or mass ever devised before the age of the computer. It was in the hands and was the primary tool that led to the creation of virtually all mobile and immobile engineering structures known. Also there are many famous names involved with it, such as Isaac Newton, Albert Einstein, James Watt, William Oughtred, Amadee Mannheim, and others. Also virtually all mobile and immobile forms in the world, such as the Panama Canal, Hoover Dam, the Empire State Building, the Golden Gate Bridge, the F16 fighter, and the Apollo spacecraft all have this tool in common as one that was a part of their design. It could be argued that the Slide Rule’s history is connected to these people and items in the hands of mathematicians, scientists, engineers, which resulted in the two major Industrial Revolutions which affected the historical shift in society and economics the world over.



Still skeptics might argue what has been called the ‘antique’ aspect of the slide rule as compared to other devices, like the ubiquitous calculator. Let’s look at some parallels and ask if technology is always the answer.

First consider the microwave. It came into the home in a similar time as did the calculator. Did it replace the gas or electric stove? No. Despite its compact size, much higher power (and power use I might add), we mostly use it to heat up a cup of cold coffee, pop some popcorn or warm up a sandwich at most. Few, if any actually ‘cook’ with it. Note all of the cooking shows today and see if the microwave is their central tool. Why the gas stove. Much like the slide rule it is a tool that forces the user to be involved with the process of what is going on. The microwave like the calculator is far away from us.

What of Velcro shoes versus those with laces? If Velcro is so inexpensive and all the rage, then why should we even teach kids to tie their shoes at all? They are antiques. The same could be said of having clocks with faces on them. Why not just hand a digital clock to a child in school and have them tell time. Why do schools still use cardboard and foam rubber face clocks? They too are antiques.

What about measuring tapes? Talk about antique. Why not just have students use the infrared beam measuring systems instead. Oh, by the way, try to measure the length of a table, or its height, or your height for that matter, let alone your waist size with one of those beam devices. I guess the antique measuring tape might just have a use after all.

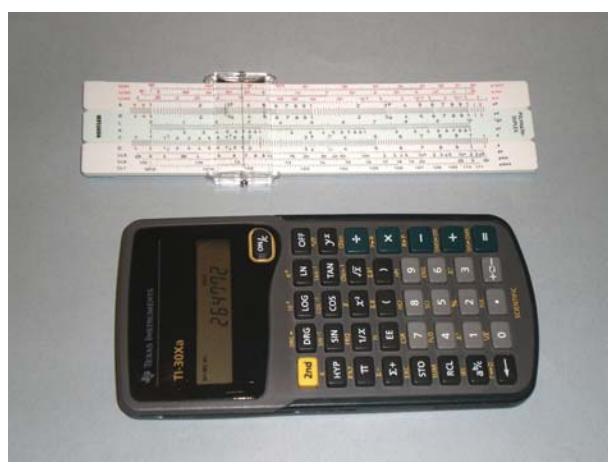
Another skeptical argument might think that the calculator has been proven to be the champion in the classroom at helping students. First note that most studies are about subjective answers to using the calculator and were sponsored by the manufacturers of the devices. In considering the results of these studies, most, if not all had students operating with a calculator and few if any groups with no calculator use, modest calculator use and excessive calculator use in their groups. What is missing? An alternative to the calculator use! One could say this is the no calculator use group studied. No it is not! If we wish to study the success of acquisition of these skills, we need to compare it to other things that can help acquire these skills too. This will help to determine the strengths, weaknesses, and rates of change for both. This is what is lacking in studies of what works versus of what does not in the classroom. This is where the slide rule is left out of the picture wrongfully.

In fact, a math panel to the US government in 2008 even noted that the calculator has not had sufficient short-term, nor long-term studies on it done, plus the ones on the record books (which are over 20 years old) show no real gains or changes in skill levels. The best that can be said of those reports are that students when first introduced to the new calculator (at that time in the 1970s) they found it exciting and interesting. Well, that is often true of most new things. Oddly, though, in a 2005 anecdotal report in the Oughtred Society publication called the Journal of the Oughtred Society in volume 14 number 1 of 2005 there is not one but two teachers, at two different school levels (middle school and high school) in two different states, who introduced their students to the slide rule and found there interest levels go up considerably and participation sharply rose as well. It is critical to realize from this that this presented hypothesis should be investigated and not overlooked. To turn away from a hypothesis based on no information or some internal prejudice is not science at all.

Finally to close out this argument – the use of the slide rule in the classroom – return to the emphasis of education – the goal being the acquisition of skills to solve problems. In history the problem solvers were the ones who took the slide rule from the originators of the tool, such as William Oughtred the mathematician and later those like James Watt, who was what might be called a entrepreneurial engineer, to shape the tool to achieve ends desired. The slide rule has been always placed in the hands of those in education seeking higher education through 350 years. The Slide Rule as noted promotes all of the critical skills to be a problem solver. One must practice these in order to use it properly. In one's hands is a tangible tool to visualize the relationships between the variables in question. One scale is one variable, the other scale is yet another variable. The Slide Rule is the bridge to becoming the computer and not seeing other things as the problem solver. We have forgotten that we solve the problems and only use tools to do that. This property of variable relation is not found on a common calculator and yet embodied by the slide rule. This is the primary goal as noted at the start of the argument for the slide rule in the classroom.

The final skeptical argument is their lack of existence. Today however, there are a number of websites devoted to the slide rule, its history, its use, and there are printable templates for them along with virtual ones to use online. This list comes at the end of the article. Also some of these groups even have slide rule classroom loaner programs that are in place. If a teacher were to want a collection in their classroom, with some time, a little money, and effort a number of inexpensive ones could be found to create a permanent collection for a classroom. Personally I have two sets, a 9-scale plastic set and even a more advanced aluminum Pickett N500 set.

Am I saying a world without calculators, maybe even computers in the long run? No, exactly the opposite. They should be the tool of last resort once the skills are mastered. This is why I promote the slide rule as the tool of choice to enhance one's skills. Note the main goal of education – to have people acquire problem solving skills and then sharpen them. The calculator promotes speed not acquisition. One must think to acquire the skills. Presently we are allowing the 'mystery box' to answer the question.



As a historical aside note that in 1960 a dictionary said that a 'computer' was a person who did computations. This is not true today in terms of that term in the dictionary and more importantly the kids today do not view it in the 1960s way. They see a world that provides them with the answers and not one where they find and determine the answers themselves but instead it is found in machines. The

Slide Rule is the tool that can open that door to personal success and mastery of problem solving skills. It is tangible, it forces one to know the basic times tables and decimal placement, make estimations, and try to visualize the relation of the variables in question. This then is the value of the Slide Rule. It is a bridge and a tangible tool to show relations and necessitates involvement. It empowers the user. Notice how it can be employed with students doing the work and then checking it with the slide rule. This philosophy follows what we are told always: measure twice, cut once. Look at the movie Apollo 13 where a calculation at a critical moment done by Lovell (Hanks character) is verified by three slide-rule bearing engineers. Before considering that only a movie, check out the slide rule history website and find a power point presentation about slide rules which shows Michael Collins of Apollo 11 fame with a slide rule in his pocket and a quote from an engineer of those times who noted that he did not even own nor use a calculator until sometime into the early 1970s and the slide rule was a common tool. Think on this, pick up a slide rule and try it for yourself. Then decide.

List of web sites :

Information :
www.oughtredsociety.com

Virtual Slide Rules :
From Derek's Virtual Slide Rule Gallery –
www.antiquark.com/sliderule/sim/

Information, Virtual Slide Rule, Slide Rule power point presentation on how to use the slide rule, and printable scales for making a slide rule
http://www.sliderulemuseum.com/

Other slide rule plans:

Scientific American magazine reference from May 2006 article on slide rules by Cliff Stoll
http://www.scientificamerican.com/meida/pdf/Slide_rule.pdf

Luis Fernandes, Dept of Electrical & Computer Engineering, Ryerson University
http://www.ee.ryeson.ca/ elf/ancient-comp/sliderule.pdf

Circular Slide Rule by Dr. Charles Kankelborg, Dept of Physics, Montana State University
http://solar.physics.montana.edu/kanel/math/csr.html