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Student Attitude Toward Science as a Function of Use and Non-use of Cell Phone Apps in High School Chemistry Classes

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Abstract: Cell phones are often a distraction in the American high school classroom. Their attachment to their cell phones is obvious. The incorporation of cell phones into, rather than exclusion from, the lesson at hand may provide a means for improving attitudes toward science providing the cell phone activity is salient to their Chemistry class. Five hundred twenty-two Chemistry students were divided into two groups: a control group using a physical hand-held calculator, and an experimental group who downloaded and used two different cell phone applications: one for an emulated calculator, and one for a set of periodic tables and elemental characteristics, and then used them in coursework. *Attitudes Toward Science Survey* measure was administered pre and post to both groups. There appear to be significantly higher positive attitude rankings toward science among learners who were introduced to phone apps for use in Chemistry class.

Keywords: Emulators, Chemistry Education, Student Attitudes Toward Science, Cell Phone Apps

1. Introduction

Cell phones in the adolescent population of the United States present a growing distraction during class time which impacts the achievement level of students. Researchers found that students sending and receiving messages while studying scored lower test results and were less effective at tasks such as note-taking [1].

In combination with this is the fact that calculators are often "missing in action" in Chemistry classes, just when they are needed the most [2]. The common responses American, in our case, California, high school teachers hear when we say "Take out your calculators" range from the simple (and truthful) "I forgot it" to "It's in my locker" or the ever-popular "Someone stole it." One of the best in my career was "It's in my friend's car in Pasadena;" and so it goes. But, as we all also know, they *always* have their cell-phones. Always!

2. Problem

The growing discussion both of cell phones as an interruption to lessons, and the effect of apps on learners in the classroom. Educators are concerned. Articles address how to detect student texting [3] and how to deal with the problem [4]. Solutions can range from developing policies, which are time-intensive and often contentious, to the recognition that discipline is a major factor in addressing the problem:

Cell phones in the classroom can be a significant discipline

problem and classroom management struggle if clear and explicit guidelines are not established the first day. Every teacher's tolerance for phone usage varies. But as an administrator, if I walk in and see earbuds and phones out during direct instruction, I see a problem that needs to be fixed. I am curious to hear your thoughts on cell phones in the classroom and the policies at your school. [5]

Clearly solutions are being sought. There is some movement toward incorporating apps into specific lessons at the elementary level, for example, they are discussed to regard to ipads[6] for numbers work. Extending this approach to the high school levels appears to be a logical next step, and for our purposes, they needed to be specific to the discipline of Chemistry, both concept and calculation-based based.

This could have multiple positive effects; by incorporating apps into Chemistry, the enchantment of learners with their cell phones could be capitalized on to both support the concepts and elemental data associated with the Periodic Table of The Elements while also making sure that the problem of parsity of calculators was eliminated. To address both these issues we decided to have students download two apps onto their cell phones that support the class, one supporting the periodicity and specific characteristics of elements, and the second a calculator. The embedding of applications appears to make good use of the device, and occupy the learner in lieu of social communication.

In this study, two cell phone apps were downloaded: the first was a series of interactive periodic charts which clarify periodicity and provide greater accessibility of atomic data; and the second was a re-implementation of an HP hand-held calculator useful for streamlining calculations; since the emulator uses reverse polish notation it lends itself to chain calculations such as adding up the molar mass of compounds in one operation. The two we chose were QuikElem [7] and Thomas Okkem's Free42 [8]. QuikElem provides both individual characteristics, and periodicity concepts from a choice of four periodic tales. A second very useful app is an emulator (embedded calculator) onto their cell phones. The emulator we chose, Thomas Okken's Free42, is a better machine than most of us would care to spend on a calculator anyway, is free, and would carry most students through their college years and professions. Engineers and scientists use this instrument their entire careers. Both of these apps are free which was a requirement for our choices of which apps to have students download.

3. Hypothesis

We hypothesized that by encouraging use of their cell phones for classroom work, supporting the concepts being taught, and making sure they had a calculator with them to understand the mathematics of Chemistry, attitudes toward science would be increased. Students who were introduced to the cell phone apps for use in Chemistry would demonstrate significantly higher rankings on an *Attitude Toward Science Survey* (Appendix B) instrument contrasted with students who were not introduced to

cell-phone apps for use in Chemistry. Further significance may be that what was once a detriment be turned into a positive influence academically and reduce discipline problems.

4. QuikElem

QuikElem is free and is interactive. It provides multiple periodic tables and a list of elements with their individual characteristics. This program has four Periodic Tables and a list of elements based on three parameters. The information within these subsets is profound.

The four Periodic Tables are colored by three parameters for classifying elements which can be accessed by pressing on the table icon in the lower right corner and swiping to the left. On the first Table the elements are identified by color as belonging to one of seven chemical categories: Alkali Metals, Alkaline Earth Metals, Halogens, Noble Gases, Transition Metals, Lanthanides and Actinides; these are the major behavioral groups and serve well for an Introductory College Preparatory high school course. On the second Periodic Table the elements are classified by metal, metalloid or non-metal. On the third Table the main-group elements are colored according to valence electron configuration; these are divided cleanly into two groups: those elements filling in the valence shell (s and p electrons), and those that are filling under the outermost shell, (d and f electrons). The fourth Table colors elements into groups according to the highest-energy occupied orbital. This clearly divides the entire table into elements which are filling the s, p, d and f sub-orbitals. Further, an element can be tapped on these tables and the table will turn sideways bringing the element up larger and showing its name, symbol, atomic number and molar mass.

The list of elements, accessed through the list icon in the lower left corner holds data about each element and therefore melds nicely into college use as well. The lists themselves are headed by three parameters for accessing information: the atomic number (a "#" sign), the name of the element and the symbol. No matter what information a learner is starting with, the columns provide ready access based on that information. By swiping to the left the first page, entitled "Chemical Properties," shows molar mass, ionic charge (how easy does that make it?!), the electron configuration, and the Lewis dot structure. The second page, entitled Atomic Properties," shows atomic mass, atomic radius, electronegativity and the first ionization energy. The third page, aimed at Physics students at both high school and college levels, is titled "Mechanical Properties," includes Young's modulus, shear modulus, Poisson ration, Brinell hardness, electrical resistivity, thermal conductivity and thermal expansion. The fourth page entitled "Physical Properties," shows commonly used data for each element: crystal structure, density, melting point, boiling point and heat capacity.

This information can be found through very detailed periodic tables or in chemical handbooks but the ease of access, the multiple ways to access information, and the clear categories of characters makes this list with its multiple layers very useful.

(Figure 1) Moreover, because it's embedded on their cell phone, the willingness of students to search may be enhanced.
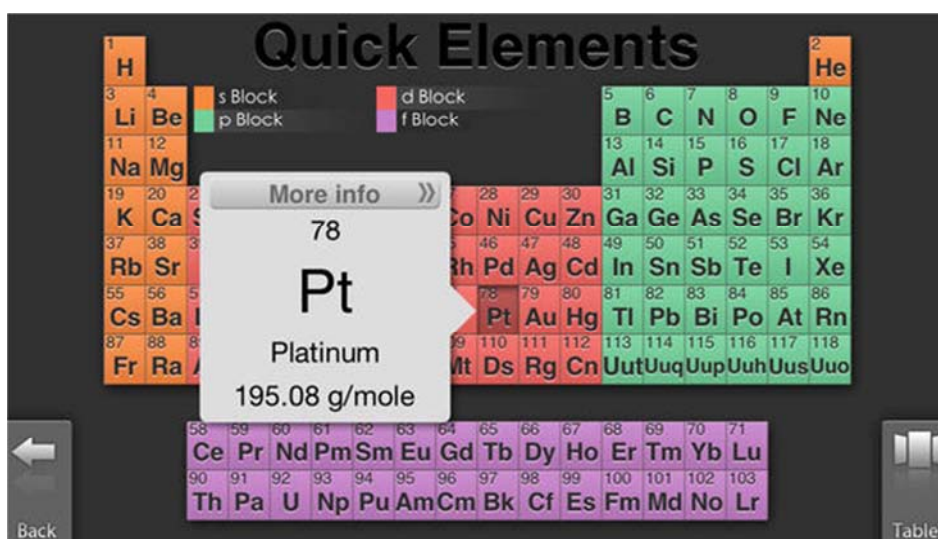

Figure 1. Sample Page from QuikElem.

5. Emulators

Emulators, which are virtual calculators, are another app that can be easily incorporated into and support a Chemistry curriculum. We suggest to start with the Free42 (picture 2). The Free42 is the name given to an application written by Thomas Okken; this a completely new implementation of a scientific handheld calculator issued by Hewlett-Packard Company in 1977 named HP42s. The original handheld scientific calculator is virtually unavailable except for collectors, unlike the emulator which is available, and free, on both iOs and android operating systems. This elegant virtual calculator was designed and implemented by Thomas Okken. For those not familiar, this is an application which is an emulator program, i.e. a calculator simulator. Free42 is a re-implementation of both the Hewlett-Packard HP-42s calculator [9] and a stand-alone HP-82240 printer. It is a complete rewrite, not using any HP code, and it does not require an HP42s ROM image. Okken's Free42 is an Open Source project. [10] The Free42 uses Reverse Polish Notation (RPN) which requires no "equals" key. For all arithmetic the two numbers are separated by "enter", see Figure 2, followed by the operation key. The result shows in the x register. This is in contrast to the more commonly used calculators in America on which the first digit is hit, then the operation, then the second digit, and finally the equal sign. Like the original HP42s, the Free42 is also programmable, but does not have the memory limitations of its predecessor. Its only limits are the amount of memory the cell phone has it is loaded on.

An alternative emulator, although it has a very small cost, is the 42s by Byron Foster. [11] This is also an HP42s emulator and also uses RPN. It emulates a Scientific hand-held calculator (which sold for $120 in our college days, now worth $400), and was introduced by Hewlett-Packard in 1988. It has advanced functions suitable for applications in mathematics, linear algebra, statistical analysis, computer science, factorials, matrix operations, menus with sub-menus, and is fully programmable. The viewing window pulls down to display four "stacked" registers which "roll" and the last resulting operational value is returned to the x-register. Over 650 functions are included in this implementation.
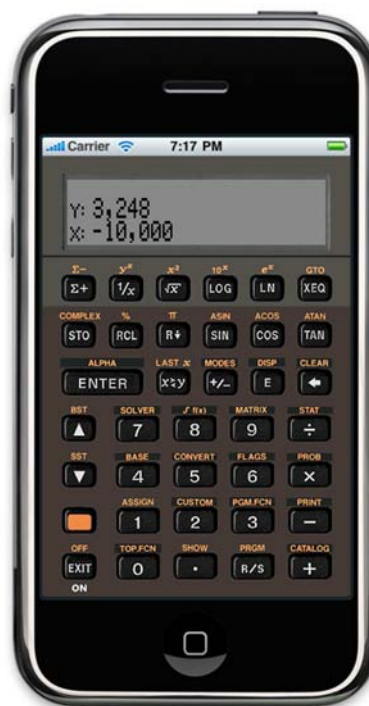

Figure 2. Skin of the Free42 emulator.

Thomas Okken's user manual, free to access at *hp-42s user manuel.pdf* [12] is an abbreviated version of the book but with enough basic explanation to start a high school student on his or her way. It is very clearly written, forty two pages long and

requires a pdf reader. This user manual can be applied to both Foster's and Okken's emulators. Downloadable, it can be placed onto a computer from the internet or placed onto a cellphone home screen. The capability of these emulators is far beyond what is approached in this article; many functions are highly relevant to the Chemistry, Physics and Mathematics classrooms. Logarithms and scientific notation are two of these, and the machine can be programmed for specific scientific operations. The 42s is fully keystroke programmable. For example, we wrote a small program, of 282 lines, for finding any three of the four acid/base concentrations: pH, pOH, $[H^+]$ and $[OH^-]$, using only one.

Since this is an instructor suggestion for download onto a minor's private cell phone, we suggest sending home a basic informational sheet for parents to sign. It states what the aps are about, how much advantage they can provide a learner in the acquisition of a fine machine for free or a few dollars (in the case of Foster's emulator), and ask for a signature from the home acknowledging awareness and approval of the download.

Instruction begins by having the students get their cell phones out. This completely and immediately engages them because most of the time all they hear is teachers telling them to put their cell phones *away*. Then I tell them to go to their apps. I watch them smile... *toward* their phones! Yes, you have now entered the exact target center of your learners' comfort zone. You have been identified as "friend." You will find suddenly, as if you turned a bend in the road, the dynamic between you and your students has suddenly changed, for the better. Forever.

High school students download games and music from their app store constantly; this is their territory, so I tell them to find "free42" and "get." This actually took me a moment to become used to, not being a huge *aficionado* of apps and downloads, but your students will dive into this in seconds. (Picture 3) Once it has loaded you can begin the primary lessons below. One of the really interesting things I found out is what a great vehicle emulator-introduction can be for identifying quiet students who are (often unbeknownst to themselves) great at articulating concepts or operations to others.

Figure 3. Students Using Emulators.

After introducing the emulator and completing the basic operations students are asked if everyone understood. Typically, perhaps half the class "gets it," and half does not.

Then I ask if anyone wants to go through the process with the class as their teacher. Invariably, there is a surprise here. This year a second-language learner raised his hand. This small sixteen year was rather shy in class but as usual, once given the reins an entire new personality emerged. He stood and in a voice that much belied his size and with a confidence that swept the room to attention, he proceeded to instruct the students with much demonstration, pausing to make sure everyone understood, walked them through the process of chain addition, walked around helping anyone still having a problem, and just did an absolutely credible job. His patience was steadfast, his instructions specific, and the understanding he evidenced was clear. Moreover, the accent that often made him shy in responses during class, although still present, didn't show any sign of reticence when he was instructing. Interesting. What happens is that he knows students can understand him, kids are used to accents in their fellows, and that it's often older folks, *vis-à-vis* teachers, who have difficulty with the vocalization of accents. Moreover, using this to back up instruction not only makes your learners more willing to ask for help but creates a new admiration and placement in the intellectual peck-order of your students when those usually quiet are promoted to head of the class. The affective side of this is an undeniable benefit, as well as the pedagogical value it has.

Following this article are a few introductory operational lessons in Appendix A. Getting past not using the equal sign, and placing the operations symbol last will be unnatural at first, but students seem to move past this faster than adults; children thrive on what they enjoy, and they do most certainly enjoy their phones! Lessons for operations for your classroom needs can be dovetailed to your curriculum.

6. Methodology

We decided to assess the effect of these materials quantitatively with *Attitudes Toward Science Survey* instrument to assess attitudes toward science. Last school year the pre survey was given the control group learners' 2nd day of school and the post survey given four weeks later without any apps introduced. This year we again administered the pre-course assessment the 2nd day of school and again, after introduction of the app downloads, four weeks into the school year. The variable was a function of attitudinal change in learners who did not use (control group) or did use (experimental group) the apps. Twelve chemistry classes totaling five hundred twenty-two learners made up the population, Two hundred forty-nine students comprising the control group last year, and two hundred seventy-three students who were introduced to the apps being the experimental group this year. The same chemistry lessons were taught by the same teacher. Both groups were at the same point in the curriculum at the time the 2nd assessment was administered and were using the same textbook and support materials; control versus experimental groups were homogenous relative to grade, sex, class standings and age.

The instrument used for measuring attitude toward science

was the *Attitudes Toward Science Survey* (Appendix B) which asks students to rank agreement or disagreement of twenty items on a scale of one to ten. Fourteen of the items measure positive attitudes and six of the items measure disapproval and required reversal of answer ranks. These are denoted in boldface in the Appendix sample but not on learners' surveys.

The findings were as follows: The control group of two hundred forty-nine students showed an improvement in eleven of the twenty rankings of attitude, a decline in three of the twenty rankings and no change in six of the twenty rankings. There was an 8.7% improvement in attitude toward science over the four weeks of the study.

With regard to the experimental group of two hundred seventy-three students, there was an improvement in sixteen of the twenty rankings of attitude toward science, a decline in one of the rankings and no change in three of the twenty rankings; there was an 18.3% improvement in attitude toward science over the four weeks of the study.

Item #	Control pre	Control post	delta	% difference	Exper. Pre	Exper. post	delta 2	% difference2
1	5	6	1	20	5	7	2	40
2	5	4	-1	-20	6	8	2	33
3	6	6	0	0	6	6	0	0
4	5	5	0	0	4	5	1	25
5	4	5	1	25	5	7	2	40
6	4	6	2	50	4	6	2	50
7	3	5	2	67	4	6	2	50
8	3	5	2	67	3	5	2	67
9	4	7	3	75	4	8	4	100
10	7	6	-1	-14	6	5	-1	-17
11	6	6	0	0	6	8	2	33
12	5	5	0	0	5	8	3	60
13	7	7	0	0	6	6	0	0
14	3	6	3	100	4	7	3	75
15	4	5	1	25	4	6	2	50
16	3	5	2	67	3	6	3	100
17	5	7	2	40	5	9	4	80
18	4	7	3	75	5	8	3	60
19	7	5	-2	-28	6	8	2	33
20	5	5	0	0	5	5	0	0

Figure 4. *Data Table: Mean Attitude Ranking Pre and Post Study of Control vs Experimental Groups.*

7. Data Analysis

To see if there is a significant difference in the average difference in ranking of the experimental group and of the control group, we used a two-sample t-test for the difference in means of the two groups with $\alpha = .05$ or 5%. Therefore assuming the there is no difference in the mean ranking difference of the two groups, the likelihood of obtaining the results we experienced in the experimental group due to

chance variation alone is about 0.0144.

In other words: If there is no difference in the mean difference in rankings of the two groups, we would see an experimental group sample like ours about 1.44% of the time. Since this is such a small likelihood, we can conclude that our results are not due to chance variation, and there must be a statistically significant difference in the mean difference rankings of the experimental group and the control group.

Data Analysis of the Δ = post-test ranking – pre-test ranking of control group (Group 1) and experimental group (Group 2)

Sample data summary statistics:

Control Group (Group 1)	Experimental Group (Group 2)
$\bar{x} = 0.9$	$\bar{x} = 1.9$
$s = 1.447$	$s = 1.334$
$n = 20$	$n = 20$

We want to see if there is a significant difference in the average difference in ranking of the experimental group and of the control group. We will use a two-sample t-test for the difference in means of the two groups with $\alpha = .05$ or 5%.

Let μ_1 = the mean difference in the rankings of the control group.

Let μ_2 = the mean difference in the rankings of the experimental group.

Hypotheses:

$H_0: \mu_1 = \mu_2$ — We begin by assuming that there is no difference in the mean ranking difference of the two groups.

$H_a: \mu_1 < \mu_2$ — We suspect that the mean ranking difference of the experimental group is greater than the mean ranking difference of the control group.

Test statistic: $t = -2.2722$ with d.f. = 37.749
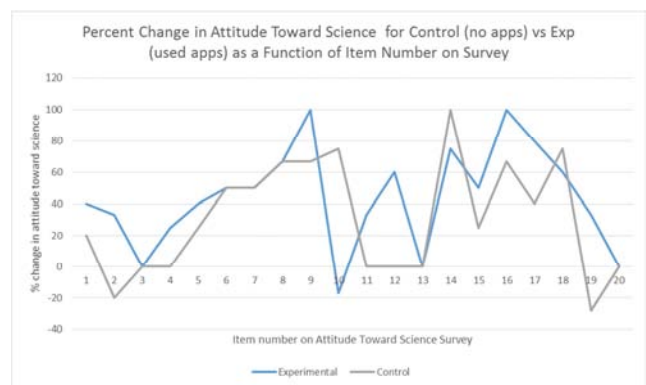P-value = $P(t < -2.2722) = 0.0144$ or about 1.44%

Figure 5. *Graphical Analysis of Change in Attitude.*

8. Summary and Conclusion

Periodic tables and Emulators provide a classroom advantage intellectually because the operations provided will serve learners in scientific and mathematical endeavors; late last year emulators were introduced and the enthusiasm

students showed led us to hypothesize that attitudes toward science could be improved through the introduction of cell-phone apps for academic use. Through using the measure Attitudes in Science Survey, our study indicates that Chemistry students who are introduced to the cell phone apps Free42 and QuikElem significantly improve their attitude toward science more than learners who are not introduced to the apps.

If you consider the introduction of these apps for your Chemistry students, let us know the results, both your perspectives as a teacher and any additional material you develop which you would care to share. These can be sent to lbartrom@hotmail.com. When the authors think back on our days with crumpled paper references, slide rules, and calculators far beyond our college-budget reach, we can only

hope that students of today realize the utility of these applications and take advantage of the power they have, literally, at their fingertips.

9. Implications for Further Research

The data from this study needs to be supplemented by data from larger student populations. Other areas which may be explored include: a breakdown contrast of attitude improvement in males versus females, information regarding the effect of each individual app used in this study, the effect of app use in Chemistry on achievement in Chemistry, and an evaluation of possible reduction in discipline concerns which are cell-phone related.

Appendix A

Suggested Basic Functions to Teach for Starting Free42 Emulator Use [12]
THE SKIN - Look at the face or "skin" of your calculator.
1. There are numeric and alpha white and orange symbols.
2. The orange characters above the white are accessed by the orange "shift" key on left. When you shift correctly, an arrow pointing up appears at the top of the green window and in addition, on Foster's machine, a "halo" appears around it.
3. Some of the orange ciphers have a darkened background behind them indicating additional sub menus. On Foster's machine, if there are more than six sub-menus a halo appears around the "up/down" arrows to scroll up and down.
4. If you have the 42s put your finger on the green window (not on the calculator part) and pull it up & down. Three registers appear when it is up, x/y/z. A printer icon is at upper right corner.
5. You can clear:
   (a) A register with the right column's white arrow.
   (b) An entire stack by pushing shift then clear (above arrow) and a new menu for clearing descends. Press "clear stack" CLST which places zero on all registers.

- BEFORE A NEW OPERATION – hit exit (takes you back to your calculator homescreen)

- RPN (Reverse Polish Notation) – there is no equal sign.

   1. Hit a number
   2. Hit the large "ENTER" key on left side (this separates the numbers)
   3. Hit the next number
   4. Hit the operation (+, -, x etc)
   5. example 2/ENTER/2/+ will add them and result in 4
   6. example 2/ENTER/2/- will subtract them and result in zero

- TO ENTER SCIENTIFIC NOTATION –

   1. Hit the abscissa numeral (with decimal if it has one)
   2. Hit the "E" at right, third row down
   3. Hit the numeral of the exponent
   4. Hit NOTHING If your actual value got smaller
   5. Hit the change sign (+/-) if your actual value got larger
   6. if you wish you can now hit ENTER you will see the full number to check your work

- THINGS TO *NOT* DO – If you hit the shift button and go to the "clear" above the white arrow on the right, a menu of things to clear will come down on the top row

   1. DO NOT now hit CLP button in top row – this is "clear program" and will eliminate the menu key for the program you hit next
   2. DO NOT now hit CLALL button in top row – this is "clear all" and will clear all user input (registers, stacks, programs and variables) and you will be back to an infant emulator

- TO FIX THE NUMBER OF DECIMAL PLACES the operator will see on the display – Hit Shift then DISP (display/above white E, third row). A menu rolls down at the top. Now hit FIX (top row left). Two blanks will appear in the green window

next to the word FIX. Enter a numeral for how many decimal places you want. You will immediately see the result of this operation on your registers; this does not change the depth of the calculation, only what you see displayed.

   a. 06 means 6 decimal places
   b. 10 means 10 decimal places

- To start a program – what is happening – the two ways explained

   1. Normally and the shorter method- hit XEQ, then the programs will come down, hit the one you want. The program will immediately start
   2. To get to the program but NOT have it start right away- hit the orange "shift", hit GTO, pick the program you want and hit it. This takes you to the first line of the program but does not start it. When you want it to run hit R/S bottom row.

- To enter alpha characters – (on Foster's 42s)

   1. Hit orange shift
   2. Hit alpha (above ENTER)

- To show value of an exponential expression – y^x

   1. Example: for value of 10^3
   2. hit 10
   3. hit ENTER
   4. hit 3 (notice at this point IN THE REGISTER y = 10 and x = 3)
   5. hit shift
   6. hit y^x
   7. answer in x register is 1000

- To do a chain calculation like the sum of atomic weights in a molecule – ex. H_3PO_4

   1. Look up atomic weights on periodic table: H = 1, P = 31, O = 16
   2. Notice there are 3 H's, 1 P and 4 O's
   3. Hit: 1
   4. ENTER
   5. 3
   6. X (for 3 1's for weight of 3 Hydrogens) Answer in x register is now 3
   7. 16
   8. ENTER
   9. 4
   10. X (for 4 16's) Answer in x register is now 64
   11. then + (adding x + y meaning 64 + 3, answer in x register is 67)
   12. then 31 then hit + (adding x + y, adding weight of a single P)
   13. Answer in x register is 98

ALTERNATIVE ORDER: 1/Enter/3/X/31/+/16/Enter/4/X/+ answer 98

Appendix B

ATTITUDES TOWARDS SCIENCE SURVEY

Directions:

Following are twenty statements concerning how you feel about science and your science classes. You will see that the statement are of such a nature that there are no correct (right) or no incorrect (wrong) answers. This is not a test or exam. We are only interested in your honest opinion. Please indicate how "you feel inside" by placing the number which shows how you FEEL on the line provided in the right hand margin. Your cooperation is appreciated greatly. Your response will remain CONFIDENTIAL

YOUR FEELINGS

10 = Strongly Agree/would argue for this position
9 = Very Much Agree
8 = Agree
7 = Mostly Agree
6 = Kind of Agree
5 = Undecided
4 = Kind of Disagree

3 = Disagree

2 = Very Much Disagree

1= Strongly Disagree/would argue against this position

1) **Reading about science does not interest me.**   1._____

2) I would like to spend more time doing science Experiments and Labs.   2._____

3) I enjoy learning a lot about science in school.   3._____

4) What we do in class is what working scientists would do   4._____

5) In science classes we study "today's problems" related to science   5._____

6) **I don't like having science class**   6._____

7) I watch more scientific shows now than I did in junior high.   7._____

8) I enjoy doing science labs.   8._____

9) I can solve problems better using scientific facts.   9._____

10) My friends enjoy science.   10._____

11) I am learning in science classes will be useful to me.   11._____

12) I think about things we learn in science classes than I have to have.   12._____

13) **I don't want to take any more science classes than I have to.**   13._____

14) Reading about science is more fun than it used to be.   14._____

15) **Science experiments or activities are hard to understand**.   15._____

16) **Science is dull for most people**.   16._____

17) **The things we do in science class seem useless**.   17._____

18) I learn a lot from doing Labs.   18._____

19) Most people I know like science classes.   19._____

20) The kinds of labs I do in science classes are interesting.   20._____

Note- Bold items are reverse statements for which numeric rankings were reversed

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