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AUTHOR	Pickard, Poppy; Alexander, Patricia
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ABSTRACT

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The Effects of Digital Measuring Equipment on the Concept of Number

Poppy Pickard
School of Communications Technology and Mathematical Sciences, UK

Patricia Alexander
School of Education, University of North London, UK

Abstract

Over the last twenty years the use of calculators and digital measuring equipment has to some extent replaced mathematical mental/written activity and also the use of analogue measuring equipment. This paper explores some aspects of number concept, reading the number line, and estimation from scales. The students being considered are mainly part of a foundation year in science/engineering/computing, many being mature students who are returning to education. The foundation year provides an alternative entry to degree courses for students without the conventional entry qualifications. The results obtained are compared with research undertaken in schools. The results of the research will be used to inform the teaching of future foundation cohorts.

Introduction

Electronic technology has revolutionised the ways in which we work with numbers. This paper attempts to address the question "Has the technical revolution effected a change in the understanding of number?"

Aids to calculation have existed for centuries, from the ancient Chinese abacus, through to logarithms, ready reckoners and mechanical adding machines, each offering its own set of shortcuts. The hand held technology of the last generation is simply an extension of this. However, digital technology has found an application in many areas where previously a graduated scale may have been used. The most obvious examples are a digital watch replacing an analogue watch, digital weighing and pricing scales in food stores replacing traditional scales. There are many more specialised uses of this technology, which abound in certain professional areas, e.g., health care, building surveying, etc. The advent of desk-top computers, with their easy to use spreadsheets capable of generating many types of graphs and charts, means far fewer graphs are produced using pencil and paper and with it the necessary exercise of deciding which scales to use and how to fit the graph on the page. The display from digital equipment is presented as a given number of decimal places. There is no need for the recorder to choose or have specified the degree of accuracy. So even at the most basic level of approximation, "rounding up" is removed. The evidence suggests that the tendency of technological devices is to bury the mathematics. These advances lessen the need to engage with numbers in a context where one may have regard for size or place value. After all 0.05 and 0.005 are both small numbers and they can both be easily given on a digital display. In some settings students may be able to differentiate between a factor of ten; however, when reading scales or digital displays, this may prove problematic as the context has been removed.

History of Digital Equipment/Calculators and Their Use in Education

As early as the 1970s electronic calculators were introduced into schools. Since this period there has been a debate concerning the appropriateness of calculating aids and their effect on the mathematics school curriculum. Within a decade changes could be seen to have been made in the design of the GCE A level syllabus, which now permits the use of programmable graphic calculators, through to the primary sector where young children are encouraged to play with calculators.

Opponents to the use of calculators argue that it can result in a deterioration in a pupil's ability to do basic computations. The recent introduction of the National Numeracy Strategy (NNS) discourages the early introduction of calculators, emphasising the development of computation in the early years. Students are taught about place value in terms of a number line. Numbers are "visualised" as existing along an infinite line. This

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understanding moves from the discrete counting numbers to a situation where other units of measure including rationals and decimals can be handled with increasing facility.

What counts as a mathematics curriculum? The use of calculators presents potential for more time to be available for understanding the structure of mathematics. However the use of calculating aids in the teaching of mathematics does need to continue to be re-evaluated.

Digital equipment may have started with the calculator, but the majority of adults use push button telephones and ATM machines on a regular basis. This usually necessitates the keying in of a PIN. Numbers are often given in the form seven, six, two, three rather than seven thousand, six hundred and twenty three. In other words, the number is being used as a token (Pimm, 1995, pp. 60-61) rather than as something that represents a particular quantity. Possibly this is the most frequent use of number outside the mathematics classroom. Inside the classroom students tap numbers into a calculator, inputting them from right to left as they move across the digital display. Even the keypad has no mathematical structure in its layout and is very similar to that of a telephone or ATM. The press of a single calculator button will result in the appearance of another number on the display. What meaning does the student attribute to this—are the numbers and the results still tokens or something that represents a specific size value? In order to make some attempt to answer this question a survey was undertaken.

Analysis of Questionnaire Results

Students surveyed were mainly foundation science and technology students at the University of North London. These students are insufficiently qualified for starting a degree programme and first undertake a one-year foundation programme, which normally includes two mathematics modules. The students are from very diverse backgrounds; about 40% are mature and may not have studied for some years and another 60% have just completed a pre-university course, e.g., A Level or GNVQ, but have not reached the required level for progression. Three questionnaires were used at different times during the academic year.

In discussing scales, reference will be made to major divisions, which are always labelled with a number and minor divisions, which are not labelled. Three activities related to scales are considered: (a) locating or plotting points on a labelled scale; (b) constructing and/or labelling a scale and then locating or plotting points; and (c) reading plotted points from a labelled scale.

The first questionnaire was undertaken during the first maths module at a time when students were starting to study graphs. The questionnaire had two parts: questions about digital equipment and questions relating to scale.

The digital equipment questions showed about half the cohort still wore watches with hands and that the use of measuring equipment mainly involved the use of graduated scales but mostly on an occasional basis. However a minority of students had some experience of using digital weighing scales and thermometers.

Activity (a) - Plotting Points on a Labelled Scale

Point to plot plus scale details		***Results***			
Point	Major Divisions (Minor Divisions)	***Accurate (%)***	***Close (%)***	***Not Attempted (%)***	***Incorrect values plotted in error (%) and *comment on close values***
2.5	0,1,2, (0 minor)	96	2	0	5.5 (2%)
7.8	0,1,2 (0 minor)	98	0	2	
37	0,50,100 (0 minor)	74	14	2	370 (10%) - factor of 10
0.63	0.4,0.5,0.6 (1 minor)	82	16*	2	*3/10 along 1st division
0.046	0,0.01,0.02 (1 minor)	84	1	2	0.0046 (2%), 0.043 (6%) ie 6/10 along 1st division, 0.011,0.021
0.0025	0,0.01,0.02 (1 minor)	44	16*	12	0.025 (20%) - factor of 10 0.001 (4%), 0.005 (2%), 0.009 (2%) *at around 0.002 or 0.003

The above table shows a high level of accuracy when estimating tenths of a division for 5.5 and 7.8. This accuracy drops in the case of 37, which is incorrectly placed at 370 in 10% of cases. Students appear to be reading the 350 and 400 as 35 and 40. This error again manifests itself when 0.0025 is incorrectly plotted at 0.025 in 20% of cases. Difficulties in understanding scale with one minor division are apparent in the plotting of both 0.63 and 0.046 as students estimate using tenths in the first section only, ignoring the existence of the second section.

Further scale questions required students to construct and label scales and then plot points, activity (b). Students were given blank scales with 10 major divisions each with 4 minor divisions. Students were expected to label using the largest suitable scale and then plot 4 or 5 points. Students who could correctly label the scale could generally plot the points correctly.

Expected choice of Major Division	10	0.1	0.01
Facility	75%	65%	55% (35% didn't attempt)

The facility decreases as the numbers become smaller (very large numbers were not tested).

These results informed the construction of two subsequent questionnaires, which were designed to test out some of the errors that were occurring in the first set of results. These questionnaires were completed by much smaller cohorts of students, towards the end of the academic year.

Both questionnaires asked respondents about what timepiece they visualised when they thought of reading the time and which they found easiest to use. Again about half thought of clocks or watches with hands and half thought of a digital timepiece. In terms of which was easier to use, 65% said digital timepieces were easier, 25% thought clocks with hands were easier, and 10% didn't mind. Reasons for choices given:

Digital: easy to read; it's done for you; I've grown up with this; on screen display; exact figures; gives the precise time; no working out where the hands are; etc.

Analogue: it's fixed in my memory; 24 hours is confusing; associate it with direction; can see the full 60 minutes, i.e., the time remaining and the time gone; I'm used to it; etc.

Both these lists indicate a sense of comfort with the familiar. However, at a deeper level, comments indicated the advantages of a digital display which gives time to the nearest minute and of a clock whose hands can show the proportions of time.

All the scales in the second questionnaire involved either 5 or 10 minor divisions, some representing numbers like 25 and 0.004. Hence, locating points involved students in too much division. When unable to interpret the scale, some students resorted to counting minor divisions in "ones." This brought a sharp focus back to the study of place value, which was perhaps becoming secondary, so this questionnaire was abandoned after completion by 15 students and the third one designed with simplified questions on scale.

On the third questionnaire, questions were designed to test a particular potential error, which had been identified earlier. This was completed by 43 students, 10 of whom were from a local further education college with most of these studying advanced level mathematics.

This questionnaire tested reading points from an existing scale which was the reverse of what was done in the first questionnaire where students had to plot or locate the points.

Activity (c) - Reading Points From a Labelled Scale

Point to read plus scale details		*Results*			
Point	Major Divisions (Minor Divisions)	*Accurate (%)*	*Close (%)*	*No Attempt (%)*	*Values read in error (%) and *comment on close values*
3.5	0,1,2, (0 minor)	85	15	0	
480	0,50,100 (0 minor)	40	40*	2	48 (2%) - factor of 10, 450.7,457 and similar (16%), *estimated as 475 or 470
0.05	0,0.1,0.2 (4 minor)	60	9	9	0.5 (7%) - factor of 10 0.045 (9%), 0.02 and 0.03 (6%)
0.78	0,0.2,0.4 (1 minor)	83	7	0	0.68 (5%), 0.73 and 0.7 (5%)
0.002	0,0.01,0.02 (1 minor)	45	26	12	0.02,0.025,0.25 (12%)- factor of 10 0.004 (5%) or 4/10 along 1st division
0.02	0,0.1,0.2 (9 minor)	56	2	26	0.2 (7%) - factor of 10, 0.01 (5%), 0.04 (2%), 00.8
0.23	0,0.1,0.2 (9 minor)	68	0	24	0.26 (5%), 0.28 (3%)
0.405	0,0.1,0.2 (9 minor)	42	27*	26	0.045 (5%) *0.4 or 0.41, inability to estimate in between value.

The accuracy rates are ranges from 40% to 85%. However the combined accuracy and closeness range is 58% to 90%. The majority of errors involve either place value or reading of minor divisions. The place value errors now exhibit a new way of including the estimated part of the division, i.e., 450.7 for 480 and also the scrambling of the digits in the 0.405 giving 0.045.

Activity (b), completing scales and locating points. Two scales each with the first two major divisions already labelled were provided. Students were expected to use these scales and locate three points. Not all students completed the last section of the questionnaire so these results refer to those that did.

Ability to label and interpret scale				*Comments on plotting points*	
Major Divisions (Minor Divisions)	*Correct*	*Incorrect*	*Change in sequence*	*Points to plot*	*Comments on value plotted in error*
0,0.2,0.4 (4 minor)	54%	29%	17%	0.004, 0.09, 0.105	0.004 plotted as 0.008, 0.002 0.105 plotted as 0.11 and 0.0105
0,0.1,0.2 (9 minor)	76%	14%	10%	0.058, 0.82, 1.12	1.12 plotted as 1.02

The scale involving counting in twos proved more difficult than counting in ones; some students changed sequence at 0.2, i.e., 0, 0.2, 0.3, 0.4, another changed at 0.6. Similarly with the second scale some changes of sequence took place after 0.9 and 1. Plotting errors, when the scale was interpreted correctly, mainly involved misinterpretation of minor divisions. There was less scope for place value error in these exercises.

On ability to use scales, 42% rated it as very important, 50% as quite important, and 8% as hardly important. Seventy-eight percent thought their ability to use scales affected their understanding of place value.

The foundation students plot graphs as part of their first maths module. The most frequent error that occurs is when a scale is inconsistent, for example, 0, 2, 4, 6, 8, 10, 20, 30, . . . or 0, 1, 2, 4, 6, 8, . . . This type of error was also observed in the questionnaire scales. Another common error is to use the heavy lines of the graph paper to represent the given data values without any regard for scale, so for example one could have 2.3, 4.6, 5.1, 6.7 all plotted at equal intervals. This often seems to be a direct result of the way a student has been taught, whereas the former is more to do with a student's perception of number.

School Studies

Although it is not possible to map the above to exactly the same studies in schools, there are elements of research undertaken that contain some comparable elements. The Concepts in Secondary Mathematics and

Science (CSMS) study and the Low Attainers in Mathematics Project both look at children's understanding of decimals and place value. In particular is the interest is a child's ability to move from an understanding of discrete counting to that where "measurement can be refined by smaller and smaller units of measure" (Dickson et al., 1984, p. 91). The CSMS study found the facility of 15 year olds to locate 5.8 at a minor division between 5 and 6 was 85% (a similar question to foundation students had a 96% facility) and to locate 2.74 at a minor division between 2.7 and 2.8 was 71%. This dropped to 61% when children were required to locate 14.65 on a tenths scale where an estimation was needed between unlabelled minor divisions at 14.6 and 14.7 (Hart, 1981, pp. 60-61). The facility of 15 year olds to write down a number between 0.41 and 0.42 was 71%. In a slightly different context this is similar to students who approximated 0.405 to 0.4 or 0.41 in order to plot it. As one might expect, foundation students seem to show competence at the simplest levels and score higher than their school counterparts. However, some students exhibit difficulty when interpreting numbers where the place value is not explicit and the number or scale are more complex.

Overview – Reflection on Findings

The findings from the questionnaires indicate some students have a problem with identifying place value. It often appears that when students make errors they are reading the digits but not reading the place value. In other words, they are looking for like digits and not like place or size. Another common error was the inability to accurately read the minor divisions. Sometimes a single minor division is ignored and estimation is undertaken in only one section. When four or nine minor divisions are used they can be attributed the wrong value, e.g., counted in twos instead of ones. The findings show a range of misconceptions but can only provide a limited insight into the students' mathematical thinking. The higher education students in the sample are studying mathematics in order to progress into their chosen field. They bring to their study a range of different experiences. Also, their views of mathematics in terms of its purpose may vary. For a majority of the students mathematics is a means to an end; it is viewed in terms of its potential usefulness in their field of study.

Conclusions and Suggestions for Changes to Teaching for Foundation Students at UNL

The challenge for the teacher is to use the technology not only as a computational device but as a pedagogic device to enhance a student's understanding of mathematical structure alongside any other necessary devices like the use of scales.

The knowledge adult learners bring may be fragmented and contain misconceptions. In terms of self directed learning we can recognise four main characteristics suggested by Alan Rogers (1986, p. 69):

- Episodic: the task is completed in a short burst of intense activity, usually followed by a period of no activity.
- Goal orientated: a means to an end, e.g., progression to chosen degree course. Learning is limited to task at hand with no desire to extend knowledge or draw on existing compartmentalised knowledge. Usually technique oriented rather than concept oriented.
- Use of a wide range of strategies: trial and error methods, learns by imitation, but takes longer to absorb than other learners, needs to understand fully the whole process and make a meaningful whole.
- There may be little interest in overall principles, hence what is stored is the "how" rather than the "why."

The teacher needs both to work with these characteristics and also to employ strategies to complement students' shortfalls. For example, provide short activities focussing on a specific misconception: what is wrong with estimating 550.7 when 570 was intended; what is a suitable measure; what level of accuracy is appropriate? The activities should develop the understanding of how place value and measurement are embedded in their particular area of science or computing. Students need to have things to imitate, starting from the simple to the more complex, enabling them to build up their own more complex "meaningful wholes." Students could be shown how numbers a factor of 10 apart can exist on the same scale, e.g., 0.02 and 0.2. This fluency should then enable active learning trial and error methods to test out what may be the best scale or measure appropriate to a given situation. This should include reading from a calculator with a view to "sensible size" for purpose.

Students should be encouraged to build up an understanding of size and place value, which shows the connectivity and simplicity of our number system.

References

Burton, L. (Ed.). (1999). *Learning mathematics from hierarchies to networks*. London: Falmer Press.

Dickson, L., Brown, M., & Gibson, O. (1984). *Children learning mathematics: A teacher's guide to recent research*. London: Cassell Educational.

Hart, K. (1990). *Children's understanding of mathematics: 11 – 16*. London: John Murray.

Orton, A., & Wain, G. (Eds.). (1994). *Issues in teaching mathematics*. London: Cassell.

Pimm, D. (1995). *Symbols and meanings in school mathematics*. London: Routledge.

Rogers, A. (1986). *Teaching adults*. Milton Keynes: Open University Press.

Watson, A., & Mason, J. (1998). *Questions and prompts for mathematical thinking*. Derby: Association of Teachers of Mathematics.

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