
http://researchrepository.murdoch.edu.au/6306/
Revisiting personal technology*

Barry Kissane
School of Education, Murdoch University, Western Australia
B.Kissane@Murdoch.edu.au

Abstract: Personal technology refers to hand-held devices, small enough to be individually used by students and yet powerful enough to provide various means of support for mathematics education. Recent developments of this kind are briefly described and their significance for East Asian mathematics education analysed. A computational role, an experiential role and an influential role are identified, and the significance of these for East Asian countries is explored.

Introduction

The last twenty years of the twentieth century and the first few years of the twenty-first century have seen an expansion of everyday technology throughout the world that very few people predicted. In both Western and in East Asian countries, for example, computers have changed from being devices of interest only to scientists, the military, governments and large corporations to being devices produced for and marketed to individuals and households. In almost all walks of life, tiny microprocessors have become pervasive and in all countries of the world, many people use high-tech devices on a daily basis, with no lingering element of surprise. To give but one example, in almost all markets and stores in East Asia routine use of small hand-held calculators to perform arithmetic is so common that we no longer notice it, an enormous change in a single generation.

So it is hardly surprising that this third EARCOME identifies technology as one of the major areas of concern, as did each of the two preceding conferences. Indeed, it is very unusual for a conference concerned with mathematics education these days to not have a significant element concerned with technology, now widely regarded as a major source of curriculum influence. However, it seems a little ironic that, in the midst of extraordinary societal change towards the use of a wide range of household and consumer technologies, many mathematics classrooms, including many East Asian classrooms, appear to be unaffected by technology. Indeed, classrooms seem to be among the few places in some societies where technology for doing mathematics is hardest to find.

This irony is extended by the industrial realities: in this paper, I will use three examples of personal technology for mathematics, a scientific calculator, a graphics calculator and a ClassPad 300. All three were designed and produced by an East Asian company (Casio, in Japan) and all were manufactured in another East Asian country (China), all are regarded very highly by Western mathematics educators such as myself and yet none of these devices appears to be officially and regularly used in many East Asian classrooms. Leung (2001) and others have observed that East Asian curricula are ‘content oriented and examination driven’ (p.35), which is no doubt part of the reason.

This paper focuses on personal technologies of these kinds, because they represent the most likely mechanisms for technologies to gain a similar level of significance in school mathematics to that already evident outside school in very many other activities. As I argued at the first EARCOME (Kissane, 1998), a personal technology such as a calculator is potentially more important than other forms of technology because it is more portable (because of its size and battery operation), and thus more readily accessible to pupils than
other technology alternatives such as the personal computer. Computers cost a great deal more than devices of these kinds, and so it is much harder to have them available on a wide scale. The portability, affordability and accessibility factors together increase the chances that technology will be accepted in important assessment, such as external examinations, opening the possibility of some consistency of classroom experience, teaching practice and assessment expectations. To what extent are these arguments, advanced at the first EARCOME, still valid now? Have continuing developments of calculators changed their potential roles in the curriculum, as far as east Asian mathematics education is concerned?

Roles of technology

Many kinds of technology are now available to support mathematics education in schools. For many people, especially perhaps those not in schools, ‘technology’ has come to refer to computer technology, and connections between technology and education have conjured up images of computer software and, more recently, Internet use. For example, Li’s informal survey of parents in Shanghai (1998) confirmed such a view. Leung (2001) stressed the high importance of practice in traditional East Asian views of learning mathematics, so that it would not be surprising if a major use of computers was to provide systematic practice of mathematical skills. In the West, too, this appears to be the main genre of mathematical software produced for home use, and is also popular with many teachers as well.

In contrast, Kissane (2002) suggested different roles for technology, and especially for personal technology such as calculators. Briefly, technology is claimed to have a computational role, an experiential role and an influential role. In the first case, mathematical computations of various kinds are carried out by machine, in order to produce results efficiently and accurately. Secondly, from the point of view of student learning, mathematical explorations with technology open new opportunities to make connections between concepts. The influential role refers to the possibility that opinions may change about which aspects of mathematics are important enough to occupy time in the school curriculum, and to be studied extensively by students, and which are better handled by careful use of technology.

![Figure 1: Performing exact arithmetic on a scientific calculator](image)

Scientific calculators, available in schools for well over a quarter of a century, exemplify the computational role well. A scientific calculator can be used to perform many different kinds of computations, and is thus a useful tool for people, such as students, who need to perform computations of those kinds. For the most part, scientific calculators seem to provide students with a reliable mechanism to calculate numerical answers to mathematical questions. While this is useful in itself, especially for applications of mathematics, access to scientific calculators means that students might also be able to give adequate attention to the mathematical meaning of their work, not only on the computations themselves. In this respect, Wong’s summary of research studies on Chinese students is especially relevant: “In brief,
students tend to identify mathematics by its terminologies and perceive it as a subject of ‘calculables’.” (2002, p.223).

As well as numerical computation, recent examples of scientific calculators have offered a limited repertoire of exact arithmetic and trigonometric calculations, such as that shown in Figure 1. While such a capability might seem to offer nothing more than computation, it might be exploited to provoke students to wonder why some results are obtained. For example, entering $\sqrt{8}$ on the calculator produces the result $2\sqrt{2}$, while entering $\sqrt{11}$ produces only $\sqrt{11}$. Such observations could give rise to student exploration and cycles of predicting and checking results, supporting some learning about radicals. Similarly, students may be surprised to find that $\sin 59^\circ$ gives a rounded decimal approximation, while $\sin 60^\circ$ gives $\sqrt{3}/2$, and be provoked to seek explanations of such phenomena.

The experiential role for personal technology is represented well by graphics calculators. Indeed, the distinctive characteristic of graphics calculators that has appealed to mathematics educators in the West is the possibility of their use for exploration of mathematical ideas via multiple means, thus providing new sorts of mathematical experience, many of which have a creative element. A graphics calculator, while providing computational support in a similar way to that provided by a scientific calculator, also allows students to experiment with mathematical concepts and relationships, and to develop connections between them. Thus, for example, functions can be explored numerically, symbolically and graphically; data can be analysed and represented in a range of ways; equations can be solved numerically and graphically or using matrices; calculus concepts such as differentiation, continuity and convergence can be experienced at first hand; and so on. There are many examples of these and other kinds of opportunities in widespread use in the West, such as those in Kissane (2003). To illustrate, Figure 2 shows an example of four different ways of exploring solutions to an elementary equation on a graphics calculator.

Figure 2: Exploring solutions to the equation $x^3 = x^2 + 1$ on a graphics calculator

The first screen in Figure 2 shows a table of values of $x^3$ and $x^2 + 1$ to help see whether these two are ever approximately the same, two of the screens show ways of representing the equation using intersections of functions (there are many ways of doing this), while the fourth screen shows the results of an iterative search. The graphics calculator provides opportunities for students to think creatively about mathematics in ways not previously accessible to them, consistent with one of the two themes of this conference. Kissane (2002) illustrated and explored these sorts of opportunities, using equations as a particular example.

A recent and important development in personal technology is the ClassPad 300, which dramatically extends the capabilities of graphics calculators and provides substantial opportunities for students to explore mathematical concepts in an interactive way, using a stylus on a touch screen. (Kissane, 2004). To illustrate, Figure 3 shows a quadratic function that has been graphed by dragging its symbolic form into a graph screen, using the stylus. In the second screen, the graph itself has been moved and then dragged back into the top screen to show the relevant new algebraic form.
As a second example, Figure 4 shows use of a *ClassPad 300* to explore relationships between an object and its image, after reflection in the identity line. In this case, the *ClassPad 300* provides the image on reflection, and the transformation matrix is generated by a process of dragging a point and its image to the top screen. The third screen shows that the matrices concerned can be used to highlight the relationship between a particular point and its image.

Explorations of these kinds provide new opportunities for students to experience connections between mathematical objects and to examine their properties directly, as well as providing new possibilities for class teaching (if a *ClassPad 300* is used as demonstration device). As for graphics calculators, many creative opportunities are opened by this device.

The substantial computational capabilities of modern technologies such as the three referred to here raise new questions about what is most important in a modern curriculum. It will become increasingly difficult to justify extensive student time spent developing and practicing mathematical tasks that can be readily performed by a personal technology device. While scientific calculators comfortably handle arithmetic and especially numerical calculation, more sophisticated devices such as a *ClassPad 300* can deal just as comfortably with exact arithmetic of various kinds, algebraic manipulations and symbolic calculus computations such as indefinite integrals and general solutions to differential equations.
Integration of technology
The mere existence of technology to support mathematics education is not by itself sufficient to improve mathematics education: an important issue concerns how the technology is actually used. Western thinking increasingly supports the careful integration of technology into the mathematics curriculum. A guiding principle has been that of coherence between teaching, learning and assessment. The technology used by students for doing and learning mathematics should be coherent with that used by the teacher for teaching mathematics and also should be a component of the assessment program.

Personal technologies still seem to offer the best prospects for approaching this sort of coherence. A scientific calculator, graphics calculator or ClassPad 300 is small enough and portable enough to be used freely by both students and teachers and to be made available in formal and informal assessment. Increasingly, technologies of these kinds are being formally included in official curricula, including official examinations, in Western countries such as Australia, and curriculum development undertaken on the assumption that essentially all students will have a reasonable level of personal access. It is much more difficult to achieve coherence with more sophisticated technologies such as desktop or notebook computers. The main reasons are that it is much more expensive to ensure that all students enjoy sufficient access during teaching and learning and it is very much more difficult to conduct important examinations fairly when computers are permitted for student use.

As well as sound curriculum and examination design, integration of technology also requires careful attention to other factors, especially those concerned with teachers and textbook materials. Many existing teachers are unfamiliar with technologies such as those described here, and integration of technology requires that attention be given to support the work of teachers. This can take a variety of forms, including workshops, written materials, online materials and even just free time to work with colleagues to develop both personal competence and also good ideas for teaching. Textbooks and other materials written for students need also to be considered from the perspective of technology.

East Asian learners
In recent years, scholars have identified characteristics of East Asian learners and education, partly in order to understand some success on various international comparisons of achievement. Despite a flurry of attention, including even some suggestions that the successes of East Asian students ought to be mimicked in the West by following similar educational practices, some have suggested caution. For example, Fujii (2002) suggested that instrumental understanding (Skemp 1976) still works effectively in almost all conventional school mathematical problems, so that the apparent success of Japanese students was illusory, and he described it as a ‘pseudo-understanding’ (2002, p.4).

Leung (2001) offered an interesting analysis, highlighting several dichotomies to explore differences between education in the East and the West, acknowledging that such comparisons are always difficult, as they involve a complex mixture of cultural difference, habit, experience and of course are tempered by important official decisions regarding the nature of school education. It is interesting to consider some of these dichotomies in the light of personal technologies such as those identified above.

On the matter of the emphasis of content versus process in mathematics, Leung’s first dichotomy, it seems important to recognise that personal technologies of today provide a good deal of what is often regarded as ‘content’, since many mathematical procedures in the form of ‘basic skills’ can be readily performed on them. While the simplest cases involve mere arithmetical calculations, more sophisticated cases include algebraic manipulation and procedures involving calculus. It seems inevitable that access to technology of these kinds
will influence views on what are really the most important foundations for mathematics, one of the themes for this conference.

Leung (2001) described a dichotomy between rote and meaningful learning by noting the significance of memorization and repeated practice in East Asian mathematics education. Whether this is characteristic of only East Asian education is of course questionable. Leung (2002) noted Huang’s conclusions from a TIMMS-R Video Study that practice was a prominent feature of mathematics lessons in all countries studied, not only those in East Asia. Similarly, Skemp’s influential paper (1976) lamented and offered some explanations for the (Western) emphasis on rote learning, including the backwash effects of examinations and curriculum materials. Personal technology has often been assumed to have only a single role – that of calculating answers – while the important experiential role has been overlooked. It seems that many things learned by rote in both East and West can now be performed directly via personal technology, and that personal technology might also be used to support meaningful learning through the provision of valuable personal experience.

Leung (2001) referred to a dichotomy between extrinsic and intrinsic motivation in order to better understand East Asian mathematics education. A key issue is the prominence of formal examinations, of continuing societal and cultural significance in East Asia; these seem to reflect best the idea of extrinsic motivation. Mathematics examinations of course have for long been of considerable importance in Western countries as well, as Skemp (1976) and many others have noted. In these countries, experience suggests that an important issue is the extent to which technology use is permitted in the examinations. One reason for this is to provide coherence between teaching, learning and assessment, as noted above. It is also important to recognise that extrinsic motivation is a powerful tool as well as an obstacle to reforming mathematics curricula in the light of massive changes in available technology in society at large. On the other hand, many teachers report that personal technologies such as a graphics calculator or a ClassPad 300 generate significant intrinsic motivation in students, because of the creative opportunities opened.

Leung’s final two dichotomies (2001) refer to the teacher as a subject matter expert (as distinct from a mere classroom facilitator) and to teaching the whole class versus teaching individuals. Viewed from the perspective of personal technology, these two dichotomies remind us of lessons also learned in the West that effective use of personal technology in the curriculum requires teachers who are themselves competent and able to model good practice. As noted above, effective integration of technology into the curriculum requires considerable energy and time spent supporting mathematics teachers in this quest. As Leung notes, educators from both the East and West will agree that teachers need to be both scholars and facilitators. It is unrealistic to expect teachers to teach well what they do not themselves know well, so that support for teachers to use technology effectively themselves is necessary before it can be integrated into the curriculum. Many teachers in the West make effective use of whole-class demonstration devices, such as overhead projector models of graphics calculators, both when students are using their own calculators and also when students are not using calculators. This seems to be consistent with Leung’s observation of typical East Asian educational practice regarding a teacher as a subject matter expert teaching a whole class.

Wong (2002) expressed some reservations about whether the educational practices common in East Asia were in fact an inherent part of the Confucian Heritage Culture (CHC) and even referred to a ‘CHC myth’ (p. 213). Rather, it was suggested that the practices in the ‘lived space’ of classrooms reinforced particular views about mathematics and mathematics education. Wong noted, for example, “… students consistently conceived mathematics as an absolute truth and they also thought there are always fixed rules to solving problems in mathematics. The task of solving a mathematics problem was thus equated to the search for such routines.” (2002, p.218) and also that there was “… a similarity in the students’ and
teachers’ conceptions of mathematics. In particular, both perceived mathematics as, by and large, a set of rules.” (2002, p.224). Wong also reported work by Lam, suggesting that “mathematics problems given to the students are found to be closed-ended, stereotyped and required only low level skills”, possibly “… due to the acute examination orientation in CHC, coupled with the cultural expectations of parents.” (Wong, 2002, p. 224). Such observations suggest that use of technology in mathematics education requires attention to the work of students, of teachers and also of examiners, reinforcing the earlier suggestion that a coherence between learning, teaching and assessment is necessary.

**Conclusion**

Mathematics educators in both East and West acknowledge that the foundations of a good mathematics education are conceptual, and not only procedural. Personal technologies of the kinds described briefly in this paper allow for exploration of important foundational concepts in mathematics, while also offering support for procedural computation. Creativity is an important part of mathematical work, not always recognised by pupils and teachers in either East or West; working within the strictures of examination-oriented environments. Personal technology continues to offer opportunities for a range of mathematical perspectives to be explored in creative ways by students, with the help of their teachers, provided attention is given to the professional needs of teachers and the nature of assessment.

**References**


*This paper was presented to EARCOME3 as follows: