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An Assessment Of Mental Mathematics Programs For Young Children

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Abstract

In this article, we present criteria to assess the usefulness of mental mathematics programs and using these criteria, we compare the abacus and a finger-based speed mathematics system.

Introduction

Ministries of Education throughout the world, including Singapore, Malaysia and the United States, have recently embarked on ambitious programs to improve mathematics education for younger learners.

- Singapore's Ministry of Education recently introduced the abacus in Primary Schools on a pilot basis (Chong, Yeap & Fong, 1996) and plans to introduce abacus classes in all Primary Three pupils by 1998 (The Straits Times, 1996a).
- In Malaysia, Standard Five pupils will be required to use the abacus and the Education Ministry is investing M$1 million on abacus training for teachers and M$800,000 on equipment (The Straits Times, 1996b).

So far these programs appear to be yielding some benefits. For example Dr. Fong Chan Onn, Malaysia's Deputy Education Minister noted that Standard Four and Standard Five pupils showed improvements in mathematical skill after learning the abacus (Kaur, 1996).

Despite these pronouncements, the introduction of these programs has nevertheless led parents, principals, teachers and even students to ask:

- What do we want to achieve with these mathematics programs?

- How are programs such as these (e.g. the abacus courses) achieving these objectives?
- Is there a better way to achieve these objectives?
- How do we choose from the plethora of alternative programs being offered?

Is Mental Mathematics only about Speed and Accuracy?

Without a doubt, the needs of our fast changing society are driving changes in our educational systems. Graduates today are expected to know *more* than was expected of graduates one or two decades ago. Two decades ago when employers talked about *basic skills* they were referring to basic fluency in language and numbers. Nowadays *basic skills* include not only proficiency in mathematics and language but also the ability to use the latest software, make a succinct presentation, write persuasively, organize information and draw conclusions from it (Avishai, 1996). This requires a degree of creative thinking skills on the part of the graduate.

As a consequence educational systems worldwide are being asked to not only *teach more in less time*, but they are also being pressed to incorporate some new *components* to develop *creative thinking skills* in students.

Guidelines for an Ideal Mental Mathematics Program

Keeping this in mind let us now lay out our criteria for a good mental mathematics program and what such a program *should* achieve.

Help the learner to do well in mathematics

Clearly a good mental mathematics program should help to improve a student's calculative ability in speed and accuracy. However we also note that to do well in mathematics requires other attributes and skills (Chong, Yeap & Fong, 1996) or as Professor Lee Peng Yee, head of Nanyang Technological University's mathematics division aptly put it, "in school, speed is not the issue, understanding is" (The Straits Times, 1996a). Therefore in order for a mental mathematics program to strengthen a learner's ability in mathematics, it needs to develop *both* *calculative ability and proficiency in skills* such as forming or grasping mathematical concepts, developing number sense, analyzing and solving problems. Furthermore, this must be done at a level the learner can *follow and absorb*. That is to say the program must be ***suitable*** for young children.

What should we look for in determining whether a program is suitable for teaching young children? We can consider whether the program:

- has the in-built capability to facilitate the teaching of mathematics
- has the in-built capabilities to help students learn and comprehend mathematical concepts more productively
- was designed, from the start, with modern pedagogical requirements for young learners in mind
- is simple enough for young children to learn, apply and comprehend (i.e. it is logical, consistent and straightforward in its implementation).

But if we drill down to a more fundamental level, we see that the underlying issue is whether the program can achieve successful engagement of the pupil's learning faculties.

<u>Build creative thinking skills</u>

If we expand the scope of our examination, we find that educationists, industrialists and national leaders nowadays do not want our schools to produce students who are *merely* walking calculators or libraries. They want graduates who are well rounded and *imaginative*.

But in order for creativity to *flourish* in a young student this child must first embark on the development of his *thinking* skills. In addition the student must also develop the *confidence* needed to tread new ground or try something new -- as well as the *courage* not to be *derailed* but to *learn* from the failure which is inevitable in most creative endeavors. As Alvin Toffler (1990) noted, "Innovation requires experimental failure to achieve success."

Traditionally, creative development has never fallen within the purview of mathematics instruction. *But this does not mean that creative development could not be successfully combined with substantive, uncompromised mathematical instruction for younger learners.* In fact, if we were able to accomplish the above educational objective, i.e. combining creativity with a mathematics program, it would be a *significant breakthrough*. Such a program would certainly merit *serious investigation*.

Mathematical validity

We must be careful to ensure that a program to teach mathematics should itself be mathematically sound. This means that the program should be able to withstand rigorous mathematical validation and offer some logical consistency in its approach.

Teach efficiently

As we noted earlier, teachers have more to teach in less time. Therefore *efficiency* of instruction is desirable. This efficiency can be obtained from one of two ways -- or both:

- by helping the student learn more productively and/or
- by helping the instructor teach more productively.

However this efficiency *must not come at the cost of compromised educational integrity*.

Other considerations

An ideal contemporary mental mathematics program *should offer more* than pedagogical value and instructional efficiency. It should also:

- be enjoyable for young learners
- help develop learners' *confidence in* and *comfort* with numbers and mathematics

But is it unreasonable for us to expect that a mental mathematics program, besides teaching mathematics *efficiently and effectively* can also offer further benefits such as building confidence and *continue extending further benefits to the development of creative thinking skills*?

That is the *real* question this paper seeks to address.

What makes a Mental Mathematics Program Effective and Suitable for Young Learners?

Educationists generally agree that a good mathematics program should have, as an integral pedagogical element the *capability* to *teach and equip* students not only with the necessary *skills and knowledge* but also the *conceptual understanding* to enable a young learner to *advance* to *higher* levels of learning.

Engaging the pupil in the learning process

How well such a program teaches and equips a student is one measure of its *effectiveness.* But in order to provide this academic development, the program needs to first *engage* the student in the learning process at not just one but the *three* domains that may affect or contribute to the learning and teaching processes:

- *The Cognitive domain* ·
- *The Affective domain* – e.g.:
  - Does the student find the class lively?
  - Does the student find the program stressful to learn?
  - Does the student find the program fun and game like?
  - Does the program require the student to perform a lot of mechanical work and/or rote learning?
  - Does the program build confidence in the student?
- *The Psychomotor domain*

If a program does not properly *engage* the student at all three aforementioned domains, its instructional effectiveness can be significantly *reduced.*

<u>Cognitive concerns</u>

A suitable program must obviously account for a young learner's state of *cognitive* development. We note that cognitive structures are progressively organized into stages from rudimentary to complex (Arends, 1994). Therefore if a program requires a significant degree of *pre knowledge* in mathematical vocabulary or concepts as well as a high degree of proficiency in language the applicability of such a program may be restricted -- especially for young learners.

Affective concerns

It is safe to assume that young children possess relatively more fragile psychological structures than those of older children. Young children can be easily frustrated by a course that they find:

- tedious,
- stressful,
- difficult to apply or
- confidence draining.

This frustration can later degenerate into a lack of confidence in mathematics causing students to develop anxieties around mathematics. As a result, students become demotivated, demoralized or in extreme cases, *mathophobic* (Chong, Yeap & Fong, 1996).

How can these factors influence a student?

1. ***Fun or tedious?*** When young children, because of either from their own prior experience or from the experience of others, expect a classroom environment to be a *leaden* rather than a *lively* learning experience, this already is *demotivating*. (We should make careful note that an educational program can be fun and game like. In fact well designed games can offer significant pedagogical value (Koay, 1996)).

2. ***Stressful or fun?*** A program that requires the learner to memorize a voluminous number of formulae and/or procedures, or *subjects* the learner to spend *endless hours* in repetitive mechanical practice can induce undue *anxiety*. Moreover programs imposing highly rigid conditioning have long been recognized by educationists and psychologists to be *a potential impediment to developing creative thinking skills* (Koh & Yong, 1996).

3. ***Difficult or easy to apply?*** A program involving considerable procedural or psychomotor complexity can also inordinately raise anxiety levels among young learners.

4. ***The confidence factor:*** Though confidence may be an intangible quality, its long term benefits cannot be ignored. A child may be proficient in mathematics yet because of a lack of confidence may appear to be mediocre. Furthermore a student who is *not confident* in his or her ability in mathematics may develop a *phobia* around numbers. Such a student could become *educationally handicapped* in the long term.

A program able to build *confidence* as well as impart a love for numbers and mathematics can provide the learner with an important psychological edge that will *propel* him or her to progress further to new, higher levels of learning with a *zest and zeal* that less confident students will lack. Furthermore, as noted earlier, for creativity to flourish *the underlying confidence must first exist.*

Psychomotor concerns

When young children are involved, it is vital to see that psychomotor considerations are also addressed, particularly if an external device such as an abacus is involved.

1. ***Acceptance or rejection***: As part of the growing process, young children spend endless hours learning how to manage and build their muscles as well as their muscular coordination. When a child *is additionally* asked to master a new, external device, the child must not only *struggle* to *overcome his or her own psychomotor limitations but at the same time master the new contraption*.

2. ***Ergonomic incompatibility** can further exacerbate this process.* That is if an external device *is additionally uncomfortable* for the student to use, the learning process *becomes even more of a strain*. This can lead the child to become frustrated which in turn can lead him or her to:

- not react well to the device,
- develop a phobia for the device or
- simply reject it outright.

3. ***Stimulation of the brain***: There is also the degree of psychomotor application to consider as this directly impacts the stimulation of the brain. The significant importance and implications of this shall be discussed next.

Creative Stimulation

While the development of creative thinking skills is beyond the scope of this paper we nevertheless can take note of a few scientific developments that have led us to a better understanding of how our bodies, in particular the biological infrastructures for thinking and creativity, function.

- In 1981 Dr. Roger Sperry won a Nobel Prize for his work that identified the *right* side of the brain as the *creative* hemisphere (Zdenek, 1983).
- Scientists further showed that the *left side* of the body is controlled by the *right* brain and that input from the faculties of the left side of the body feeds directly to the right brain and vice versa.
- In 1988 Chiye Aoki and Philip Siekevitz demonstrated that the brain responds to stimulation from the senses and the faculties by *physically* growing. This growth is proportional to the amount of stimulation received (Harvey, 1994). Thus stimulation of the right brain (that comes from the left side of the body) results in growth in the right brain.

A program can help to build *creativity* in a student by helping to *promote* the development of the *right* brain. Such a program can also help by developing *confidence* in the young pupil.

Mathematical Validity

Earlier we remarked that a program to teach mathematics should itself be mathematically sound; that is, the program should be able to successfully withstand *rigorous mathematical validation* and offer some logical consistency in its approach. While the need and benefits of this should be apparent, relatively few mathematics programs offer this strict substantiation. Thus when a system has been proven to withstand strict mathematical scrutiny, *for this reason alone it* *merits serious attention*. One such system in use today, the ***Speed Maths System***, has been validated by rigorous mathematical testing (Lai, 1996).

Good management of time and energy

Given the time pressures on teachers today -- i.e. they must teach more in less time -- and the fact that both a learner and teacher have *a finite amount of time and energy* to devote to the process of learning, it behooves us to identify programs that provide maximum educational returns for the required investment in time and energy of both the learner and teacher. But how does any educational program manage both this limited time and limited energy well?

As noted before, educational *efficiency* can be obtained:

- by helping the student *learn* more productively and/or
- by helping the instructor *teach* more productively.

This can be achieved through:

1. the elimination of unnecessary tasks
2. application of a logical, straightforward methodology or approach and
3. energizing students in the process of learning.

Eliminate unnecessary tasks

Numerous business management textbooks cite process improvements as ways to increasing organizational efficiency. Process improvement exercises improve efficiency through the elimination of unnecessary steps or procedures.

Let us consider for the moment two mental mathematics programs that produce similar results, the major difference being that one program requires the user to master an external device (after spending considerable time and effort) while the other does not (and consequently saves substantial instruction time). Of these two which would be preferable?

Obviously if a program does not require the use of an external device:

- it *avoids all the problems of managing an external apparatus* (e.g. bringing it along, not forgetting it, not breaking it, etc.) -- which require *energy* on the part of the learner and the teacher and
- it *does not require the user to spend time and effort* mastering a foreign device.

There is another reason why we should avoid the necessity of learning an external device -- particularly when young children are involved. Science has shown that a young child experiences prodigious biological growth that peaks, then drops off precipitously at a young age. This growth explains why young children are capable of astonishing feats of learning (Harvey, 1994). If we want to take advantage of this early biological development we must start introducing educational content at a young age. By imposing the need to master a device we not only *delay* the introduction of this instruction, thereby *losing the opportunity to capitalize* on this biological development, but we also *divert* student's precious *learning and development energies and time* to activities that may seem unnecessary.

We should take note that the need to master an external device is not necessarily undesirable, for example in learning the piano the need to master an external device is inevitable. Rather it is our contention that for a mental mathematics program if an alternative to an external device exists, the alternative should be considered.

Enhance efficiency through a logical approach

As noted previously, a good program should be logical, consistent and straightforward in its procedural approach. It should incorporate good mathematical subject content and should engage the learner in the learning process. There are very sound pedagogical reasons why procedural streamlining is valuable.

A logical, straightforward *approach yields several important benefits* in addition to increasing instructional efficiency. A logical approach is:

1. *more readily comprehended* by the learner and *less likely* to lead to *confusion*
2. *less stressful* for the learner to apply and

3. *less prone* to error unlike a system that requires the user to execute numerous and highly involved procedural steps or involves an over-usage of formulae.

Furthermore a logical system is *easier for the instructor to use and apply.* The last point is especially noteworthy.

A system that involves many procedural steps is inherently more prone to error than one that accomplishes the same results with fewer procedures. Procedural complexity can *cause a learner to err not because of the learner's lack of mathematical proficiency but because of a higher probability that a procedural mistake or omission may occur*. This will not only cause unnecessary stress on the part of the learner but may incur the *added undesirable effect of lowering the learner's confidence levels in mathematics for reasons that are, in fact, unrelated to mathematics.* It should now be obvious that a mathematics program, particularly for young learners, should be procedurally straightforward, consistent and mathematically sound yet there are cases where this is not true.

A Chinese Paradox?

Out of academic interest, let us examine one such example. There appears to be a method originating from China called the *Shi* technique that uses a finger representation scheme on the left hand for *addition only*. It curiously *deviates* from this finger-based scheme for other operations (e.g. subtraction, multiplication and division). Rather, for these other operations, considerable paper and pencil work as well as memory work is involved.

For subtraction the *Shi* technique employs transformation of subtrahends to combined numbers and utilizes mathematics that is currently not in vogue. Although it is a well known fact that subtraction is the logical inverse of addition, the *Shi* technique does not exploit this fact to handle subtraction.

In the case of multiplication the user is subjected to the task of memorizing a completely new set of tables that are clearly different from the current common multiplication tables taught in schools. This causes great concern to both students and educators. Furthermore, to complete the multiplication task, the user must apply a dizzying array of number manipulations; conversions and procedures far too involved for many older learners *to begin to fathom*; for younger children this is *a nearly impossible* feat.

So far, the *Shi* technique has not succeeded in producing anything tangible for division.

Finally *no mathematical validation* or any reference to such mathematical validation can be found in his documentation (Shi, 1991).

<u>Energizing pupils</u>

Returning to the subject of efficiency, we note that a program that can *motivate and energize* students in the process of learning also increases efficiency of instruction.

Children that want to learn and who are *galvanized* to learn require less energy from the teacher and are far preferable to lifeless individuals *resisting* instruction. How can we *motivate* students to want to learn? We noted earlier that program which is game-like can bring about significant positive effects on a child's affective domain. Such programs also can strongly motivate students to learn (Koay, 1996). Furthermore it has also been shown that the body can be energized by external stimuli (Ostrander & Schroeder, 1994). If a program is able to tap into these faculties and *motivate* students to learn, it would increase instructional *efficiency* manyfold.

Clearly a program that applies a child's energies fully in the learning process to *maximize productivity* and *invigorate* students is *far more desirable* than one that *dissipates* learners' energies with unnecessary activity which, in turn, has the potential of *enervating* and *demotivating* these pupils.

Design Suitability

This brings us to the question of how to assess whether a program is suitably designed for teaching mathematics to young learners.