

Automaticity of the basic facts of arithmetic

Nowadays, we have calculators and computers for doing arithmetic. Few people can compete with a \$5 calculator in terms of speed and accuracy when doing arithmetic. This raises important questions. Should arithmetic be learned at all? If so, why and how much? Answers to these questions are not simple, but it seems clear that students should still learn to do arithmetic for at least three important purposes.

-  Learning arithmetic empowers people to do calculations remote from the tools of technology. Mental arithmetic is an important skill for estimating answers and for obtaining precise answers. Paper and pencil arithmetic is still useful for doing calculations. The situation is comparable to learning to write. The word processor and the spell checker have not eliminated the need for writing and spelling skills.
-  Arithmetic provides a useful context for developing mathematical concepts and principles (you cannot develop them in a vacuum). To put it another way, arithmetic can provide a forum for thinking about numbers and the relationships between them.
-  Doing arithmetic provides one way of “touching” mathematics. Arithmetic is part of mathematics. Without it, much of mathematics and its application to the real world would grind to a halt.

What does this have to do with automaticity of the basic facts of arithmetic (knowing them “by heart”)? In the final analysis, all knowledge is memorized in the sense that it is stored in the brain. In order to do something, particular knowledge must be available for recall when needed. The faster the recall, the better we can do a complex task, other factors being equal. Knowing the facts “by heart” greatly improves proficiency when doing mental arithmetic, and paper and pencil arithmetic.

If you investigate why some students are frustrated and struggling with arithmetic and number concepts, you will often find that the pertinent arithmetic facts are not mastered. Doing arithmetic, whether mental or written, is a complex cognitive task. If the facts are not available at the level of automatic recall, this means that the student has to shift cognitive attention from the arithmetic task to obtain an answer for such facts questions as $3 + 4$ by counting or using some other slow procedure. Because the short term memory of early years students is quite limited, this disruption of focus can negatively affect performance and learning. In other words, the student can too easily lose the train of thought concerning an arithmetic task because too much cognitive attention is being paid to a minor component of that task.

Some people might argue that mastering the facts is boring. That may be so, but to continually use a slow procedure such as counting to obtain answers to simple arithmetic questions like ‘ $3 + 6$ ’ is likely even more boring.

We are not saying that mastering the basic facts is the first thing that students should do. That would take us back to the “good old days”, days that are best left behind us. We are saying that students first need to understand the meaning of the particular arithmetic operation (e. g. addition), do simple problem solving involving that operation, and use methods such as counting to obtain answers. Only then are students ready to begin to master the basic facts for that arithmetic operation. A nice feature of this sequencing is that some facts will already be in place as a result of students’ past experiences with doing arithmetic by counting (for example).

Unfortunately, learning by osmosis only works to a certain point. Explicit attention is also required. There are many methods for mastering the basic facts at the level of automatic recall. Some work well; others do not. The following four criteria are useful for assessing whether a method is likely to be effective for mastering the facts.

- The time for responding to a facts question should be under 2 seconds (monkey one, monkey two). Any longer, and the student will be able to use cognitive bypasses such as counting to determine the answer. If time is made available for cognitive bypasses, that is what will tend to happen, thereby defeating the purpose of the method. Why should any sensible student master a fact if s/he is given the opportunity to use a familiar skill such as counting to get the answer?
- If the student’s answer is incorrect, the question along with the answer must appear together in some way so that the student has an opportunity to learn the fact. Research says that the optimum time for this is about 4 to 5 seconds.
- Facts questions should be presented randomly. This is precisely how the facts must be recalled when they are applied to complex arithmetic tasks.
- Immediate feedback should be provided so that incorrect answers are identified and attention can be paid to learning the correct answer at that point in time.

A common practice in elementary schools is to use a 'mad minute' strategy for mastering the facts. It is useful to assess this strategy from the point of view of the criteria described previously.

The 'mad minute' provides information on how many facts questions students can answer correctly in a minute. As such, it does provide assessment information. But, it is not a good teaching strategy. Some facts learning may happen because students might be motivated to "beat the clock" but that is due more to happenstance than to design. Why?

- ☐ It is not possible to determine how long it takes a student to answer individual facts questions. This means it is not possible to tell which facts were answered correctly by using instant recall (the goal) and which ones were answered correctly by using a cognitive bypass such as counting. Remember the goal is not simply getting a correct answer but getting it quickly.
 - ☐ The student is not given an opportunity to learn an incorrect/unknown fact because the question and answer need to be associated with each other at the same moment in order to make learning possible. The typical mad minute only involves asking questions; it does not provide the answers to questions close to the moment of asking.
 - ☐ The student does not receive immediate feedback; this means that incorrect answers go undetected at a crucial moment, and thereby tend to be positively reinforced.
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Are there better teaching strategies for mastering the basic facts of arithmetic? Yes, one possibility follows.

The following strategy is a slow and easy approach to mastering the facts, one that meets the criteria described above. The strategy can be used for 5 minutes or so at a time during any "spare" moment in the school day or at a centre. It involves cooperative learning because pairs of students help each other learn. From the point of view of 3 stages of teaching, the strategy is best seen as a series of brief DEVELOP activities, where the learner takes charge of his/her own learning.

Getting students ready for learning the facts

Students usually need a reason for mastering the facts. Discuss the advantages of knowing something "by heart" (like someone's name). Include the arithmetic facts in the discussion. If you have a good relationship with your students, play a speed game with them to counter their references to using calculators to do arithmetic. Select one student to write his/her "hardest" facts question on a sheet of paper (hiding it from you and the rest of the students). That student holds up the question at a signal from you. You do the facts question in your head while the students use a calculator. You should "win" every time. Discuss why.

A facts mastery strategy

The strategy requires a special set of cards. A particular facts question appears on one side of a card with the question and answer on the back side of that card. Each student should make his/her personal set of cards because making them helps establish ownership of learning and can help students learn some facts in the process.

Naturally, the correctness of answers will need to be checked.

The strategy involves pairs of students. One student presents facts questions; the other student answers them.

The activity begins with the question presenter shuffling the cards (this randomizes the order of the questions). Next, the presenter shows one card at a time, question side facing his/her partner (learning buddy).

If the correct answer is not forthcoming in a time of "monkey one, monkey two" (about 1.5 seconds), the presenter says "*Not fast enough.*" and shows the question and answer side to the answering student for about 4 seconds. During that time, the answering student should learn the particular facts question in whatever way makes personal sense.

If the answering student's response is correct within 1.5 seconds, the presenter shows the next card. The presenter keeps showing cards until the deck is exhausted. Then the students switch roles. **[Notice that the presenter also has an opportunity to learn facts as s/he is looking at the question and answer side of the cards.]**

Each student should keep a record of mastered facts on a facts table (a personal record of learning). As each fact is mastered (as assessed by the teacher), the appropriate spot in the table is filled in. Besides serving as a record of mastered facts, the table also can motivate students.

$$7 + 9 = ?$$

$$7 + 9 = 16$$