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Using Computer Algebra to Improve Student Confidence

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Abstract

We describe a system, TREEFROG, which gives step-by-step feedback of the correctness of a pupil's argument in simple algebra. We use data collected in a trial in a local secondary school to support the claim that the confidence of the pupils using the software was increased as compared to those being taught in a traditional manner.

What is TREEFROG?

TREEFROG is a Windows based package which allows pupils to enter multi-line solutions to simple algebraic problems set by their teacher. For example, if the teacher set the problem "Solve the equation $2x + 4 = 6$" to the pupil, the sequence of steps entered might be as follows;

1. $x + 4 = 3$
2. $2x = 6 – 4$
3. $2x = 2$
4. $x = 1$

The first step is incorrect, and is highlighted in red by TREEFROG. This step will be replaced by the correct step 2, and this and the remaining correct steps will continue to be displayed on the screen. Step 4 is recognised as being in the form needed to finish the question, and a congratulatory message is displayed to the pupil before moving on to the next question.

It is worth emphasising that there is no "correct" solution to this question; for example, the pupil could have divided the equation $2x + 4 = 6$ by 2 to make their first step

1. $x + 2 = 3$

Each step is checked by using mathematical manipulations (rewrite rules). These attempt to reduce each step to an equivalent form. The final step is recognised as a legitimate final step by matching it against a supplied template.

If you would like to experiment with TREEFROG for yourself, a demonstration version is available from

http://java.cms.livjm.ac.uk/treefrog/treewin.htm

or by contacting the authors.

Other types of software to aid the learning of algebra.

1. Many packages for helping students learn algebra use multiple choice assessment; so if a student is presented with an equation such as $2x = 2$, the alternatives presented might be

a) x = 0 b) x = 1 c) x = 4
corresponding to the student's removing the 2 from the left-hand side and

a) subtracting 2 from the right-hand side.
b) dividing the right-hand side by 2.
c) multiplying the right hand side by 2, or adding 2 to it.

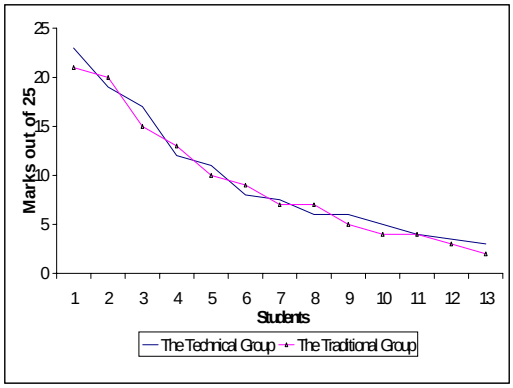
An advantage to this type of question is that a well-designed question (this one is not) may enable some diagnosis of what the student is doing wrong when they make a mistake. However, it is not clear that this question is testing the ability to manipulate and solve equations; after all, the student may be substituting the suggested values of x into the original equation. Questions may be designed to test other aspects of algebra, but we would suggest that this type of test is an unnatural environment for practising mathematics, and that manipulative skills may not

2. Computer algebra packages can have a good contribution to the learning of algebra, as has been demonstrated by extensive research. A system such as DERIVE can empower students to tackle much more life-like problems, and improve attitudes and understanding of the subject. Computer algebra software can achieve this because they can undertake the lower-level skills, leaving the user free to focus on problem-solving and strategic skills. Where they have perhaps proved a little weaker is in the development of manipulation skills, which we feel are important to master early on in the learning of algebra. These skills provide a 'concrete' experience which can form a foundation for more advanced work.

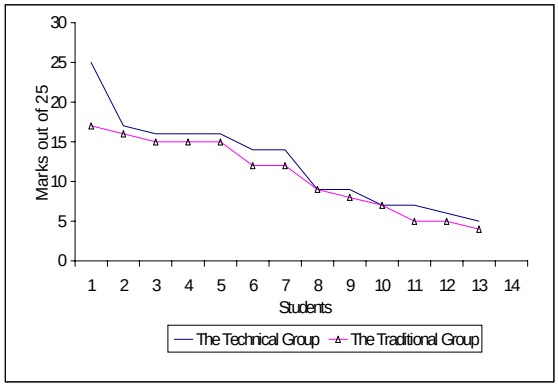
   It is also possible to use computer algebra packages to assess student's solutions, as has been achieved by Theodore Kolokolnikov of the University of Ghent. Some of these assessments are available at http://calculus.rug.ac.be:8080/.

Benefits of using TREEFROG.

Initially we hoped that TREEFROG would improve students' ability to manipulate simple algebra, and some small-scale trials in local secondary schools provided some confirmation, as reported in [SAJ]. In each trial children were ranked by a paper-based pre-test, and then divided into two equally matched groups. One group (the "traditional" group) was exposed to pen-and-paper practice sessions, with their own teacher present to help them if they got stuck. The other group (the "technical" group) was allowed to practise using TREEFROG, with the researchers present to offer help with using the software. After about a week the whole class was tested again, once again using a paper based test. Over such a short space of time we found no significant increase in the children's' scores, but we did find a significant effect in the overall class ranking as shown by the following pair of graphs.

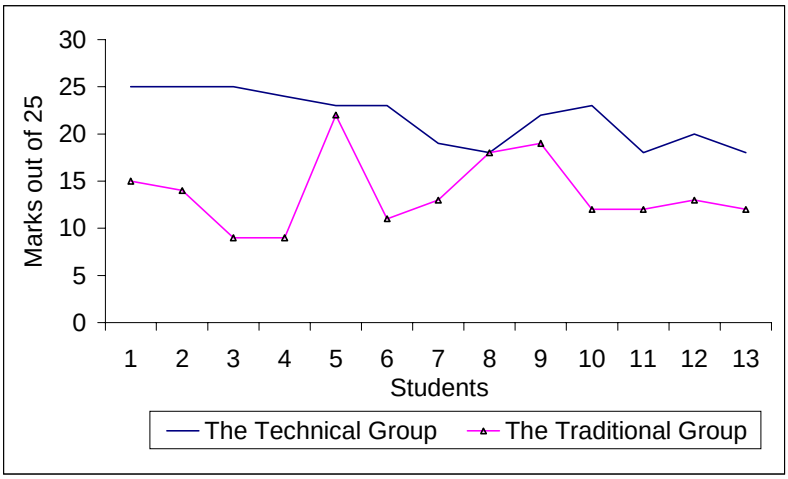


Pre-test scores



Post-test scores

In going back over the data obtained we were surprised to see a bigger difference in the two groups in terms of how many questions they attempted in the post-test. As the graph below shows, the pupils who had used the software were much more likely to have a go at a question in the paper-based test.



Originally we put this down to an increase in confidence due to the immediate feedback offered by TREEFROG in a relatively natural learning environment; however, other researchers [SB] have felt it better to measure confidence by obtaining the learner's own assessment. The willingness to attempt questions, as measured by the number completed, is perhaps better referred to as *effort*. Clearly these two factors are strongly linked, and more research using more subtle forms of measurement is needed.

There are doubtless other factors that need to be taken into account when assessing the impact of computer aided learning packages. Referring to intelligent tutoring systems in [SEH], it is suggested that the ability of an ITS to finely tune instruction may be less important than the fact that it permits teachers to spend more time with slower students or that it increases student motivation.

References

[SAJ] Strickland, P.and Al-Jumeily,D, "A Computer Algebra System for Improving Students' Manipulation Skills in Algebra", The International Journal of Computer Algebra in Mathematics Education, Vol. 6, No 1 (1999).

[SB] del Soldato, T. and du Boulay, B, "Implementation of Motivational Tactics in Tutoring Systems, Artificial Intelligence in Education (Fall-Winter 1995), pp 337-378.

[SEH] Schofield, J.W., Evans-Rhodes, D. and Huber B.R., "Artificial Intelligence in the Classroom: The Impact of a Computer-based Tutor on Teachers and Students", in Social Science Computer Review, 8(1), 24-41.