FaSMEd

Raising Achievement through Formative Assessment in Science and Mathematics Education

Algebraic equations

Subject:	Mathematics
Age of students:	14 - 15 years
Hardware:	iPads and IWB
Software:	Mathspace
Functionalities:	Sending and displaying, processing and analysing
Time:	1 hour
FaSMEd partner:	University of Nottingham
Short Abstract:	The lesson focused on developing students' understanding of multi-step linear equations.

1. Content

The purpose of the lesson was for students to develop fluency with solving multi-step linear algebraic equations with one variable. The type and complexity of these equations is indicated by the examples provided later but there was some variation in the actual questions attempted by individuals due to the use of software (*Mathspace*) with an adaptive mode of questioning.

Students were expected have prior knowledge of how to manipulate and simplify algebraic expressions and of the processes involved in solving multi-step linear equations, including familiarity with how to multiply out brackets, re-arrange equations, collect like terms and simplify expressions. They were expected to apply these skills to solve linear equations with one variable and numerical coefficients consisting of positive and negative integers. Students were expected to find solutions to a series of questions of increasing complexity, whilst receiving frequent feedback electronically on their work.

2. Activity

2.1 Aims

The aims of the lesson were to:

- Enable students to apply their prior knowledge of algebra to find accurate solutions to a restricted range of linear equations;
- Extend students' understanding of the meaning of algebraic expressions and the processes involved in solving equations;
- Develop students' fluency with finding solutions for multi-step linear equations and expressing their working coherently;
- Develop students' understanding and use of common conventions when recording written solutions to equations.

2.2 Structure / Methodology

The lesson focused on the use of an electronic learning environment called *Mathspace*[1] by students, for individual work on these equations. The tasks given to the students were selected by the teacher from a range of 'types' of activity supplied by the software but the program then generated a series of questions for each student, utilizing an adaptive system to suit their needs.

Firstly, students were provided with three equations to solve that were generated by the software. The teacher had preselected the 'type' of equation required (each involved at most three steps) and the software provided equations with different numerical coefficients for each student. Examples of the question types used are shown below.

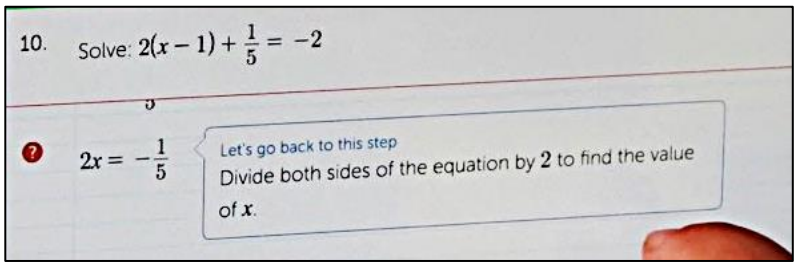
Question 1: $\frac{x}{6}+5=0$

Question 2: $\frac{8x+40}{12}=-88$

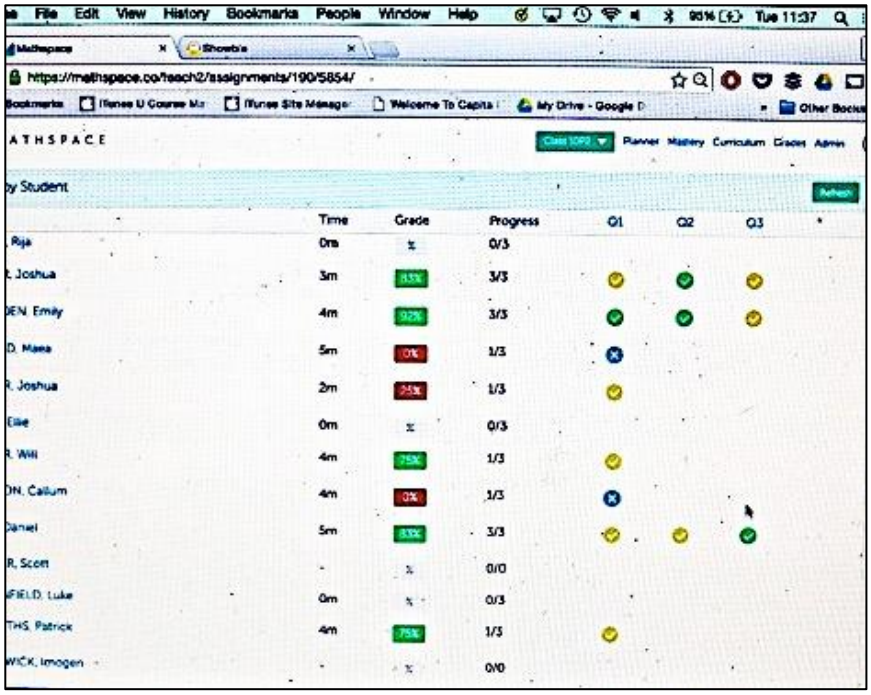
Question 3: $5(x-2)-13=-53$

[1] An animation showing the functionality of *Mathspace* is shown here: https://mathspace.co

Students were asked to write their solutions step-by-step using their fingers on the iPads. As they wrote a line of algebra, the app interpreted their handwriting and re-presented it in printed form. (This occasionally caused confusion when, for example, the iPad interpreted the student writing x as an instruction to multiply rather than as the name of the variable.) Each line of working was assessed by the system as correct or incorrect, and hints were provided electronically, should the line of working be incorrect. For example:



The teacher was able to monitor students' progress electronically and identify common errors that needed to be followed up by verbal questioning or class discussion.

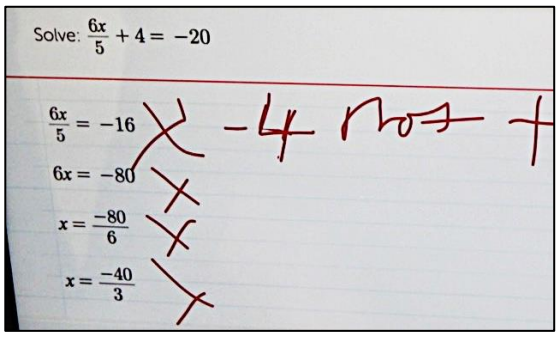


After the students had attempted these three questions the teacher showed student responses on the IWB for discussion. There were two purposes for the class discussion. Firstly, since the software was new to most students, the teacher used samples of work and questions to clarify the main features of the software and help students interpret the feedback correctly. Secondly the teacher showed samples of student work and discussed the common errors and misconceptions that this revealed.

The teacher then presented the main task for the lesson. This was to complete as many questions as possible. The software was adaptive, so if the student completed one equation incorrectly, the software would ensure that the next equation was of a similar type and difficulty. If students were successful, the software would generate a more difficult equation. Students had to show each line of working and have this checked by the system before proceeding to the next line. If lines of working were incorrect then students either corrected their own errors or asked the system for a 'hint'. When they had worked out sufficient solutions correctly, according to the criteria set for this task, they achieve a

'mastery' score of 100% even though the system continued to generate additional questions with increasingly more difficult numbers.

Finally, the students were provided with two worked examples containing some errors. The students worked in pairs to assess each line and provide the 'hints' that they think *Mathspace* would provide in order to guide them towards a correct solution. For example, here is one where the very first line is incorrect.



2.3 Technology

In this lesson the technology performed a complex function. Data was sent, shared, analysed and processed by the *Mathspace* software but the system also provided feedback and adaptation that enabled students to self reflect and explore alternative approaches. The marking and 'hints' prompted students to consider their methods, adjust their thinking and correct their own errors, whilst the adaptive nature of the program ensured new questions were posed to gradually increase the level of challenge for the individual and move their thinking forward. *Mathspace* therefore created an interactive learning environment in which formative assessment processes took place involving individual students and their iPads without any teacher intervention.

The teacher, however, was supplied with data by the *Mathspace* system on student progress that they did use to intervene and initiate further formative assessment processes themselves. For the teacher the technology performed both a 'send and share' and a 'process and analyse' function since information was made available in various forms that they could use formatively, for the class or for individuals.

2.4 Aspects of Formative Assessment

The formative assessment strategies planned into this lesson were mainly focussed on the interaction of individual students with the software rather than on activities directly involving the teachers or their peers. These processes were, however, supported by the teacher by monitoring, observing and at times intervening during individual work on the iPads to correct errors or extend understanding.

During individual work using *Mathspace* students submitted their working, line by line, in response to computer-generated questions. The system marked each line and provided hints when they made errors, thereby challenging existing thinking and prompting self-reflection. This feedback from the system was designed to move students forward by indicating where they were already and what needed to be done to achieve success if they were not already 'on track' to an accurate solution. There was evidence that this did lead to changes in students' understanding and that their interaction with the system resulted in an effective formative assessment process. Although students seemed to have greater ownership of

their learning due to increased independence from their teacher, the adaptive software actually controlled their pathway through the questions. In effect the computer made decisions regarding students' learning pathways, although students' prior work was used to inform the decision. In this way ownership was removed from the student although they retained a sense of being able to work in their own personal space.

Teacher-led formative assessment was secondary but took place during individual work on *Mathspace* in several ways. The system provided information on student progress and teachers used this to decide where and when intervention was needed. They observed students' work in progress using *Mathspace* but also viewed work by circulating around the class. The teachers questioned students and responded to queries from individuals to elicit evidence of understanding, establish where students were and how they might move forward. On occasions teachers identified a common misconception from their observations and engaged students in a short whole class discussion to address the problem.

In the final activity where students were asked to provide feedback on sample written solutions to equations, students acted as assessors, making decisions about accuracy and providing feedback intended to move the (unknown) learner forward. In practice this acted as a means of generating discussion between peers to clarify the criteria for success and enable students to become instructors for each other, thereby contributing to their awareness of where they were going when solving these types of equations and how they might get there.

Feedback was an important step within each of the formative assessment processes described above. The *Mathspace* program was the primary source of feedback to students and teachers in this lesson. Firstly, the feedback from *Mathspace* to students was helpful in clarifying the criteria for success and moving them forward without intervention from the teacher. This interaction with the computer program was a key strategy and therefore the quality of the feedback generated by the system was important to student success. Meanwhile the information accessed by teachers from *Mathspace* allowed them to identify what interventions were necessary, for individuals or the whole class, to provide further feedback in the form of correction or discussion.

In the final part of the lesson students themselves worked together to provide feedback on a sample of work, in the style used by *Mathspace*. This functioned as a prompt for discussion between students rather providing feedback to the writer of the sample work. In this way the feedback was not part of a reciprocal process involving the learner and their work but it initiated new formative strategies involving students and their peers.

3. Further Information

Teachers commented on the way in which the use of the Mathspace program assisted them in formative assessment but also changed their role. They valued the information that *Mathspace* provided for them since this allowed them to see common mistakes within the class as well as overall 'mastery' statistics for each student. This information was useful in deciding what interventions were necessary during the lesson and also in planning subsequent lessons. The use of the technology did, however, change their role within the lesson. One teacher observed that their role was different because the number of interventions needed was "dramatically reduced". Using the data provided by the system, they were able to make quick whole class interventions when common misconceptions were apparent but, because *Mathspace* was providing hints and feedback to the students, there was less need for one-to-one interventions.

Another unexpected benefit mentioned by one teacher was the large amount of work that some of the students managed to complete in the allotted time. This could be attributed, at least in part, to the speed and quality of feedback provided by *Mathspace*, although the students themselves identified some issues with the feedback.

Students' responses to the software, from the teachers' perspective, were surprising. One commented on how "against the technology" the students were at first but how quickly they adapted to using it successfully and seeing its advantages. Some pupils still seemed more keen to ask the teacher for help than use the hints offered by the system, although others students seemed to prefer the hints since they felt they were working more independently. This needs to be taken into account when planning to use this type of software. Students had mixed responses to the *Mathspace* system, which was unfamiliar piece of software and these seemed to be mainly due to having to learn about the technical aspects of the software before they could use the system fluently. During the lesson the teacher needed to explain various features of the software and deal with technical frustrations.

In addition, the system was designed so that there were restrictions on how and what students could write. Some students found this frustrating and others argued that they did not understand the feedback given by the system. For example the instruction 'Move variables to one side and constant terms to the other' was not always understood and therefore the feedback from the program was ineffective without teacher intervention. The lesson followed from previous work on solving equations and sometimes the hints or explanations offered by *Mathspace* conflicted with students' established ways of thinking. Challenging existing practices can provide useful cognitive conflict, particularly when reasoning needs adjusting, but in this case the alternative approach offered by *Mathspace* seemed unproductive for students who were employing an appropriate, but different, method. Although from a teacher's viewpoint, this was valuable as a means of developing good habits, it was an enforced discipline that some students resented. The way in which the *Mathspace* system works, in comparison to prior learning about the processes involved, is an issue that needs careful consideration in order to make a smooth and effective transition from teacher-led learning activity to an interactive digital environment.

4. References

Information on Mathspace available at https://mathspace.co/

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in education*, 5(1), 7-74.

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