2021 cohort

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Does repeated practice of graph drawing improve secondary science pupil's confidence and exam results?

Introduction

Pupil's in secondary schools often report low confidence in applying fundamental maths skills such as graph drawing in science. The aim of this project was to design and deliver a series of lessons for a low ability year 8 class in order to improve key aspects of their graph drawing abilities.

Literature review

Graph drawing and interpretation is a fundamental skill in all three scientific disciplines. It requires pupils to be able to work with data, display and interpret that data visually as well as interpret the results by applying it to real life scientific concepts. An inability to do this adequately is considered to be a serious barrier to understanding key concepts in science (Gultepe, 2016). Anxiety has been negatively correlated with pupil confidence in using maths; this review therefore will consider the literature about pupil confidence in the use of maths in science and possible strategies through which pupil confidence could be increased.

Many students' express anxiety about using maths and this apprehension has been linked to the decrease in female students choosing to study STEM subjects such as physics in further education (Ellis et al., 2016). The gender gap in numeracy favourable to male students increases as pupils age; it is small by the age of 10 but grows considerably above the age of 15 (Borgonovi et al., 2021). Therefore, action needs to be considered during the early stages of secondary school to address this imbalance. A report by the OECD in 2015 stated that this imbalance was not related to innate aptitude but instead was linked to lower confidence in female pupils (OECD, 2015). Pupils who are disadvantaged or lower achieving at the start of secondary school also face a widening gap in achievement; this is likely to have been exacerbated by the Covid-19 pandemic. A study in the USA recently predicted that high school students returning to school following pandemic-related closures, have approximately 30 to 57% of the expected mathematics learning gains (Kuhfeld et al., 2020). The lack of class practicals during Covid-19 and the use of home learning means that a large swathe of secondary school pupils have had limited practice drawing graphs in lessons over the last two years (Ofqal, 2022). It has been argued that pupils who

have had limited exposure to graph interpretation and construction will struggle with these skills; meaningful practice is required (Friel et al., 2001).

Research consistently demonstrates that pupils of all ages struggle with understanding graphs. A study of secondary school pupils in the United Arab Emirates suggests that pupils are better at interpreting graphs than constructing them (Tairab & Khalaf Al-Naqbi, 2004). In GCSE science, both of these skills are vital, often intertwined and can be worth valuable marks in the final assessments. I have decided to focus on improving pupils ability at constructing graphs. In order to aid pupils in constructing graphs, some of the principles highlighted by Rosenshine will be of use (Tom Sherrington, 2019). These are related to the idea of guided practice in which the "best way" to construct a graph is broken down, the process of doing so is scaffolded and then the scaffolding is gradually removed over a series of lessons so the pupils can increasingly independently practice. Explicitly teaching the process of drawing a graph and modelling that process has been found to be an invaluable tool for improving college students proficiency (Harsh & Schmitt-Harsh, 2016). This process can also reduce the cognitive load of the pupils by 'chunking' information to make it more manageable (Martin et al., 2021).

Modelling of the thought process required to construct and interpret a graph by the teacher is also a demonstration of metacognitive practice. Metacognition is, in short, getting pupils to reflect on their own learning and different strategies of cognition. Modelling a thought process is an effective way of demonstrating "thinking" skills which a pupil can then use in their own independent practice (Education Endowment Foundation, 2018). In science education, metacognition has often been discussed in terms of aiding pupils with the conceptual understanding of science rather than its application to a specific process such as graph drawing (Zohar & Barzilai, 2013). A small scale study in a science classroom found that pupils who received direct metacognitive instruction scored better on a conceptual physics test and reported higher levels of motivation following the intervention (Zepeda et al., 2015). In contrast, the utility of metacognitive strategies when teaching science has recently been questioned by Adam Boxer, who argues that the definition of metacognition is somewhat confused and so the strategies labelled as such are very broad and often are applied with mixed/limited success (Boxer, 2021).

In conclusion, the ability to draw and interpret graphs is a vital component of studying science. Pupils often lack confidence in mathematical skills and this is likely to have been exacerbated by the limited practice pupils have had recently due to the Covid-19 pandemic. Explicitly teaching the thought process (metacognition) and modelling the mechanisms of drawing graphs combined with repeated practice should, in theory, boost pupils confidence and proficiency in this area.

Methodology

I chose to undertake this project with a low ability Year 8 class which consisted of 20 pupils. This class had had limited exposure to graph drawing so far in their secondary school education and thus I was able to start with the very basics. This class was also selected as they had time available in the curriculum which could be dedicated to this unlike the KS4 classes that I teach. I planned a series of four lessons which were to be done once weekly. These lessons consisted of graph drawing practice with decreasing levels of scaffolding as the weeks progressed. This process is in keeping with some of the principles highlighted by Rosenshine Tom Sherrington, 2019). These are related to the idea of guided practice in which the "best way" to construct a graph is broken down, the process of doing so is scaffolded and then the scaffolding is gradually removed over a series of lessons so the pupils can increasingly independently practice. In order to provide the scaffolding, I created a series of worksheets. At the end of the project graphs were assessed using common AQA exam guidance. It was expected that most pupils will improve their graph drawing ability (which is currently at zero) to the point of being able to competently draw their own graph.

The main risk to this project was related to persistent absenteeism. This class has numerous pupils with low attendance and as the project will stretch over weeks with decreasing scaffolding, a missed lesson could impact results. It was therefore likely that the only pupils included in the final analysis would be those who attended all four of the planned interventions.

If this intervention is a success, it is likely to be rolled out to other classes within the year group and possibly other year groups as well going forward. This means that the activities and worksheets were designed to be as adaptable as possible for use across a variety of topics. If successful, this ultimately could improve outcomes for an entire year group if not more. As graph drawing is a vital skill in science and are often worth numerous marks in exams, any improvements will be valuable both to students but also to the department and school progress. The ideas behind this project have already been disseminated across the department during department meetings. Findings will likewise be disseminated to the department alongside any resources if the project is successful.

Consent for this study was sought from the Head of the department as well as the pupils who were participating. All personal data was stored on a secure network and all school safeguarding protocols were followed.

Findings and conclusions

Originally, a series of four lessons was proposed for this project. However, due to the time constraints this was reduced to three lessons. These three lessons were focused on three separate aspects of graph drawing: numbering consistent scales on axis, plotting data, and finally drawing an appropriate line of best fit.

The class which was selected for this project was a low ability, year 8 class comprising of 18 pupils. Four of the class have SEN needs and 50% are pupil premium. At the start of the first lesson, the

class was asked to attempt to draw a line graph from data provided with limited guidance. I decided to use this strategy as a starter task as the class were adamant that they did not require graph drawing lessons due to their recent maths lessons. The graphs produced were assessed based on ability to label a consistent axis, plot data, and draw a line of best fit. Zero pupils in the class were able to successfully complete any aspect of the success criteria.

The first lesson was based around labelling a consistent scale. Pupils were provided with worksheets on which axis had been pre-drawn and the data which was provided was designed to have a scale which would be easy to plot. A visualiser was used so pupils could see correct scale drawing modelled. By the end of the lesson,

The second lesson was focused on plotting data points accurately and once again pre-drawn axis on a worksheet were used. Pupils were provided with an example axis which had a scale also prelabelled. The data was specifically designed to be easy to plot as it would fall on the lines of the scale. Further graphs in the lesson required the pupils to label a scale themselves (thereby practicing using skills from the first lesson).

In the third and final lesson, drawing an appropriate line of best fit was focussed on. This was once again using specially designed worksheets, a PowerPoint presentation and a visualiser. At the end of the lesson, pupils were presented with data and asked to draw their own graph independently complete with a line of best fit. Of the 13 pupils present, 11 managed to successfully complete this whilst satisfying all the three of the success criteria. The remaining two pupils managed to successfully label an axis but struggled with plotting therefore satisfying one of the success criteria. The two pupils who struggled with this are SEN pupils with complex needs.

Participants in the whole research project saw a marked improvement in their graph drawing ability over the course of three lessons. Although the success of the intervention are difficult to analyse statistically as the sample size is low, it appears that for most participants there was some benefit. Making sure that graphs are at the forefront of future lessons and revisited often will help secure this knowledge and build on these key skills. The worksheets and accompanying PowerPoints are now resources which can be used by myself or others in my department in the future, and adapted for the needs of each class. The research around graph drawing in science suggests that it is a vital skill in aiding pupils to interpret and analyse data; it is important that the work in this project is now further extended with the class to ensure that these vital skills are also practiced.

Although not as bad as anticipated, a weakness of this project was pupil absenteeism. Of the 18 pupils on the register for this class, 13 attended all three lessons meaning that 5 pupils did not experience the full intervention. Therefore, any data from those pupils was discounted. This also means that the sample size for this data was far too low for any form of statistical analysis. An

unexpected difficulty included a shortened second lesson on plotting due to an unanticipated fire drill.

In conclusion, most of the pupils who had this intervention showed improvement in three key aspects of graph drawing. It will be important to now ensure that this is fully embedded through repeated practice in future lessons and that other graph-based techniques including graph interpretation are explored.

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