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Learning by Questions

Supporting maths for biologists

Notre Dame High School

Introduction

Problem: Describe the problem or issue your innovation addresses What challenge(s) do your school(s) have that need to be addressed?

Achievement in science at Notre Dame High School is generally high, and vulnerable pupils make good progress at our school. But pupils find it hard to apply mathematical skills that they have learned elsewhere to biology contexts.

This issue causes further problems later, as many of our pupils go on to study biology at A-level, and are hampered by their maths skills. This is particularly true for the weaker, and more vulnerable pupils, who find it very difficult to catch up at Key Stage 5 (KS5), when the demands have increased significantly across the board.

We should like to support all pupils taking biology at GCSE to improve their maths skills, and we have designed and implemented a structured programme to help do this. This includes:

- a specific maths skill assigned to each KS4 biology topic
- pre-testing of maths skills in biology context
- teaching materials for these skills, which are used across the biology department
- worked examples and practice questions, designed centrally, and used by all biology teachers
- post-testing of maths skills in biology context.

This programme has been implemented across the department for 12 months/ seven topics, and our initial internal evaluation suggests that this approach is promising, with improvements in maths skills and application within context particularly pronounced for weaker pupils.

This is evidently something that is worth continuing, and we feel it would benefit other schools in the Norwich Opportunity Area, where KS4 attainment needs to improve. We would like to

develop the programme and share more widely, as we feel it will be easily transferable to other contexts.

We want to see if we can increase the impact and transferability of the programme by using Learning by Questions for the 'practice question' stage. Learning by Questions would increase the number of questions available, and tailor the feedback, as well as the questions themselves, to individual pupils.

We feel this would be particularly valuable for weaker pupils, who would benefit from the individualised programme. It would reduce the potential for less vocal pupils, or those who need more time to practise a particular skill, to feel pressure to move on more quickly. It would also help to give all pupils an equally high level of help and support, whatever their individual context.

Existing evidence: What existing research evidence exists?

What does the existing research evidence say about this problem and how it could be addressed?

Numeracy is an aspect of learning as opposed to a specific instructional approach or intervention. In 'Is it true that some people just can't do math?', Willingham states that every year some of his pupils tell him "I'm just no good at maths". However he argues persuasively that the vast majority of people are fully capable of learning the mathematics required to master GCSE and A-level equivalent study.

Two important findings from the last 20 years are relevant: (a) humans are born with the ability to appreciate the concept of number; (b) humans seem to be born with a sense that numbers and space are related. There is a strong argument that we need to raise our expectations: pupils are just as capable of learning mathematical skills as they are mastering their native language.

Teachers at our school have focused their efforts to raise numeracy standards on:

- Metacognition: teaching pupils how to plan, monitor and evaluate their use of cognitive approaches. For example, there is often more than one way to solve a calculation, and exploring such choices via teacher modelling, pupil activities and the feedback we provide will lead to better outcomes.
- Cognitive load theory: the brain has limited capacity for conscious processing in working memory. Recognising and planning to allow for this will ensure that we do not overload pupils with extraneous (unnecessary) cognitive load, but that we do increase germane

(desirable) cognitive load so as to maximise learning. There is much research to suggest that the way in which we use worked examples, and the way in which we structure pupil practice, is key to their mastery of numerical problem solving techniques.

Our uniform, centralised departmental approach allows metacognitive skills to be taught directly and in context, which is known to be most effective for improving self-regulation, and is particularly powerful for weaker and more vulnerable pupils. Our structured approach with a full lesson dedicated to worked examples, scaffolding and practice questions ensures cognitive load is considered at all stages.

We feel that the use of Learning by Questions at the practice stage will allow teachers to concentrate more deeply on the metacognitive skills for individuals, because pupils will receive immediate feedback about the questions themselves, freeing up time and space for teachers to support pupils individually to increase their self-regulation and develop personal strategies.

Learning by Questions would increase the number of questions available, and tailor the feedback, as well as the questions themselves, to individual pupils. This will allow teachers to better anticipate the areas that need more attention and explicit teaching of metacognitive skills. It should also increase the transferability of the programme, helping to give all pupils an equally high level of help and support, whatever their individual context.

Innovation: Describe the innovation you will evaluate

Give a brief description of the innovation. What existing research suggests the innovation will help improve the problem you have identified and benefit teachers and learners?

Gocmen (2003) determined that frequent testing was beneficial to pupil learning. The metacognition involved in de-coding mathematical questions has been researched by Basol and Johanson (2009) in the meta analysis of problem solving activities. This innovation will help improve pupils' basic maths skills by repetitive practice and will help the stage process in decoding biology maths problems.

Pre-intervention:

The innovation will take place with Year 10 biologists currently undertaking their GCSEs.

SBD to assign groups for the intervention and control.

We hypothesise that using LbQ will condition the pupils to practise fundamental skills such as percentage change regularly. LbQ will allow pupils to practise problem solving maths skills that

are required to be successful in their biology mock exams. For example, current Year 11 pupils found a question on SA/V Ratio difficult last year. This year, the 10X half will practice SA/V Ratio questions from the Year 8 LbQ and we will analyse the grades to ascertain effectiveness.

The intervention will start in July and the 10X pupils will have four months to improve their problem-solving using the examples in LbQ.

Action pre innovation:

Source questions from the current LbQ set of maths/science question sets where possible, and add in further questions where needed. Design centralised department-wide resources.

Assign groups (intervention and control).

Train biology staff.

During July 2019 we will collect pupil feedback from class 10XTS1 (the lead teacher's class – neither an intervention nor control class) on Learning by Questions to allow scope for improvement as needed. This evaluation will be carried out via a google questionnaire.

All pupils to take mock exams in June 2019

Post – intervention

All pupils to take mock exams in December 2019.

We will therefore be able to compare the progress of intervention and control groups from percentage performance in mock exams in June and December 2019 (questions compiled externally by AQA). Classes will be marked by teachers from the paired group and moderated internally.

We will also use feedback surveys from pupils and teachers to assess usability and transferability and to monitor teacher fidelity to the approaches. Dr N Kaiser to conduct short interviews with teachers involved to evaluate teacher fidelity to the planned approach.

Research question(s) or hypothesis

What effect will the intervention, implemented for how long, with which pupils, have on which outcomes?

What effect will Learning by Questions, when compared with paper-based activities to practise specific maths skills, used for two terms at the practice stage of our 'maths skills for biologists'

programme have on current Year 10 pupils' attainment in their Year 11 mock exams?

Method: Describe exactly how the evaluation will be conducted

Sample

Who will participate in your evaluation? What consent will be gathered for them to participate? Briefly describe the key characteristics of the setting and participants.

The following classes in Year 10 will participate:

- 10XTS1, in order to familiarise the lead teacher with how the system operates
- 10XDS1
- 10XDS2
- 10XDS3
- 10YDS1
- 10YDS2
- 10YDS3.

Each Year 10 class consists of pupils with similarly matched target grades for the X and Y half and is evenly matched in terms of boys and girls.

Each Year 10 set has been analysed to include even numbers of boys and girls and high prior-attaining (HPA), medium prior-attaining (MPA) and low prior-attaining (LPA).

The cohort includes:

- 10D1 – 13 Girls, 10 Boys 14 x HPA, 9 X MPA
- 10D2 – 14 Girls, 10 Boys 10 x HPA, 14 MPA
- 10D3 – 7 Girls, 3 Boys 1 x HPA, 6 x MPA 3 x LPA

Both groups also consist of similar percentages of pupils eligible for pupil premium although as there was only three pupils in receipt of pupil premium funding in each set, this data will not be analysed separately.

No consent will be sought for participation in the innovation and mock exams, as both intervention and control group teaching consist of normal variations within the school environment. Pupils will be aware of the project and the use of the LbQ software. Parents will be informed of the project and, although pupils will still participate in classes, will be given the option

to opt out of having their children's data included in the analysis or, anonymised, shared with the IEE.

Assignment to condition

How will you allocate participants to the intervention and control groups?

Classes were allocated in pairs, in a pragmatic allocation of X to intervention and Y to control, to the following conditions.

- Classes 10XDS1, 10XDS2, and 10XDS3 will use LBQ to practise specific maths skills.
- Classes 10YDS1, 10YDS2 and 10YDS3 will use paper-based activities to practise specific maths skills.

The pairs of classes were set according to achievement as a result of their Year 9 end of year grades.

High prior-attaining (HPA) pair: The target grades for 10XDS1 and 10YDS1 are as evenly matched as possible.

Medium prior-attaining (MPA) pair: The target grades for 10XDS2 and 10YDS2 are evenly matched.

Low prior-attaining (LPA) pair: The target grades for 10XDS3 and 10YDS3 are evenly matched.

Three pupils were taken out of the study from 10XDS1 that had a higher FFT as a HPA than the matched 10YDS1 to ensure that the pupils were matched for HPA/MPA and target grades. One pupil was taken out of the study from 10XDS3 as they were a LPA than the matched 10YDS3. This ensured that each class had an equal number of pupils of each gender with the same attainment and FFT50 target.

In the final report, we will include an analysis of mean score and standard deviations of the whole sample and for pairs of classes.

Innovation

Describe your innovation in detail.

Pupils in both intervention and control classes will carry out the following:

- A specific maths skill assigned to each KS4 Biology topic

cells unit – microscopy

organisation – ratios

immunity – standard form

bioenergetics – graph skills

homeostasis – percentages

inheritance – rounding and significant figures

ecology – tables and data analysis

- Pre-testing of maths skills in biology context.
- Teaching materials for these skills, which are used across the biology department.
- Worked examples and practice questions, designed centrally, and used by all biology teachers.
- Post-testing of maths skills in biology context.

For intervention classes, LBQ will be used throughout the unit to practise specific maths skills. LbQ will be used at least once a fortnight (once every three lessons).

For control classes, paper-based activities will be used to practise specific maths skills. Paper based alternatives will be provided once every three lessons for the 10Y side.

Each unit consists of 17–20 lessons. The project will last for four months.

Outcome measures

What outcome measures will you use? When and how will they be administered and scored?

The pre-test will be an end of Year 10 science mock exam taken in June 2019. The post test will be a Year 11 mock exam taken in December 2019.

Both exams will comprise questions compiled externally by AQA and will be moderated by non-teaching staff. All exams will be marked by teachers from the paired group and moderated internally. Both mock exams will be out of 75 marks, with 20 marks from each exam from biology maths questions. A total percentage score for each mock exam and a percentage score for the biology maths questions in each mock exam will be calculated for each pupil.

Process analysis

What data will you gather for the process analysis?

Teachers will complete a Google questionnaire to evaluate the ease of use and to identify any difficulties prior to commencing the innovation in September. SBD and NKA to carry out drop-ins to ensure fidelity to planned approach. This will be triangulated with staff questionnaires and pupil feedback.

The staff questionnaire will include open questions to determine any amendments to the study.

The pupil questionnaire will enable qualitative and quantitative analysis as we will accredit a score to the questions. For example, how effective do you think the LbQ questions were in helping you with the maths questions? Rate 1 not effective to 5 being very effective.

Analyses

How will you analyse your outcome and process data?

We will calculate mean pre and post-test percentages for the whole intervention group and the whole control group for:

- overall mock exam percentage
- percentage score in the biology maths questions.

We will also calculate effect sizes to compare the progress made by pupils in the intervention group and the control group in:

- overall mock exam percentage score between the pre- and post-test
- percentage score in biology maths questions between the pre- and post-test.

The following subgroups will also be analysed for progress in the same measures (change in overall mock exam percentage and percentage score in biology maths questions between the pre- and post-test):

- Boys
- Girls
- Class 10XDS1 compared with class 10YDS1

- Class 10XDS2 compared with class 10YDS2
- Class 10XDS3 compared with class 10YDS3.

Conclusion

Potential limitations

What are the potential limitations of your design?

The potential limitations of the design is that each biology maths question is unique and involves a multi-step process to decode. LbQ will help with the maths questions such as radius of a circle to determine antibiotic effectiveness, but some biology maths questions are not specifically tested as they appear.

This innovation will take place over four months. Pupils will have maths-related questions in the mock that are from previous units that are not tested as part of the project. This will potentially underestimate the impact of the intervention on achievement in maths-for-biology.

Implications

What would you do if your results were positive? What about if results are negative or neutral?

If the results are positive, the biology department will look at the prospect of embedding LbQ as practice throughout the GCSE, including Year 9 cells.

Although a short trial, the biology department is committed to carrying out a disciplined enquiry to improve maths skills and this will continue with a two-year cohort on a larger scale.

If the results are negative, review of the testing will be carried out and modification of the pre- and post-tests will be trialled.

If the results are neutral, further analysis is needed. Is any maths teaching in biology improving pupil scores? What is the best method to improve pupil scores? How effective is the feedback of the maths activities?

References

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