**A game to re-engage GCSE students to mathematics.**

Hannah Louise Fessey, *University of Central Lancashire,*

Davide Penazzi, *University of Central Lancashire.*

Abstract

We present an activity for top tier GCSE mathematics students in which we challenge the perception of the subject, with the aim of increasing the number of students taking A-level mathematics. We investigate the causes of the disaffection with mathematics during GCSE, then present the activity called “Little Z” and argue that it can provide opportunities for reflection on the causes of disaffection and possible solutions. We then introduce the method used to evaluate the activity and finally present the outcomes of this activity.

1. An activity for the disaffected top students.

In the UK, there is a well-known problem of students not choosing to study A-level mathematics, even among the more able students. The 2017 Government report (Dep. Education 2017) highlights how, although 87% of the A\* grade achievers in mathematics CGSE continued their studies with A-level mathematics; this number drops to 61% for achievers of an A grade and 21% for achievers of a B grade. There is also a large dropout rate: the A-level completion by the age of 17 is only 38% for students who obtained an A grade at GCSE and 5% for those obtaining a B grade. This shows a disengagement with mathematics even among the most able GCSE students.

Among the most able mathematics students, the creeping dislike for the subject is often not easily noticed: there is no disruption or absenteeism, but it takes the form of a quiet disaffection. Nardi and Steward (2003) study the origin of this disaffection, identifying it stemming from the repetitive nature of the tasks, the way that rote learning is taught, the lack of clarity about how the mathematical concepts are used in adult life, and the isolating nature of the subject, which in the school context, is mostly individual. Brown, Brown and Bibby (2008) interviewed students on the reason for not taking A-level mathematics in UK. Their findings are similar to those of Nardi and Steward but they identify the lack of self-confidence, particularly among girls, as the main cause. Girls, in fact, are more often placed in intermediate tier sets in a “desire to be protective of [them], since there is evidence that some wish to avoid the masculine atmosphere of competition that tends to exist in these sets”.

We present an activity which we have delivered to the most able year 10 students. The aim is to change the common perception among students that mathematics is ‘boring’ and ‘insignificant’, and at the same time, boost the confidence in the students’ capabilities to tackle this subject.

1.1. Little Z.

The activity is a team game called “Little Z”. The aim is to find the number value of Z, using a system of equations with, the letters A to Z as variables, which are provided at the beginning of the game. To find the numerical value of each letter between A and R, the students must complete a series of challenges. To find the numerical values of the letters S-Z the students need to solve systems of equations. These challenges range from mathematical riddles and logic puzzles to physical activities.

Each team is given an initial budget of £250 and in order to submit an answer or attempt an activity, teams must pay £50. Rewards of varying monetary value are given for correct submissions. This ensures that students are confident in their answers before submitting them for consideration.

Examples of the activities include a game called “stepping stones” in which the whole team must travel across a ‘river’ (a space cordoned off between 2 pieces of rope on the floor) using only ‘stepping stones’. No stone can be left in the river without someone standing on it. If this were to happen, the stepping stone would ‘float away’ and be lost. The game builds the communication skills between the team which can be used in subsequent activities. An example of a mathematical riddle is “cows and chickens”: the students are told the total number of cows and chickens which a farmer owns along with the total number of legs of the animals; their task is to calculate how many cows and chickens were in the farm. This task masks a simple simultaneous equations problem, which once recognized as such, requires some mathematics that has been taught in class.

The teams are given 2.5 hours to complete the task and the team who correctly calculates the value of Z in the quickest time or, if no teams had the exact value, the team who had the closest value to Z, wins.

1.2. Reviewing before, during and post-action.

We designed a session reviewing the activity. We used an “introduction-action-reflection model”, or “metaphorical model” (Bacon 1987), which gives a brief introduction to the activity before starting “Little Z”, such as “Today we are doing a game, which, although it will not look like mathematics, it is mathematics”. The idea is to make the students aware that the activity is a metaphor for their mathematics studies, which can give a deeper context to the students’ reflections during the activity.

The introduction is purposefully limited as Bacon (1987) suggests that “Within the context of [helping a higher percentage of students achieve experiential metaphors], the smaller the introduction, the less defined the introduction, the better”. We want to avoid students’ overthinking the connection between the activity and school mathematics and losing the benefit of the activity It should be noted that Bacon (1987) describes the changes in participants’ perceptions when delivering the “Outward Bound” course – which is a wilderness course lasting several days. This is different from the half-day activity we present, but we believe that “Little Z” is an activity meant to challenge the students and provide them the chance to have a “peak” experience, which pushes the boundaries of what they are confident working with. In that view “Little Z” is structured in a similar way to the “Outward Bound” course.

At the end of “Little Z”, a brief review session occurs with each group of students. The method used in the review session is the “four F’s” of Greenaway (2015):

* FACTS. What happened during the activity? When students are asked to describe the experience, they will describe their perception at the end of the activity. This is not going to be the same for all students participating and it is necessary to let them express and compare their perceptions.
* FEELINGS. This is a reflection on the activity itself, and focused on the emotions and feelings around it. This allows students to relate with each other and also leads naturally to observe patterns and similarities between experiences during the activity other life events (in our case mathematics schoolwork).
* FINDINGS. This stage allows the students to reflect on what they can learn from the experience
* FUTURES. This stage allows the students to discuss how they can apply what they have learnt to other activities.

Greenaway (2015, p. 25) warns that following this cycle as a guide can tend to create a boring set of questions, so he advises including a wildcard question when needed if necessary.

After the first event, we realized that this was a good closing session, but most of the reviewing happened during “Little Z”. Due to the nature of “Little Z” and its small activities, there was plenty of opportunity for the facilitators to have small reflective sessions during “Little Z”.

Hovelynck (2000) observes that the intervention of the facilitator during an activity (“reflection-in-action”) can bring more benefits than simply a final review “after-action”. Not only can they intervene at the right time to save the activity itself, for example if students get demoralized and decide to not participate after a few failed tasks, but they can help students distinguish between “theory-in-use” and “espoused theory” An example is when students have found a solution to a task but have not submitted an answer. The common belief is that the students are not good enough at mathematics to have obtained a correct answer. But in reality this is due to the cultural assumptions of doing mathematics, as Lampert (1990) describes, “the school experience, in which doing mathematics means remembering and applying the correct rule when the teacher asks a question; and mathematical truth is determined when the answer is ratified by the teacher”. This tendency is manifested more acutely in tasks where the mathematical nature of the problem was more visible. In the Little Z game, the fact that the students have to pay to submit an answer demonstrated the students’ lack of confidence.

Another example of in-action intervention is during the organization and choice of tasks for Little Z. If a group seemed lost, the facilitators can direct the students to attempt the tasks in an efficient way, e.g. doing the tasks in parallel.

Reflection-in-action best simulates the timings of useful interventions in mathematics schoolwork. It is when students are attempting exercises that any issues needs to be identified and guidance given so that students can progress.

2. Outcomes.

At the end of the activity, students were given a questionnaire with six questions. The first three questions asked for an evaluation from 1 (not at all) to 5 (very much). The questions were:

* ‘Do you like mathematics?’
* ‘Did you enjoy the activity’
* ‘Did you feel challenged by the activity?’

The vast majority of students said that they enjoyed the activity (101 out of 113 students answered with a 4 or a 5) and they were challenged by it (100 out of 113 answered with a 4 or a 5).

Even among the high achievers, not all the students were passionate about mathematics: the average score for the question ‘Do you like mathematics?’ was 3.65; but when then asked ‘did you find this activity enjoyable?’ the average score was 4.45. This shows that even the students who are starting to disengage themselves with mathematics enjoyed the activity. We believe this is because the activity is designed to make students engage with mathematics but in a way where the problems causing a negative perception of learning mathematics are avoided. On the review session students who do not usually like mathematics were asked to identify why they liked this activity compared to mathematics at school. This started the discourse on the perception of the subject.

The other questions were open. Two were for internal evaluation of the activity:

* ‘Which task did you like the most?’
* ‘Which task did you like least?’

The final question ‘What will you take back to the classroom?’ is more insightful on whether we successfully challenged the perception of mathematics. The most popular response was that they could help each other and work as a team when tackling mathematical problems (60 out of 113). During the review session one student realized that ‘when I am stuck in my homework I can ask my friends and try to work it out together’. Many of them only considered learning mathematics as an individual activity, but they realized that it can be more interesting and helpful to cooperate when possible. The students also said that their problem solving skills had improved and that they will remember to read the questions carefully. One student stated ‘when I sit my exams, I will read the question twice before trying the question’. With regards to their studies, some students have reconsidered the perception of mathematics being ‘useless’ in the real world. One activity involved using basic trigonometry to find a distance, and one team of students recalled ‘we will remember it now that we have seen it being used’.

We plan to use this activity in schools, to make students reflect on their preconceived view of mathematics and encourage a positive approach to their future mathematical studies.

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