Investigating the use of Peer Assessment in Degree-level Mathematics

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Abstract

This paper describes the author's experience when trialling the use of formative peer assessment in a higher education mathematics class. The aim was to move from a cognitivist towards a constructivist style of teaching, and also to embed formative assessment techniques into class activities. Current literature suggests that peer assessment can be an effective tool in maths teaching at all levels from primary to higher education. It can deepen understanding of the subject but also strengthen skills in reasoning, analysis and communication. It was found that the student group engaged well with the peer assessment tasks and they found it useful as a formative activity. To be fully effective however, further training would be required for the students in giving effective feedback, and it would need to become a regular, integral activity within the course.

Key Words: formative peer assessment, constructivist teaching, higher education mathematics.

Introduction

This report discusses a trial of peer assessment which I recently implemented in one of my degree-level mathematics classes. I will firstly describe the methods used, and explain why I chose to try this technique with this particular class. A literature review then summarises the various academic theories and recommendations which influenced my planning and reasons for selecting this innovation. The processes used for creating and delivering the peer assessment will then be discussed, along with the methods of evaluation. Finally I will reflect on what I have learned from this task, and how it could be incorporated into my future teaching practice.

The technique I was testing was the use of formative peer assessment in teaching mathematics. The trial was conducted in the differential calculus outcome of a maths module for the first year of a graduate apprenticeship civil engineering degree. For the first task, the 13 students in the class undertook a piece of challenging homework, and then were given a marking scheme and asked to mark each other's work in pairs. The students then discussed their marking and gave each other written and verbal feedback. The second homework task required the students

to create their own set of questions on the topic, along with a marking scheme. In class they were paired up, and attempted to answer the questions their partner had written. They then marked each others work and again provided feedback.

There were three particular reasons why this technique was selected for this class. The first was that in the previous three times I have delivered this module, this learning outcome has consistently had the worst results. I wanted to try to improve this by employing more active learning strategies, moving from a mainly cognitive teaching approach towards a more constructivist style. Secondly the students in this class had a very wide range of ability in maths; therefore one aim was to increase the level of support given by stronger students to the others. Thirdly I had observed there seemed to be quite poor class dynamics, with some very close-knit small groups and other isolated students, so I wanted to get them working together in different groups, in order to strengthen their peer support network. From my research, peer assessment appeared to be a potentially effective tool to achieve all three of these goals.

Literature Review

There are two particular ideas which underpin my approach, and the evidence and current thinking on these will be examined in more detail in this section. The first of these is the shift from a cognitivist towards a constructivist teaching style, and the second is the concept of formative assessment as a central principle of teaching. I will demonstrate how these two ideas led me to investigate and test out the use of peer assessment in maths.

As noted above, in this course the teaching predominantly followed a cognitive teaching style. For maths as a subject I consider that this is a justifiable approach. Cognitivism focuses on the way the mind stores and processes information, and requires students to connect what they are being taught with their existing knowledge (Gregson and Hilier 2015). The "spiral curriculum" is a recognised cognitive teaching model as defined by Bruner, where concepts are visited repeatedly, but each time looking at them in a more complex way (Bruner 2006 cited in Avis 2015). This spiral can be applied directly to the way maths knowledge usually grows over several years of learning. This is demonstrated through the SQA maths courses, for example, which often require students to demonstrate a deeper understanding of the same subject areas (geometry, algebra etc) at subsequent SCQF levels (SQA 2019).

However, there are drawbacks to focussing too much on this style of teaching. It has been noted that in cognitivism the teacher is seen as the transmitter of knowledge (Wells 2015), with the student being purely an interceptor. There is an emphasis on the student as an "individual, isolated learner" (Gregson and Hilier 2015, p44), so the support and knowledge of other students in the group is not utilised. I therefore

wanted to try employing a more constructivist approach, which encourages group activities, collaboration and interdependence between teacher and students (Gregson & Hilier 2015). When moving from cognitivism towards constructivism, learning becomes more active: "the focus of instruction shifts from teaching to learning, from the passive transfer of facts and routines to the active application of ideas to problems." (Ertmer and Newby 1993). One of the earliest concepts of constructivism was Vygotsky's well-known "zone of proximal development", that is the nascent areas of development which can flourish with the help of teachers and more experienced peers. Vygotsky claims that "an essential feature of learning is that it creates the zone of proximal development; that is, learning awakens a variety of internal development processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers" (Vygotsky 2015). Peer activities are therefore seen a critical element in effective learning. Two of the key principles of constructivism are *generative learning strategies*, whereby the students create a product to demonstrate their knowledge, and *co-operative support* between peers (Bostock 1998). I consider that peer assessment tasks can be aligned to both of these principles as discussed below.

The tasks I designed were for formative, rather than summative assessment. Formative assessment, sometimes referred to as assessment for learning, has become a very popular and well-publicised technique in recent years. Black and Wiliam (2010) claim that formative assessment is "at the heart of effective teaching". In their report, formative assessment is described as the regular use of questioning and low-stakes testing to gather evidence on the students understanding, and to modify teaching accordingly. Ecclestone et al (2010 p50) emphasise the connection between active learning and formative assessment, stating that "activities and processes should engage students actively in becoming motivated and independent in achieving the purposes of formative assessment". According to Gardener (2009), peer- and self-assessment are key strategies in formative assessment, because they generate motivation, encourage deeper understanding and provide opportunities for collaboration and cooperation.

It must be noted though that there has been some criticism of the widespread adoption of formative assessment in schools. Bennett (2011), suggests that the concept is not sufficiently well-defined and its effectiveness is not fully proven. He also comments that the most challenging problem with formative assessment is that it loses value when carried out in isolation; it needs to work in conjunction with summative assessment in an aligned approach. This echoes the principles described by Biggs and Tang (2011) who discuss how teaching, learning and assessment activities must all be clearly linked to the skills that students require to achieve the intended learning outcomes, therefore improving the "constructive alignment" of the course, in order for a much greater diversity of students to succeed.

As discussed previously, learning maths is very often seen as a solitary activity, with the students developing their own understanding supported by the teacher. This is especially the case in higher education, where traditional lecture-style teaching can result in isolation, passivity, and gaining only a surface knowledge of the subject (Rosenthal 1995). However, the benefits of peer discussion and peer assessment in maths have been demonstrated at all levels from primary to higher education (Cobb et all 1991, Tanner & Jones 1994, Reinholz 2016) and for students with additional support needs (Calhoon and Fuchs 2003). Reinholz describes a peer assessment learning cycle for university students of "task engagement, peer analysis, feedback provision, feedback reception, peer conferencing and revision". This cycle provides opportunities to develop skills such as verbal reasoning, and critical analysis, which all help to deepen the students' understanding of the concepts. It should be noted that his research found that specific training was required to enable students to provide effective feedback and hold meaningful peer conferencing sessions.

Taking part in peer assessment is also known to help students to develop their self-assessment skills, which is "an essential component of formative assessment" (Black and Wiliam 2010). By discussing solutions to maths problems with their peers, students have to justify their decisions and assumptions, and therefore increase their ability to self-assess and to apply the objectivity which is essential in problem solving and real-life applications of maths (Tanner and Jones 1994).

The National Centre for Excellence in the Teaching of Mathematics provides guidance on the application of the Assessment for Learning strategies in maths classes. They stress the importance of understanding the success criteria before attempting to assess a piece of work. The NCETM guidance states that success criteria are critical because they "help to illustrate what success looks like and so provide a framework through which learners can find intrinsic reward and reinforcement" (NCETM 2012).

Race (2001) corroborates this, noting that getting the students to help generate the success criteria provides ownership, increases objectivity and significantly helps to improve their own understanding of the outcomes. Ashenafi's (2017) extensive review of research into peer assessment in higher education also supports this view. His review notes that when the assessment criteria are defined by the students, there is much closer correlation between student and teacher marks. To help the students to know what success looks like and create meaningful assessment criteria, the Assessment Standards Knowledge Exchange recommend that the class should first examine and discuss previous examples of assignments (ASKE 2016), which was a technique I used.

There is little mention in the literature of students creating their own questions as part of a peer assessment task. However as noted above, generative activity is one of the key principles of constructivism. Wells (2015), a supporter of social

constructivism, says that students should be "encouraged to show initiative and creativity in formulating questions and problems and in attempting to solve them in collaboration with their peers and teachers." Students writing their own questions for others to attempt is also recommended by NCETM (2012) to encourage deeper learning. I therefore decided to include it as an extension task.

Development and Evaluation

When developing my trial, I followed recommendations from my literature review, and also discussed my ideas with colleagues in the maths team, who suggested that getting the class to try writing some questions themselves could be a good way to provide differentiation and stretch the more able students. I concluded that I should run the innovation over 3 consecutive class sessions, to give the students time to become familiar with the processes and techniques required.

In delivering the peer assessment tasks, it was important to provide an overview and some level of guidance in the new skills required (ASKE 2016, Reinholtz 2016). So, in the first session we started by discussing the concept and benefits of peer assessment. The class then reviewed sample questions and answers, and compared these to a marking scheme. Finally the group together, with guidance from me, created a list of success criteria which they would look for in each other's work (and hopefully would influence their own work). In the second and third sessions where marking and feedback took place, I paired up stronger and weaker students, but also mixing the social groups within the class.

My three criteria for evaluating the successfulness of the technique were observed student engagement in the classroom, feedback from the students and finally an improvement in exam marks. My observation in class was that the first task went well, with all students engaged fully in the task and the feedback discussion with each other. I felt that the second task was not quite as effective as the first. The students struggled to write new questions, some of them had not prepared or checked their answers, and there was a wide variety of complexity in the questions.

Verbal feedback to me and other lecturers about the task was very positive. The students said it had helped them to understand the marking schemes much better and they enjoyed the fact that it was different from a typical maths class. I also collected written feedback in the form of a questionnaire (Appendix 1). 84% of the students said that it helped them with their maths skills and they all said it improved their understanding of how to succeed in the exam. Some criticisms were that they would prefer more evenly matched pairings, and more time to work on the questions. At the time of writing the student have yet to sit their exam, so the longer term effects on their maths work are not known.

Discussion and Conclusion

In this final section I will reflect on the effectiveness of my innovation and consider how peer assessment could be implemented into my future teaching. I consider that on the whole the peer assessment tasks were successful. The students benefited in a number of ways, as demonstrated by my observations and their feedback. The class reported that the most useful aspect was a better understanding of how marking schemes work. It is interesting to note that all of the female students reported that they really enjoyed taking part in the peer assessment and found it useful, compared to 70% of the male students. This contrasts with research cited by Ashenafi (2017) where the majority of the female students taking part in a peer assessment task found it stressful. It must be acknowledged that the sample size in my class was very small, and the type of task being assessed was different.

Some of the potential effects are harder to measure, such as closer links with their classmates and a more objective approach when tackling maths problems. These intangible outcomes are still valuable as they are providing transferrable skills which will help the class in their future learning.

There are certainly some aspects of the process which I would like to improve on. Although the students did discuss their marking and assessment views with each other in detail, their written feedback to each other was mainly numerical, without many suggestions of how to improve in future. I had given them prompt questions to help with written feedback but these were not used by everyone. They struggled with marking when there were some mistakes early on in the working. They also had only two opportunities to carry out peer assessment which was not enough to really develop their skills. Also, as mentioned above, the second task (writing their own questions) was not as well-executed as the first.

I would address these issues in a number of ways. To maximise the effectiveness of peer assessment, students need to be trained in how to provide useful feedback and how to undertake "peer conferencing" (Reinholz 2016). Also, peer assessment should be a regular part of the teaching programme rather than a one-off activity. This would allow the students to build up their competence over time. Finding space in the timetable is always an issue, so the feedback training could be made broad enough to apply to other modules in the course, (and delivered during general tutorial time) or else the module could be restructured so that peer assessment replaces another instrument of assessment, and hence more time would be available for it.

Following the recommendations of ASKE (2016) I did start by showing the students sample solutions to some maths questions, but it would have been better to also provide genuine student examples with some errors in them to demonstrate the "follow-through" aspects of marking more clearly. Finally, creating maths questions is challenging, so it was not surprising that at the first attempt the results

were mediocre. Again, to make this work better the students would need more practice and perhaps more detail in the task description.

To embed peer assessment more fully into my teaching practice, it would need to be adapted for different student groups. For example, to use it with a National 5 Maths class, much more structure would be required. I would start off using shorter questions, provide more guidance on how to do the marking, and create some detailed feedback prompt questions to help the class with generating useful comments for each other. The class would definitely need time and opportunities to practise this in order to develop their objectivity, so I would repeat the activity several times over the academic year, and most of the work would be done in class rather than as homework.

Peer assessment is just one technique which can be used to encourage constructivist learning. As a stand-alone activity it can be effective, as I have discovered, but to really embrace constructivism there would need to be changes to the instruments of summative assessment for the course, not just the teaching activities, in order to provide constructive alignment. Researchers have found that in higher education "the assessment procedures have a profound effect on the way in which students learn. Providing a constructivist teaching environment will have little effect on the quality of learning while conventional assessment procedures remain in place." (Entwhisle 1993 cited in Bostock 1998). Entwhistle goes on to suggest that peer- and self-assessment should form part of the summative assessment for a course.

Whilst I found that the students engaged well with peer assessment and found it useful as a formative activity, I would be cautious about using it for summative assessment. Ashenafi (2017) noted that work should be assessed by several peers, and compared with assessment grades given by the teaching staff. Factors such as anonymity would need to be considered. However, Ashenafi also notes that summative peer assessment has been particularly successfully in maths-based subjects, because of the small range of success criteria compared to other disciplines.

In conclusion, then, I have found peer assessment to be a very useful teaching technique, which can help students to move away from traditional solitary learning in maths towards collaboration and interdependence within the classroom. Peer assessment used formatively helps the students to understand how to answer questions, because they are more familiar with the success criteria, and it encourages them to think more objectively about their own and each other's work. To be fully effective however, it would need to be a regular, integral activity within the course. I will definitely continue to experiment with this technique in my future teaching, and also consider how to draw more constructivist methods into my practice, in order to promote deeper and more meaningful learning.

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Appendices

Appendix 1: Results of Student Questionnaire

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Rating questions (1 = Never, 5 = Always)	Male students										Female students			Mean
I found the peer assessment task interesting/ enjoyable	4	4	5	4	5	4	4	5	4	3	5	5	5	4.4
The peer assessment tasks increased my understanding of differentiation	3	4	2	4	4	5	3	5	3	2	4	5	4	3.7
The peer assessment tasks improved my understanding of how to succeed in the exam	4	3	3	4	4	4	3	5	4	4	5	5	4	4.0

Open text "What did you learn from doing the peer assessment tasks?"
How the marking scheme works between each stage of working out
Both people I was paired with did not complete tasks but I learned where I make mistakes
How marks were given in the assessment allows me to understand how marks will be given in the exam
Its hard to allocate marks
How to come up with equations, what I need to do to gain marks
Easier to understand when creating your own questions as you need to understand
How marks are awarded
Different approaches to the same problem
Better understood the marking process
How to lay out questions better
Interesting and enjoyable. Learned where marks come from.
How to gain marks if I get stuck.