Peer-learning activity for communicating algorithms in a level 2 computer science module

eSTEeM Final Report

Ravi Rajani, Jason Clarke, Phil Hackett, Stephen Rice
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Executive Summary

Peer learning is widely believed to address essential transferable skills such as teamworking, communication, and critical enquiry, that are not easily pursued by other means (Topping, 1998; Boud, Cohen and Sampson, 1999). The level 2 Open University (OU) computing module *M269 Algorithms, Data Structures and Computability* has the following "key skill" listed as one of its learning outcomes:

> Explain how an algorithm or data structure works, in order to communicate with relevant stakeholders (Open University, 2023).

This professional skill is well suited for development in a peer-learning context.

Although many computing and other STEM modules at the OU have now incorporated a peer-learning activity in their assessment schedules, this is not the case with M269. The goal of this project is to fill this gap. To this end, we develop a collaborative algorithm activity that follows the structure of a successful peer activity that forms part of each Tutor-Marked Assignment (TMA) of the level 3 module *TM354 Software Engineering*.

A trial of the activity was run with eight student volunteers from the M269 cohort over the course of three weeks after which a survey was conducted to gauge student perceptions. Some of the free text survey responses were followed up with email questions to delve further into the answers given. Three members of the project team – who are all tutors at the OU – analysed the student outputs and survey responses and then met to discuss their perceptions of the activity.

The quality of the peer feedback was very high with all participants making good contributions and most improving their algorithms based on comments received. The survey responses were largely positive indicating that students enjoyed the experience and found it valuable. Some minor suggestions for improvements to the activity were made by students as well as tutors.

It should be noted that, despite the small number of participants, our sample had a comparable demographic distribution to the full M269 cohort, although inevitably some groups were not represented. Also, no statistical analysis (such as testing for an effect in TMA scores) was conducted since no significant inferences would be possible with such a small sample. However, the activity's design is based on a tried and trusted template that is successfully employed in multiple other modules at the OU (Thomas *et al.*, 2018). Therefore, we do not see any reason why it would not generalise well to the whole M269 student population and can recommend that the activity is adopted in future M269 assessments. A set of guidelines for implementing the activity are included in this report.

Aims and scope of the project

The specific goals of our project are to:

- design a peer-learning algorithm activity for students of M269;
- collect and interpret data from a trial of the activity and a survey of participants;
- if the activity is deemed a success, produce a set of guidelines for implementing it in M269 assessments.

The reason we wish to pursue these goals is to realise the following broad objectives.

Create an increased sense of community

A distance-learning model such as that adopted by the OU presents unique challenges in creating communities of learners compared to traditional brick-and-mortar universities. Studies have shown that a sense of community can increase student satisfaction and achievement (Moore, 2014), reduce isolation (Croft, Dalton and Grant, 2010), and improve rates of progression and completion (Lake, 1999). It is therefore important for distance-learning institutions to include provision for student interaction and community building as part of the learning design. Our peer activity addresses this need.

Provide training in key transferable skills

By giving and responding to peer feedback, students are learning important professional skills in social interaction, collaboration, self-reflection, and learning-to-learn (Boud, Cohen and Sampson, 1999; Altınay, 2017; Loureiro and Gomes, 2023). Furthermore, by functioning both as assessor and assessee, students are believed to gain cognitive and meta-cognitive benefits that can accrue before, during, and after a peer activity – so-called “sleeper effects” (Topping, 2009).

Enhance students’ learning

By communicating their ideas to others, students are deepening their understanding of complex topics (Liu and Carless, 2006). Therefore, in addition to the holistic benefits referred to above, peer feedback can enhance learning of the subject matter. This view is supported by quantitative studies that attribute improved academic achievement to peer activities (Topping, 1998; Pereira *et al.*, 2022). Topping (2009) offers another reason for this effect: Since students outnumber instructors by some margin, peer feedback can be more immediate and individualised than teacher feedback, thus boosting students’ learning.

Reduce marking load of tutors

An early pragmatic motivation of peer assessment was to reduce the load on teaching staff whilst maintaining the level of student learning (Boud, Cohen and Sampson, 1999). However, Topping (2009) argues that staff must provide training to ensure students are well-prepared to give good quality constructive feedback. He also recommends that teachers monitor and coach the peer activity as well as provide feedback on students’ performance. As such, it is not always clear that savings in teachers’ time will be realised. Nevertheless, as we will explain, the findings from our study, together with our guidelines for assessing the algorithm activity, mean that Topping’s concerns are not warranted in our case.

Activities

Eight volunteers from the October 2023 cohort of M269 were recruited to participate in a trial of a new peer-learning algorithm activity. The trial was run over the course of three weeks starting in mid January 2024, falling in the period between the first two TMAs. Log data of students' "click" activity was collected during the trial to provide insight into the pattern of participation over time.

In the week following the trial, a survey of participants was conducted by means of an online questionnaire to gain insight into the strength of satisfaction with the activity. On receipt of the responses, consenting students were sent emails to follow up on some of their free-text answers.

Following a request by one of the students, the participants were sent a document containing a summary of the approaches taken during the activity along with some model algorithms.

Finally, the student activity outputs and feedback were discussed in a reflective meeting with three tutors from the project team. In this meeting, a set of guidelines for adopting the activity in M269 were formulated.

Participant recruitment

An invitation to participate in the trial was sent by email to 525 eligible[1] students from the M269 cohort of 1157 students. In addition, an invitation message was posted in a module-wide forum which was seen by approximately 70 students. Is it not known how many of these would also have received the email, but if we assume 50%, we get a rough estimate of 560 students who were invited to participate. Of these, 22 signed up to the activity by following a link to an online consent form from the invitation message. This represents a 3.9% initial recruitment rate.

Of the 22 students who signed-up, only 10 ended up participating in the activity and two of them dropped out after the first week. One of the students who dropped out cited a lack of time; the other did not give a reason. So just 8 students completed the activity and final questionnaire, corresponding to 1.4% of the 560 initially invited to participate.

Activity instructions

Participants were sent the following three documents by email at the start of the activity:

- The algorithm problem and associated peer-learning tasks.

[1] according to the OU's rules on how frequently students are allowed to be contacted for surveys and studies.

- A worked example containing model algorithms as well as comments.
- Instructions for the OU's in-house peer-learning platform *OpenStudio*.

The algorithm problem

Participants were asked to design an algorithm to compute an ordered list of intersections of overlapping intervals filtered by the maximum number of overlaps. The problem was described in terms of the schedule of a delivery company so that the task had the air of a real-world scenario that might be encountered in a workplace. One attractive feature of the chosen problem is that two distinct algorithmic approaches of different complexities naturally present themselves, creating the potential for interesting debates among students.

The peer-learning tasks

The participants were given three asynchronous tasks, each with a duration of one week:

1. Design an algorithm to solve the problem, write it in English, and post it to OpenStudio.
2. Comment on algorithms by two other students, choosing those with the least number of existing comments.
3. Revise your algorithm based on feedback received, post it to OpenStudio, and add a comment explaining the changes (or justify why none were made).

This structure reflects a peer-learning activity from TM354 and aligns with Thomas *et al.*'s (2016) learning model of showing & sharing, viewing & reviewing, commenting & critiquing, and receiving & reflecting. The final step of producing an artefact after critically evaluating feedback is considered particularly important for learning (van der Pol *et al.*, 2008; Liu and Lee, 2013) and for students to achieve "closure" (Hilliard *et al.*, 2019).

Following recommendations by Topping (2009), Sadler (2010), and Thomas *et al.* (2018), the following items were included in the instructions:

- A deadline was specified for each of the tasks and the importance of timeliness so as not to hold up other people's progress was emphasised.
- Guidelines and scaffolding were provided for giving feedback.

The worked example

Numerous papers on peer learning and assessment recommend that students are given worked examples of how to give and evaluate feedback (Sadler, 2010; Thomas *et al.*, 2018; McConlogue, 2020; Kerman *et al.*, 2024). We provided participants with a document containing an example algorithm problem at a similar level to the activity's problem, a model first draft of a solution, two model comments, and a final revision together with an explanation of the changes made. This demonstrated the type, depth, and length of algorithms and comments that were expected from students.

The OpenStudio instructions

OpenStudio was first developed as an environment for students of a Digital Photography module to share feedback on their work. It has since been adopted by numerous OU modules across the STEM disciplines and has been shown to have more than 95% satisfaction among users (Lotz, Jones and Holden, 2019). One aspect of OpenStudio which sets it apart from a standard Moodle forum is its *Share To View* feature which means students cannot see others' posts until they have shared theirs. This ensures that students' initial posts are their own work. However, as experienced on TM354, this feature can sometimes lead to confusion, with students wondering why they can't see any posts. Therefore, we were careful to emphasise the Share To View feature in our instructions on how to access and use the basic posting, sharing, and commenting functionality of OpenStudio.

OpenStudio log data

Timestamped clicks were logged for each participant throughout the activity. Although each log line contained an event type corresponding to e.g. sharing, commenting, etc., we were only interested in the spread of general activity: Did participants interact all throughout the week or mainly in bursts just before each end-of-week deadline? This information would help us determine whether students planned their interactions according to the provided deadlines and give us some indication of their usefulness for time management.

Survey and email discussions

In order to help us evaluate the suitability of our algorithm activity for inclusion in M269 assessments, we designed a questionnaire around the following research questions:

- Did students enjoy the activity?
- Do students feel they learned something from the activity?
- Do students feel the activity will lead to better outcomes in terms of grades/completion/employment?
- Which aspects of the activity could be improved?

Most questions were of the multiple-choice/Likert kind, but there were two free-text questions at the end:

- If you feel the activity could be improved, please tell us how.
- If you have any other feedback on the activity, we would love to hear it.

A link to an online version of the questionnaire was sent out in the week following the activity and all eight participants responded. Five of the eight agreed to subsequent email contact to discuss their answers to the free-text questions. These follow-up discussions consisted of one or two email exchanges.

Summary of methods

A student emailed us to ask if we would provide some model solutions. We discerned two algorithmic approaches taken by participants and summarised them in a document, comparing their complexities, and providing a model solution for each.

Tutor reflective meeting

A meeting was held with three associate lecturers from the project team approximately one month after the email discussions were completed. The purpose of the meeting was to

- discuss the quality of students' algorithms and comments;
- analyse and interpret students' log data, questionnaire and email responses;
- form a view as to whether the activity was successful, how it could be improved, and whether to recommend it for inclusion in M269 assessments;

formulate a set of guidelines on how to implement the activity in practice, taking account of the improvements that were suggested by students and tutors alike.

Findings

Briefly, we can summarise our findings thus:

- Students' responses to the questionnaire were on the whole positive.
- The free-text responses and subsequent email conversations provided useful additional insights and suggestions for enhancements and improvements to the activity.
- The tutor reflective meeting concluded with a recommendation to adopt the activity in M269 assessments as well as a set of guidelines for its implementation.

Questionnaire responses to multiple-choice questions

The algorithm problem

Students reported that:

- The problem was clear and presented a good level of challenge (neither too easy nor too difficult).
- They enjoyed designing an algorithm for the problem and writing it in English.
- The majority felt more confident in describing algorithms as a result of completing the activity. Importantly, nobody felt less confident.

The peer-learning component

Students felt that:

- The different peer-learning tasks were explained clearly.
- The worked example was useful and they understood the type and depth of comments that were expected.
- The majority found OpenStudio easy to use, with a couple finding it neither easy nor difficult.
- The majority enjoyed collaborating with their peers, with a couple feeling neutral about it.
- Half of the participants felt anxious about giving or receiving comments, although all students conceded that the comments they received were encouraging and helped them improve their algorithms.

Impact of the activity

- Half of the subjects felt they would gain a better grade in M269 because they participated in the activity.
- The majority thought the activity helped develop teamworking skills valued by employers.
- Half felt more motivated to learn because they were sharing their work with peers.
- Half thought the activity helped create a sense of community.

Other aspects

- Most students spent between 2 and 4 hours on the activity, with two students reporting that they spent 10 hours.
- The majority thought a peer activity should count for at least 5% and at most 25% of a TMA.

Free-text responses and emails

Here we summarise a selection of the comments provided by students in the questionnaire's free-text boxes and in subsequent email follow-ups.

Talking should be included

A student felt that they do not get enough opportunity to practise communicating technical concepts verbally even though this is quite common in job interviews and in the workplace. After discussing, by email, the practicalities of including talking in our peer activity, it was concluded that synchronous meetings might be tricky to arrange. However, there is a current eSTEeM project by Waters and McMullan (2024) in which oral presentations are embedded in the assessments of an OU level 2 STEM module. Their results could provide valuable insights into how our activity can be adapted for verbal collaboration.

Do not require "pure" English algorithms

A student noticed that many comments centred around the use of Python-specific language in the algorithms. They suggested that the requirement to write the solution in English without reference to a specific programming language should be relaxed.

Collaborative activity at start of module

A student made reference to the feeling of isolation they experience at the OU and believes the activity helps alleviate this by creating a sense of community. However, the student feels the activity should take place at the start of the module as that is when students want to meet each other and form connections. Such connections can lead to friendships as well as sow the seed for future practical collaborations.

Contingency measures for lack of comments

A student commented that they were lucky to have received two good quality comments on their algorithm. There should be contingency measures in place for the situation where a student does not receive two comments or where they are not of a sufficient standard.

Flaw in OpenStudio's comments count

A student received just one comment on their algorithm. This was because they posted a reply to the comment which the system counted as a second comment. When viewing the Shared Content Page, other students would have seen a total comments count of 2, implying that the post had already received two comments and did not need any more.

Tutor perceptions

The activity

Tutors noted that:

- It was a good algorithm problem at the right level and everybody had a good attempt at it. It is important that the level is just right: we don't want it to be so easy that there is little interesting debate, but we also do not want it to be so hard that students aren't able to contribute. In an activity like this, the process is more important than the outputs, so the problem should have a low barrier to engagement.

- The algorithm problem had two main solution approaches, with one having better complexity than the other, and it turned out well that exactly half the students took each approach. Quite a few comments were regarding the approach taken, which is exactly the kind of discussion we wanted to see. Although none of the participants changed their approach based on feedback, it was still useful for commenters to have gone through the thought process of comparing the merits of two approaches.

- It was helpful to split the tasks into timeboxed chunks; students engaged on a weekly basis with most of the activity occurring just before the deadlines.

- The quality of the comments was generally very high; some even exceeding the level of detail a tutor would reasonably have time to provide. There were conversations within the comments that modelled the type of interaction one might have in a real design meeting. We also saw examples of students defending their position and convincing their peers of the correctness of their approach. It seems all participants managed to make valuable contributions in comments.

- There were too many uninteresting discussions over whether the word “tuple” was too Python-specific and the like. This indicated a lack of affinity among students with standard mathematical terminology. None of the student algorithms contained Python-specific language and there should not have been any debate around this.
- None of the optimal student solutions were fully correct so all students would have learnt something from the model algorithms provided after the activity.
- Some student algorithms contained strange formatting due to writing the algorithm in an external word processor and copying and pasting it into the web editor.

Student feedback

The survey and email responses showed that:

- The activity was enjoyable and valuable to students’ learning.
- The worked example provided adequate training for students to participate effectively in the activity.
- Although half the students indicated they felt anxious, there was no evidence that this affected their contribution. We note that, in TM354, no adjustments are made for students with anxiety and the TM354 module team are not aware of any issues arising as a result.

- Students should be given guidance on what to do if they don’t receive enough useful peer feedback.
- We should ask the OpenStudio team to enable us to set it up so that replies to comments are not included in the overall comments count.

It might be a good idea to provide an OpenStudio ice-breaker activity at the start of the module. This is also done in TM354. It gives students a chance to try out OpenStudio (or refresh their memories since most will have used it before) and provides a forum for creating early connections with peers.

Impact

At least half the participants thought our activity helped develop employability skills and create a sense of community. If the activity were adopted by M269, a significant number of students could be expected to benefit, as has been the case in TM354 and other modules (Minocha, 2009; Thomas *et al.*, 2018; Lotz, Jones and Holden, 2019). Moreover, we also expect tutors to benefit as we will explain.

Guidelines for implementing a peer algorithm activity

Based on the findings outlined above and existing knowledge from TM354, we offer the following guidelines for implementing a collaborative algorithm activity in OpenStudio.

Activity

1. Provide a worked example which includes model comments.
2. Each peer group should consist of a tutor group.
3. Divide the activity into subtasks:
    a. Share an initial draft algorithm.
    b. Comment on two algorithms posted by other students, choosing posts with the least number of existing comments.

    c. Post a revised algorithm based on feedback received as well as a comment explaining the changes made (or justifying why none where made).

4. Make clear that if a student does not receive enough useful comments, they may take inspiration from others' posts and comments, thinking about how they may apply to their own work. They should then refer to the other posts and comments in their explanation of changes.

5. Ensure each subtask has a clear deadline.

6. Provide a set of criteria to assist students in evaluating the work of peers. For example:

   Clarity

   Is the algorithm easy to understand?

   Length

   Is the explanation concise and to-the-point?

   Language

   Is the algorithm written in English without making reference to a specific programming language?

   Method

   Does the algorithm solve the problem? Is there a better way to solve it?

7. Ensure students are sufficiently prepared to be able to differentiate general mathematical English from a programming language.

8. Encourage students to write their draft algorithms directly in OpenStudio to avoid formatting issues.

Assessment

9. The peer activity should consist of a single question counting for 20 marks (out of 100) of the TMA. Marks are allocated as follows:

   Uploading an initial draft (2)

   Marks are purely for engagement.

   Quality of initial draft (3)

   Awarding full marks for any reasonable attempt since this is just a draft and isn't expected to be perfect.

   Comments made (8)

   Four marks per comment, looking for constructive and specific feedback.

   Uploading a final solution (1)

   Explanation of changes made (4)

   Looking for evidence the student has considered the feedback received (or has taken inspiration from others' algorithms and comments).

   Quality of final solution (2)

Checking the final solution incorporates the explained changes.

10. Students can copy and paste their algorithms and feedback in their TMA Jupyter Notebook and include links to their posts on OpenStudio.

11. Each tutor can produce a general summary of the approaches taken within their tutor group, and post this in OpenStudio along with a model algorithm written by the module team.

Savings in tutors' time

As noted in our project aims, a peer activity can reduce the workload of tutors. This view is not shared by everyone (Topping, 2009) since students require training in giving and receiving feedback. However, our findings indicate that a worked example constitutes sufficient training. In fact, this is already more training than is provided in TM354 where there is no worked example (and we should note that the quality of peer feedback is high regardless).

With a cohort size in excess of 1K students, a single worked example constitutes a minor investment in time per student. If we allow for 8 hours for the preparation of the worked example, it comes to less than half a minute per student.

The additional training does not therefore present a significant increase in workload, but our argument is that *savings* can be realised. These savings come from the manner in which the activity is assessed. The tutor does not need to carefully read each algorithm and give detailed feedback as they would normally do – a task which would typically take anywhere between 10-20 minutes per algorithm. That task has been delegated to students. The tutor's task, instead, consists of two things:

- Scan the solutions of the tutor group and provide a general summary of the approaches taken. Just one summary is provided to a group of 15-20 students, and it can be written in around 1 hour[2], amounting to less than 4 minutes per student.
- Evaluate each student's contribution to the peer-learning process according to the criteria set out in point [guidance:marks] of the guidance above. Essentially, tutors can judge the quality of algorithms and comments on the merit of being a good faith effort: whether students responded to all items and wrote something reasonable. Grading on such criteria is easier than analysing the correctness of algorithms and deciding whether the comments made were defensible and justifiable (see Nilson (2003) for details on this assessment strategy). A tutor can be expected to spend on average 3 minutes on this per student.

So we see that the average time per student for the assessment task has been approximately halved.

OpenStudio improvements

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[2] This estimate is based on the time taken in the present study.

A student pointed out that they got one comment instead of two on their algorithm. This was due to their having replied to the comment which caused the comments count on their post to increase to two, signalling to other students that no further comments were needed.

This has highlighted a possible new feature that would improve the usability of OpenStudio: add an administrative setting that changes the displayed comments count to represent the number of comments by unique users excluding the original poster. This feature request has been submitted to the OpenStudio team.

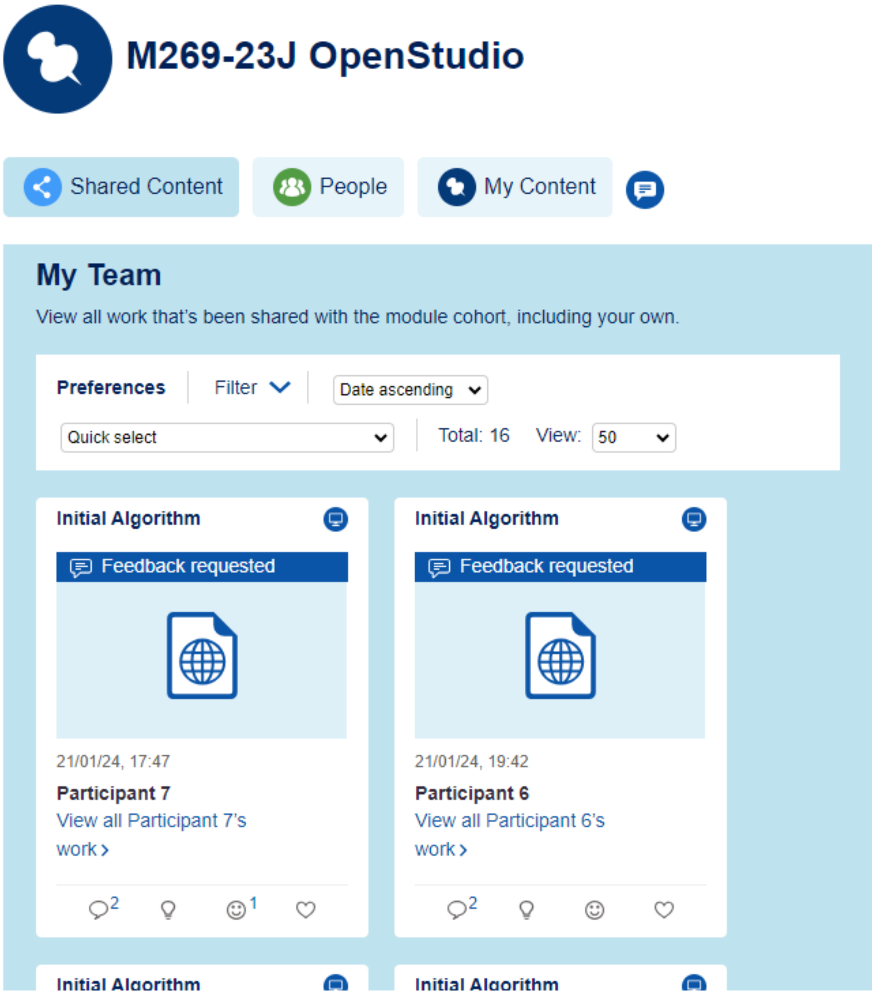

Figure 1. The Shared Content Page on OpenStudio showing the list of posts with comments counts.

University approval processes

SRPP

Approval from the Student Research Project Panel was obtained according to the Open University's code of practice and procedures before embarking on this project. Application number 2023/2604.

Ethical Review

An ethical review was obtained according to the Open University's code of practice and procedures before embarking on this project. Reference number HREC/2023-0095-2.

Data Protection Impact Assessment/Compliance Check

A Data Protection Impact Assessment/Compliance Check was obtained according to the Open University's code of practice and procedures before embarking on this project.

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