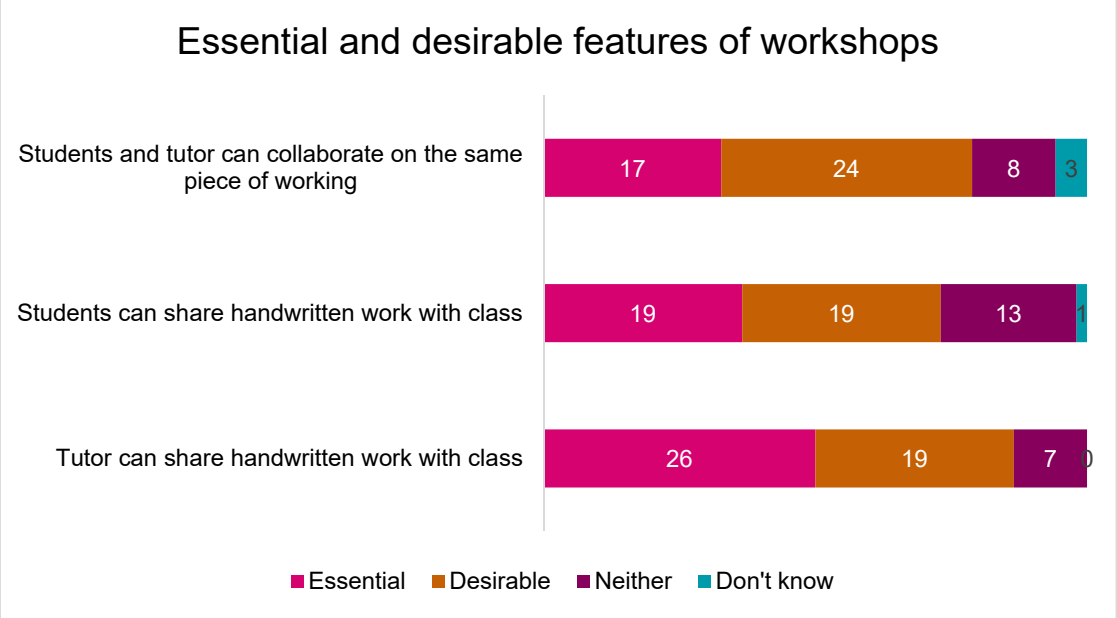
Sharing mathematical working synchronously

Steven O'Hagan (s.ohagan@ed.ac.uk)

Context

Discussions are underway in the Teaching Support Working Group about how best to move certain aspects of courses online for the 2020-21 academic year. One of this group's objectives is to develop a small number of models that may be used to guide hybrid course design in the School of Mathematics. An example of a traditional model for a 20-credit[1] course is: 3 hours of lectures per week, 1 workshop every week, with assessment comprising 20% coursework and 80% final exam.

It may be an essential or desirable feature of a course's design that small groups are able to work synchronously and collaboratively on a mathematical problem or task. Such activities were common during in-person workshops, for example, and while we may not wish to try to recreate in-person workshops online in their entirety it seems likely that that there will be a need to support this sort of work among groups of students or between students and tutors. Indeed, a recent survey of teaching staff in the School found broad support for students and tutors being able to share mathematical working.



Responses of 52 members of teaching staff when asked to rate features of online workshops

Therefore, without prejudging what an online equivalent of in-person workshops or tutorials might be – or if such a thing might even exist in 2020-21 – we focus on the much more specific problem of how to share mathematical working synchronously.

[1] Credits refer to the Scottish Credit and Qualifications Framework. See https://scqf.org.uk/media/1118/credit-point-explained-march-2017-web.pdf

Description of use case

A small group of people wish to collaborate synchronously on a mathematical problem or activity. The group may be made up of students alone or may be a mixture of students and tutors. When doing task like this in person, it is helpful for the group to be able to see (and possibly annotate) each other's working. We compare four possible solutions that achieve this use case online and discuss their relative merits.

To test each solution, groups were invited to work on a task consisting of two Year 1 calculus problems. Within each group, one participant took on the role of tutor.

The participants were: Richard Blythe, Nikolaos Bournaveas, Keith Brunton, Philip Clark, Charlotte Desvages, Ross Galloway, Judy Hardy, Stuart King, George Kinnear, Andy Lawrence, Iain Murray, Steven O'Hagan, David Quinn, Serveh Sharifi Far, Susan Sierra, Kristel Torokoff, Heather Yorston, Kostas Zygalakis.

Criteria for comparison

Easy to set up ○○○

An estimate of how easy it was for participants to get set up and started working on the task.

Works in real-time ○○○

An estimate of how quickly working done by one participant was visible to the others.

Cost £££

The estimated additional financial overheads of implementing this solution.

Shared-space or Read-only

Whether participants can only read each other's working (read-only) or can annotate and amend it (shared-space).

Assumptions

Students based in the School of Mathematics are assumed to have a computer, smart phone and a place to work with internet access. The assessment of criteria makes these assumptions.

Solution 1: Video

Typical setup

Each participant uses a mobile phone as a document camera and shares video of their writing with the group.

Typical hardware might look like:

Easy to set up	Works in real-time	Cost	Shared-space or Read-only
●●○	●●●	£	Read-only

Comments

See the following blog post by George Kinnear for a detailed discussion of this solution:
https://blogs.ed.ac.uk/georgekinnear/2020/05/16/sharing-mathematical-writing-using-video/

Note that writing on a tablet and doing a screencast is essentially equivalent to this solution but requires each participant to have a tablet with pen input. Because of the much greater cost, this solution was not considered separately for this particular use case.

Findings from the trial

- Participants were using either special “phone as webcam” apps (e.g. https://www.androidpolice.com/2020/05/10/how-to-make-your-smartphone-into-a-pro-webcam-for-zoom/) or just joining the call from their phone using the Teams app.
- A lot of time was spent getting set up - how to position camera, how to share it. An induction session would be needed.
- People found it hard to set up their space in a usable way, e.g. how to position the camera, the paper etc. so that everything is in view. Perhaps some cheap extra kit is needed, e.g. a flexible phone holder https://tinyurl.com/y6u69zha
- Once up and running, it was quite natural for one person to be acting as scribe. A couple of issues:
    - Could be hard for other students to contribute, e.g. to point out a mistake that had been written down, had to describe where it was rather than just pointing.
    - The other students could end up not actively participating - a role for the tutor to prompt this, and switching scribes regularly could help
- There was no shared copy of the work at the end. Perhaps the scribe could scan to PDF and share with the group.

Solution 2: Online whiteboard

Typical setup

Participants join a shared video call and contribute to a shared online whiteboard, for example through https://www.notebookcast.com/

Typical hardware might look like:

Easy to set up	Works in real-time	Cost	Shared-space or Read-only
●●●	●●●	£££	Shared-space

Comments

Other setups are possible, for example participants could use a tablet with pen input to join the shared whiteboard.

Findings from the trial

- This seemed to be quite a successful solution for being able to work together.
- The group quickly developed ways to work together, e.g.:
    - each person writing in a different pen colour;
    - putting ticks next to parts that had been checked by another participant.
- There were some issues with being able to write legibly. Slight network lag meant that some participants found it hard to write anything at all.
- A good tablet and reliable whiteboard service are essential.
- Constrained by having a bounded whiteboard - ran out of space and struggled to fit working in. As a result, made a mistake with missing an important coefficient and not noticing this (either with copying from line to line, or by erasing accidentally). Perhaps there are better apps.
- A variety of devices were used by participants:
    - tablet and stylus (e.g. iPad with pencil) worked quite well;
    - trackpad on laptop to draw but this was fiddly;
    - basic £30 Wacom tablet took practice but worked fine.

Solution 3: Collaborative notebook

Typical setup

Participants join a shared video call and contribute to a shared collaborative notebook, for example using OneNote:
https://www.ed.ac.uk/information-services/computing/comms-and-collab/office365/onenote-and-office-online

Typical hardware might look like:

Easy to set up	Works in real-time	Cost	Shared-space or Read-only
●○○	●●○	££	Shared-space

Comments

Other setups are possible, for example participants could use a tablet with pen input.

Findings from the trial

- Participants spent a lot of time getting familiar with the software, OneNote in this case.
- There seemed to be quite considerable issues with lagging in OneNote and other user interface and user experience issues, e.g. it seems other people cannot delete other people's writing.
- Participants felt it was probably only usable for about 4 or 5 people working together.
- Some participants were disappointed with the technology, finding it hard to get up and running. The iPad app was not able to use the "convert writing to text" feature.

Solution 4: Typed text

Typical setup

Participants join a shared video call and contribute to a shared LaTeX document in Overleaf: https://www.ed.ac.uk/information-services/computing/desktop-personal/software/main-software-deals/other-software/overleaf

Typical hardware might look like:

Easy to set up	Works in real-time	Cost	Shared-space or Read-only
●●●	●●○	£££	Shared-space

Comments

This solution is essentially cost-free as students are assumed to have a computer and internet connection.

Findings from the trial

- The group spent around 20 minutes figuring out how best to work together.
- Working with the code-and-compile method was just too slow and easy to get out of sync when multiple people were working on the document concurrently, but the WYSIWYG editor was better.
- There was little discussion going on in the group about the task as it was very hard to deal with the cognitive load of doing algebra and typing it at the same time – some participants ended up having to do by hand first then type it up. “A waste of time!”
- Just not viable for real-time work. Participants felt this solution was more suited to producing a final draft after the work had already been done.

Conclusions

Each of these solutions has its benefits and drawbacks in certain circumstances. Particular use cases come to mind where each solution may be the best option:

- where students are working on a joint project where the end-product is a written report, a shared Overleaf project will likely be the best solution (indeed, this is already standard for students doing group final year projects);
- where a student wishes to show a piece of working to a classmate during a video call, using their phones camera might be more natural than starting up a shared online whiteboard;
- where students are working asynchronously, and so low latency is not important, the more permanent record offered by a collaborative notebook may be the best option.

However, for the particular use case under consideration, that is collaborating synchronously on a mathematical problem or activity, we recommend the **online whiteboard** solution above the others. During the trial, more than any other solution, participants were able to quickly and easily attend to the task in hand and engage in the mathematical work without wasting time setting up or familiarising themselves with software.

Recommendation

We recommend, as a minimum, the purchase of a small graphics tablet costing no more than £50 for each participant to allow good pen input.

While not a negligible expense, this solution seems to strike a good balance: as well as supporting meaningful participation in this particular use case, the graphics tablet supplements the equipment that students are already expected to have for their studies in the School. (For example, should we decide as a School to have mixed computer- and human-marked assessments, then we may wish to offer students the option of writing their solutions to problems directly into the assessment system.)

Next steps

1. Identify a recommended graphics tablet.
    a. Find a supplier with suitable stock levels.
    b. Determine which students should be given the equipment and which should be expected to provide it themselves.
    c. Note: School of Physics & Astronomy has elected to provide all new entrant students, UG and PGT, with an iPad and Apple Pencil.
2. Identify a recommended online whiteboard.
    a. Identify requirements.
    b. Arrange another trial exercise to test candidates.
    c. Any online whiteboard must work well when some users are in China.