# Mathematical Massive Open Online Courses (MOOCs): Report of a Panel at the 2014 ICM

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October 12, 2014

**Abstract**

The author moderated a Panel of Bill Barton, Robert Ghrist, Matti Pauna and Ángel Ruiz at the 2014 International Congress of Mathematicians. This paper contains the initial panel brief, the author's summary of the Panel statements, the question-and-answer session, and some conclusions.

## 1 Panel Brief

This panel[1] had been arranged by the Committee on Electronic Information and Communication (CEIC) of the International Mathematical Union (IMU). The title was carefully chosen, not "MOOCs in general". Though the panel could have had a long, and interesting to some, debate on general questions about MOOCs, it was part of the the ICM and therefore the focus was on Mathematics. What might make Mathematics a special subject for MOOCs? CEIC's initial thoughts, circulated to the audience, were as follows.

1. The highly sequential nature of mathematics: it is little use trying Analysis II until one has done Analysis I, and so on. In a given university, Directors of Studies (or their equivalent) carefully plan an *ordered* curriculum, and write a list of pre-requisites etc. An *individual* MOOC provider might do the same (though there is little evidence of this so far), but there is currently no evidence of a general catalogue/list of prerequisites.

This is not helped by the language of mathematics: "Elementary Proofs of the Prime Number Theorem" is unlikely to be "elementary" in the usual sense (OED 7a: "Rudimentary, introductory") of the word.

*The Moderator is grateful to Matthew England and Ravi Vakil for taking notes, and the ICM Team for recording the Panel session. Above all, he is grateful to the Panel members, before, during and after the ICM, but any errors or misattributions are his fault alone. His own attendance was supported by EPSRC under grant EP/J003247/1, and by a National Teaching Fellowship from the U.K.'s Higher Education Academy.

[1]The live panel can be seen at https://www.youtube.com/watch?v=bRjkbmuCm20.

2. The notation. Many Virtual Learning Environments (VLEs) do not support the display of mathematical notation well, and certainly not the construction of mathematical notation "on the fly". Equally, entering mathematics is often difficult for students. Notation is also not as universal as is commonly believed, and a student who learned arithmetic the Spanish way, even though fluent in English in general, may well be baffled by Anglo-Saxon long division of polynomials (or *vice versa*).

**However** if this barrier can be crossed, MOOCs way well be a means of getting advanced mathematics to those who would not otherwise have the opportunity (as closed online courses already do).

3. The fact that mathematics is a practical subject: one learns by doing. It is not clear how MOOCs can support the sort of routine exercise that is a vital part of learning mathematics. Multiple Choice Questions do not fit the bill here.

There are solutions to some of these problems, but they are not widely known, and not in the "mainstream" VLE/MOOC systems.

# 2 Panelists

**JHD** *James Davenport, University of Bath, U.K. (Moderator)*
He is a CEIC member, and knows something about MOOCS as the University of Bath has been involved in MOOCs as part of the U.K.'s FutureLearn consortium, which is led by the U.K.'s Open University, which many people would argue has been involved in MOOCs since it opened its doors in 1971. The Open University had advised FutureLearn against early involvement in Mathematics, since OU experience had been that Mathematics was one of the more difficult subjects to do well. The second wave of FutureLearn MOOCs will include a statistics MOOC.

JHD uses quite a bit of "MOOC technology" in the large "face-to-face" courses he currently teaches. His initial opinion is that there is not a simple either/or between traditional teaching and MOOCs.

**BB** *Bill Barton, University of Auckland, New Zealand*
He works in the Mathematics Department at the University of Auckland, but is a mathematics educator. He does teach undergraduate mathematics to large classes. Given his rôle in the International Commission on Mathematical Instruction (ICMI), he wrote the MOOC report for CEIC in 2012/13 — a long time ago in this subject. Auckland is also a member of FutureLearn, and is developing a Statistics MOOC.

**MP** *Matti Pauna, University of Helsinki, Finland*
He has been involved in many projects regarding online teaching and assessment of mathematics.

**AR** *Ángel Ruiz, Universidad de Costa Rica, Costa Rica*
He is a Vice President of the International Commission on Mathematical Instruction (ICMI). He is the Director General of the Project Mathematics Education in Costa Rica that elaborates pedagogical resources and carries on several courses: face-to-face, blended and a collection of 20 MOOCs for 2014-2015. The MOOCs are oriented to in-service teachers preparation to deploy the new curriculum.

**RG** *Robert Ghrist, University of Pennsylvania, USA*
He wrote and produced a calculus course in the Coursera framework, available at `https://class.coursera.org/calcsing-005/lecture/preview`, and there's a trailer at `http://www.youtube.com/watch?v=BKpBbzYYXrk`.

# 3 Panelists Statements

## 3.1 Bill Barton

I have two main points, and various sub-points.

1. MOOCs, in general, and Mathematical MOOCs in particular, are still in a very early stage of development, and they are only one part of the impact of transformative technology on mathematics education. It will change things, but we do not yet know how. We mathematicians must stay involved and treat it seriously and rationally use these technologies and research their impact.

2. I personally do not see MOOCs *replacing* face-to-face education of various kinds (although it will change it). My understanding of the educational process, and particularly the mathematical educational process, is that working together **both** at a distance **and** face-to-face is required. Indeed, one of my optimisms about MOOCs is that they will enable us to *enhance* face-to-face teaching and learning. In particular, it may allow us more focus on mentoring authentic mathematical activity at undergraduate level.

- We need to maintain a research stance on MOOCs. That is, we need to keep an open mind on whether MOOCs, or future manifestations of MOOCs, or MOOC technology, are positive or negative for mathematics education in each of its many contexts — and we must make evidence-based decisions on these matters.

- It is essential, as with any change, that we have people who *dream* what can be; we have people who are pushing for things that cannot be done now; and we have realists who worry about issues of cost, impact on lecturers and students.

- We must be partially guided by the students' world — else we risk becoming passed by, to the detriment of mathematics. When I was a student I remember mathematics teachers resisting the introduction of scientific

calculators because we would not then experience logarithms properly through using slide-rules.

- My prediction is that MOOC technology is likely to become integrated more and more into conventional programmes, both in supportive ways, substantive ways, and as main components – to the benefit of everyone. (Of course stand alone MOOCs are likely to exist).

- Our fear of MOOCs changing mathematics as we think it should be is, for me, simply an argument for staying strongly involved. Or we will be passed by: think of the rise of testing, how that has been cornered by governments and private testing institutions because we did not hang on to the rational assessment of our own subject.

- Assessment: the first time a pilot flies an actual passenger jet it is full of passengers. And he or she has certainly been competently assessed by the flight simulator as competent. Of course, the (human) system will still have taken great precautions against personation etc., so our legitimate worry is not about electronic assessment *per se*, but against the human problems that might go with it.

### 3.2 Matti Pauna

His complete slides are at `http://blog.wias-berlin.de/imu-icm-panel-moocs/files/2014/08/ICM-Pauna.pdf`.

I have been involved in many projects regarding online teaching and assessment of mathematics over the last ten years. This has formed my belief that you cannot learn mathematics without doing it and you really need feedback as well (from peers, computers or instructors, and the last becomes difficult in a MOOC context). We have a substantial emphasis on assessment, but this is assessment *for* learning, not just assessment *of* learning.

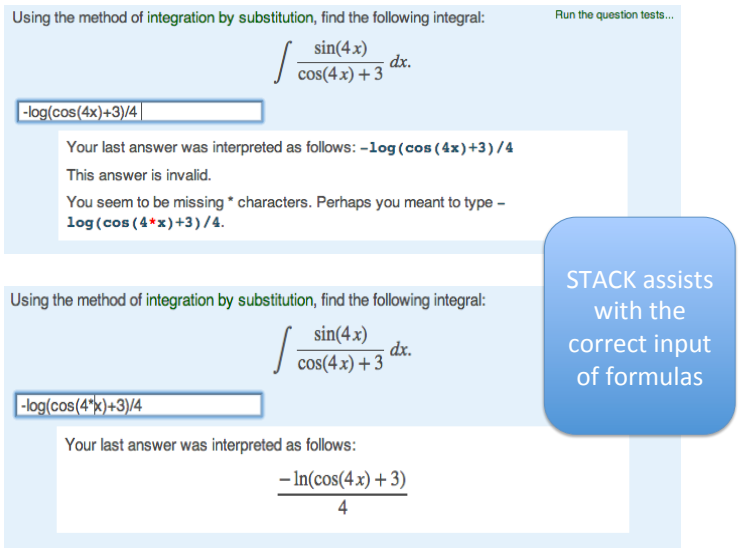
Our main educational vehicle is World Education Portals (see `http://myweps.com`), which provides free education material. There is a mixture of slides and animations. Students get instant (computer generated) feedback online, and can monitor their own progress. This means that students do need to learn syntax of the system but that usually happens within a week. Our vehicle for this is the Automatic Assessment tool STACK created by Chris Sangwin (now at Loughborough): see [San13], and Figure1 for an example, which also shows how the system responds to syntax errors without penalising the student. This provides:

- diagnostic tests at the start of course so instructors know where they stand;

- continuous learning by practising and getting constructive feedback.

We also make use of peer assessment, where the process for a workshop module in Moodle works as follows.

Figure 1: Automatic Assessment (STACK) Example

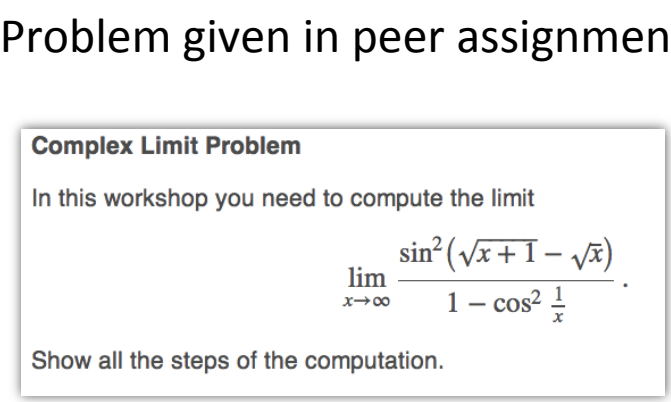



1. Student are given homeworks that are to be submitted by Wednesday: an example is in Figure 2.
2. After the submission deadline, an example solution (or several solutions) is provided.
3. According to the model solution and assessment criteria, students have to grade and give constructive feedback to five randomly selected students by Sunday.
4. A student's own grade from this assignment is the average of the five grades.
5. The teacher's role is to monitor and support.

This forces students to study the model solution in order to mark (as well as study the solutions of others). Students learn how to communicate mathematics. This creates interaction between students, which is particularly important in an online course. The instructors must make it clear that the aim is to help others to learn, rather than to become a grader.

One effect of this whole approach is that a large amount of data is collected. We are only beginning to answer the question "what can we learn from these data" — questions such as "which parts of the course helped the most".

Figure 2: Peer Assessment Example




### 3.3 Ángel Ruiz

His complete slides are at `http://blog.wias-berlin.de/imu-icm-panel-moocs/files/2014/08/Angel-Ruiz-on-MOOCs-ICM-2014-short.pptx`. There's also a supporting document: `http://blog.wias-berlin.de/imu-icm-panel-moocs/files/2014/08/MOOCs-in-the-reform-of-Mathematics-Education-in-Costa-Rica-final.docx`.

MOOCs are in an initial stage so a wide and flexible perspective is necessary, hence I am offering this one, from a small developing country. It shows the use of this e-learning strategy for very specific objectives.

In May 2012, a major reform in the mathematics curriculum of all primary and secondary education was adopted in Costa Rica. For its implementation the most important activities are courses for in-service teachers face-to-face, blended and virtual. I will concentrate now of course on the virtual courses. These courses are associated with the new curriculum, thus the nature is a little different from university courses. The content is not mathematics, not general pedagogy but a specific pedagogy of mathematics.

Why did we go for MOOCs? They are dynamic through videos, so the teachers can make contact with prestigious researchers who elaborated the new curriculum and conduct its implementation. Also we thought it would be easier but we are no longer so sure of that: to elaborate these courses has taken us more effort than we expected! We are using, basically, Powerpoint presentations, and we always have a person talking to you, so there is clear eye contact with the professor of the course.

We expect a greater completion rate than other MOOCs have experienced for two reasons:

1. the courses are very specific;

2. the new curriculum must be implemented.

There is a maximum number of participants because of the lack of resources. Note that there are some voluntary face to face activities involved as well: these are conducted by Ministry of Education officials. So we do have open courses, but not so massive, and online but with an external support within the different regions of this country.

## 3.4 Robert Ghrist

I'm a research mathematician and engineer at the University of Pennsylvania, and I want to tell you a little bit about my experience with MOOCs, more specifically my Coursera Calculus course. Only half the people signed up do anything and only a tiny proportion of those make it to the end[2] of these fourteen weeks. The number that matters isn't how many people make it to the end but how much content is transferred. For example, over 1.6 million 15-minute videos were viewed — that's a lot of calculus watched! The course contains lectures that evolve over time, and after each lecture there is a homework that takes one, two, maybe several, hours. There is a lot of information at personal webpage (`http://www.math.upenn.edu/~ghrist/`). The main idea is that video is key, and indeed very well suited to mathematics. Our subject has a real advantage over other subjects in the ways in which video etc. can enhance the presentation. I've put a lot of effort into taking advantage of what the medium can do. Small clips, slides, comic book style, all draw the student in. Most of all it allows us to do what we as mathematicians want to do: show students what we see in our heads. MOOCs allows us to increase the bandwidth of our communication. It is far easier to show the beauty of mathematics in this medium than on a chalkboard.

Mathematics as we know is a very subtle art. It takes years of discipline and training to appreciate.

So we are at a relative disadvantage with respect to other fields in terms of this. I see a future where we have a lot more mathematics majors, because we can communicate better, because we can show many higher and more beautiful truths.

We complain that our students think that our rules are tricks that you follow like a robot. We know it is not that true, but we struggle to show that to our students. It is doable on a chalkboard, but not that easy. It will be easy to communicate, not only to our students, but to the rest of the world.

I would like to see a future where we have a lot more mathematicians making content. It will take much more work on our behalf to do this but the result will be worth it.

[2]The actual numbers were roughly 150,000, 70,000 and 3,000.

# 4 Discussion

## 4.1 A (post-doc) speaker from NYU

I hear a lot about MOOCs, and wonder how they will affect me. But my real question is "What problem are MOOCs solving?"

**JHD** In UK it allows for a critical mass of graduate students from different universities to attend courses that no individual university would find it economic to run.

**BB** Engagement with students perhaps. But then, what problem did evolution solve? The world is changing and we need to adapt.

**MP** No specific problem. Technology helps with visualisation of mathematical concepts.

**RG** Students can't pause or rewind live lectures. Lecturers do not give great lectures every time, nor can they, but you can get perfect content on MOOCs.

**AR** The mathematical community must understand MOOCs broadly and use them in different ways as appropriate and when they are effective. For the Costa Rica example it was needed for the flexibility as the teachers were all over the country (rather than being in one university) and needed to study in the evenings.

## 4.2 Ingrid Daubechies, President IMU

People in developing countries like the idea of MOOCs. But if you need to stream them online then it can be difficult without a good internet connection. Surely they need to be downloadable or local.

**AR** Some regions in Costa Rica have much better internet than others. So different regions are treated differently in terms of the logistics — sometimes material gets sent out physically. Also, one can take steps like adjusting resolution to help with worse connection. Finally, note that the internet in developing countries may be very different in 10 years time.

**BB** We did not stop developing radio when most of the world could not get it. If MOOCs prove effective the infrastructure will follow.

## 4.3 Marie Farge (ENS Paris)

Do you make your MOOCs free to all? Note that this does not mean just to download but to also reuse, to take a component, to re-use in one's own teaching. This requires an appropriate licence, as the default position does not permit re-use.

**AR** Our courses are free online. Were intended only for Costa Rican teachers but have been used internationally already! Work not licensed for reuse yet but there is intention to do so.

## 4.4 Thorsten Koch, TU Berlin

There was recently a major article in *The Economist* [The14a, The14b, a linked pair] stating that online courses are much cheaper. Does traditional education no longer pay? Will you charge for them?

**RG** There is nothing wrong with free/low-cost material as long as the quality is high. Even if this technology only works for first year courses (and students can take them in high school) that then reduces the time to degree, and would save a lot of money (in the U.S., often $50–60,000), which is a positive thing.

**BB** Innovation is driven by those who dream the impossible. But we also need the realists, and do need to worry about cost and the impact on academia. If the change is just driven by economics then it won't be high quality and the change won't last.

**JHD** There's nothing specific about mathematics here, so can we move on?[3]

## 4.5 Ingrid Daubechies, President IMU

Being specifically mathematical, how does homework work on the Coursera platform? How do you grade 3000 students?

**RG** It is multiple choice (due to constraints on the technology and platform) with some automated feedback on wrong answer. Not many people will agree that multiple choice is the best way to assess mathematics. This is the main shortcoming of our course, but it will evolve and get better. Some constraints with the technology, and I preferred to experiment elsewhere.

**MP** Important to allow students to come up with their own solutions. Automatically generate problems. Some students take a quiz multiple times, getting a different question each time. Gameify it and they practice more.

**JHD** I have used the system MP was speaking about, and it can take me over an hour to write a quiz question and design all the alternative feedback mechanisms: it is certainly not free to the author! There is other software available but each piece tends to be tailored to a specific system and not well supported by the generic MOOC software that institutions tend to buy.

[3] This was in accordance with the remit of the panel. It does not mean that the issue isn't of wider interest.

### 4.6 László Lóvasz, Past President IMU

We seem to have a choice between face to face with an average instructor verses online with an excellent instructor. Are there any studies on which is better?

**JHD** MP has done some studies.

**MP** We have some limited studies (tens of students). Our experience at Helsinki shows that the MOOC-supported class is slightly better. Mika Seppälä in Florida State University is also using this material to support students in his sections of Calculus, and these students did a grade better, on average

**BB** It is not an either/or situation. MOOC technology will become integrated into face to face courses. We cannot test a new education idea like a drug trial, but that doesn't mean we shouldn't develop new ideas. We should be thinking about evaluation throughout.

**RG** In chess, we can set up competitions between human and computer, to find out "which is better". The best by far though is the human player augmented by software. I believe that the same will happen in education. Why not rely on the well-produced videos to motivate and excite students then get face to face time to work out the details with students.

### 4.7 Jean-Marie Laborde, Grenoble

I agree with the last speaker. Intelligent tutoring systems (ITS) have been around for a while and they have generally over-claimed. To make progress we need to understand how students learn, and what is the best way to support this.

**All** General nodding in agreement throughout this speech

**BB** Agree but the current situation is not well understood and does not examine aspects such as idea exploration and concept formation properly either. We may be expecting more of MOOCs than we are currently getting from conventional teaching.

### 4.8 A speaker from Mexico

What real world problems did you have implementing this? Technology, graphic design etc.

**MP** I am a fan of this technology of course. But it of course requires a lot of IT skills which need to be developed. Getting software provided throughout the university is hard. This is a new subject and we are experimenting. You need to be ready to make mistakes and errors and react to them. Students are quick to complain and flag up problems with the software, but tend to be happy if it is fixed quickly.

**JHD** At my university it took 6 months to get IT guys to install STACK in a system that could be used by undergraduates due to their quality assurance procedures.

**RG** It took an enormous amount of time and there was a huge learning curve. A good analogy is the video game industry. At the start could make a good game with two people and two months. Now, in the very big video game industry, you can (and have to) have an enormous team with a huge budget. We could be on a similar trajectory.

### 4.9 Mina Teicher, Bar-Ilan University

How will MOOCs effect the job market, in the United States and in the rest of the world?

**BB** A more interesting question is how will it change the mathematics learned?

### 4.10 A speaker from Canada

I am very much in favour of these technological developments, having been the first person on my university's web site. Even if you can see their benefits, how do you implement this organisationally (office hours, workload management, credit for working on these etc.)? As has been stated, these courses take a great deal of time to develop. If you have thousands of students, how do you tutor them? My Teaching Assistants have strict working conditions, not taking more than fifty students etc. Teaching credit is independent of class size in my university.

**RG** I am not a trade union negotiator. I did not get any teaching credit for developing my MOOC course, so I took a risk. It paid off through all the positive feedback, but this is not a model that will work generally. But universities must find a better model. As well as credit and compensation issues, there are also ownership issues. That's probably why my university's effort is headed by someone from the Law School.

### 4.11 An unknown speaker

How do we use this technology to motivate students, especially the more able ones?

**BB** I think these technologies offer the opportunity to really motivate the more able student, as illustrated by RG's presentation.

**JHD** But it won't do that automatically: we the authors have to put the effort in.

**AR** I am dealing with teachers, not university students. But we are dealing, in general, with a new generation of students: much more visual, much more multi-tasking. They don't need a manual to operate a device.

A separate question for us is accreditation. Our courses are free (which is good for the students), but the process of accreditation (at least in Costa Rica) has not caught up with these changes. I look forward to discussing this in Brazil in four year's time.

### 4.12 An unknown speaker

Even if all the courses are not (yet) available worldwide, can we get a copy of the presentations?

**JHD** Yes: at the website (`http://blog.wias-berlin.de/imu-icm-panel-moocs/`), and under a CCBY licence.

### 4.13 A speaker from Spain

Will MOOCs replace face-to-face teaching? In face-to-face, we can see if we are losing the class, or some members of it, and we get interaction. These are valuable things I would be sorry to lose. but in Spain the economic point of view is very powerful.

**BB** Some things can only be done face-to-face. Others can be done better by MOOCs. I therefore expect the two to become more integrated. We have a fear of changing the nature of teaching and mathematics. Some of these fears are genuine. That fear is an argument for us to be **more** involved, to ensure the changes, which are coming anyway, are positive. We need to have a rational voice in these changes. We have lost control of mathematics testing in schools (to government or private companies). This was detrimental and so we must keep in control of MOOCs to avoid similar loss.

**RG** If mathematicians do not build good online content, and demonstrate how we can improve our teaching *by augmenting* our teaching with these technologies, then non-mathematicians will build bad courses.

### 4.14 An unknown speaker from Argentina

How does one promote this technology, if it is good?

Also, how should we use the errors of the students to improve the class with MOOCs?

**BB** Students already have their communication methods, mostly digitally enhanced and through social media[4]. Similarly, we need to ensure technology enhances learning. Once again, it is not an either/or question.

[4] Author's note: though not much studied in mathematics, social media are ubiquitous among students. See [PHS14] for one example.

**JHD** I put my face-to-face lectures online for students who miss out. These can contain my errors, either mathematical or pedagogical. The students present have already debugged the lecture. Without students present at the time of recording there would be many more uncaught errors.

**BB** I leave the errors in: they promote more reaction!

### 4.15 Marie Farge (ENS Paris)

The example of the computer game industry shows the size of the industrial investments involved. Therefore shouldn't everything (the content and the software etc.) be open source, so that good ideas can be widely adopted?

**RG** There is plenty of technology around to do media delivery. The hardest gap is the last half-metre [between the technology and the student]. Therefore we need good software tools for course development. The technology to send it around the world is already here. But currently my content is made in Powerpoint. I need a better platform.

**MP** WEPS is completely open source and free. Our base system, Moodle, is under heavy development by a big community, who are very conscious of their responsibility for production software.

The content I have under `myweps.com` is also free: the only restriction is that if you modify the content you must put it back up on the server.

### 4.16 A speaker from Africa

If you do not use technology, the students will — they will video lectures and distribute them etc., as I have seen in Cameroon. We are very happy to use cash machines and book airline tickets online: education has to benefit from this, and support the interaction so necessary in mathematics. We can, and do, make use of computer algebra (WIRIS) to do computations supporting our students work.

**All** General nods of approval.

**JHD** I am afraid we are out of time: my thanks to panellists and audience. MOOCs are *part* of the solution to a range of problems, not the be all and end all. Discussion will continue online (`http://blog.wias-berlin.de/imu-icm-panel-moocs/`).

## 5 Moderator's Conclusions

1. One common theme is that the question is not "MOOCs or face-to-face". The question is how best to take advantage of the strengths of both. "MOOC" is in fact a marketing phrase encompassing a range of technologies, and the real issue is which of these technologies can we use to enhance our teaching, and how.

2. Assessment was a significant topic: see Panel Brief point 3 and section 4.5. RG was using multiple choice because it was available, and admitted to its weaknesses, MP demonstrated a much more advanced piece of technology, but it's non-trivial for the course author to use well. MP's points about the integrality of assessment to the learning process are important, and his phrase *assessment for learning*, rather than just assessment of learning, is worth remembering.

3. The Intellectual property/licensing issues, raised in sections 4.3 and 4.15 are interesting. Most universities have not addressed this systematically (section 4.10).

4. The question of infrastructure (Internet bandwidth etc.) was raised in section 4.2, but is well-answered there, and we should not let infrastructure deter us, though we need to be conscious of it.

5. Evaluation of the technologies is difficult (even blind experiments are practically impossible, and double blind completely so) and poorly understood: some experiences are reported in section 4.6.

# References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