Benefits and Risks of Media and Technology in the Classroom

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Abstract

Media and technology can bring enormous benefits to the classroom. They allow to spice up lectures and help to make the material more accessible. But there are dangers too. In this talk, I want to share some my own experiences both as a teacher as well as a part of a team of a group involved in teacher training. The text will focus primarily on the special case of media and technology. It is an aspect of pedagogy, where the benefits and risks of teaching are accentuated well.

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1 Choice

Independent of the subject, teachers face a plethora of teaching possibilities, especially in the realm of emerging media and technology. To beef up a lesson, one can tap many sources:

- **knowledge and passion:** mine personal research interests
- **audio-visual media:** show slides, movie clip or do make a demonstration.
- **computer technology:** use calculators or computers
- **social tools:** group work, discussions, games

Due to the competition from online content, the question of how to beef up a lesson or how to add salt and pepper to a topic has become increasingly important. Learning works best when many different channels are used. Here are the main ingredients we use or have used for calculus courses:

Lectures in Classes	sometimes with demonstrations
Textbook, handouts	students usually read in private
Homework assignments	usually from book or handouts
Computer based quizzes	multiple choice questions, QA tool, "webwork" etc.
Online activities	applets or flash tools
Question Center	help center staffed by teachers and assistants
Electronic voting system	project Galileo at Harvard
Labs using technology	Mathematica computer algebra projects
Problem sessions	by course assistants
Meeting with instructors	office hours

Choice happens on different levels. We look at four levels and in each level we look at 9 parameters:

Teaching can be done on different **presentation levels**:

- Power-point lecture: they need heavy preparation, are highly linear and easy to deliver.
- Blackboard lecture: needs solid preparation, but once rehearsed, it works well. It is mostly linear.
- Interactive lecture: this needs skills to interact with students for example in group work. It is Nonlinear.
- Workshop or lab: needs heavy preparation a good structure and often resources.
- Seminar type lecture: needs a lot of preparation. Quite linear, students prepare a talk and present it.
- Coach lecture: with a smaller group of students, typically to catch up, quite nonlinear.
- Office hour: mostly one to one and unstructured, very nonlinear.
- Discussion lecture: needs moderation skills, direction of discussion could go anywhere, highly nonlinear.
- Discovery and inquiry based lecture: needs leadership skills and discipline and is extremely nonlinear.

The teacher not only has to decide about **pedagogical parameters** like

- rigor or informal (i.e. ϵ-δ definition of continuity)
- fast or slow, complex or simple (i.e. relative to homework and exams)
- technology or traditional (i.e. how much technology is healthy)
- geometric or algebraic (i.e. first the power rule or the geometric slope definition)
- conceptual or algorithmic (i.e. first to teach "how" and then "why"?)
- drill or challenge (i.e. in homework for example)
- interaction or lecture (i.e. group work, Socratic teaching or one way lecture)
- discovery or instruction (i.e. how much is discovered by the students)
- applications or theoretical (engineering, physics or chemistry related problems)

Besides lectures, literature or discussions, there are many **teaching tools** to chose from:

- Course websites to disseminating information (often content management systems)
- Slides during lecture (overhead or increasingly with power-point)
- Online quizzes or online homework (from ad hoc multiple choice systems to webwork)
- Applets and Flash tools for demonstrations or interactive experiments (labs, experiments)
- Movie clips in class or online (for fun, or to make problems more interesting)
- Computer algebra systems for homework or labs (for solving homework or for projects)
- Instant messaging (for help or virtual office hours)
- Email for help and information (round the clock office hours, announemcents)
- Intelligent agents (for deepening knowledge and to get answers to problems)

The lecture is also expected to illustrate a subject from **objective directions**

- Visual or geometrical point of view
- Symbolic or algebraic point of view
- Numerical or algorithmic point of view
- Entertaining or artistic point of view
- Application or practical point of view
- Social or collaborative point of view
- Historical or cultural point of view
- Challenging or discovery point of view
- Exploratory or inquiry based point of view

2 Media and technology

Teaching with electronic tools and especially with online tools has sometimes been abbreviated with the term **E-learning**. But because learning with electronic tools has become so common, the term has become obsolete. **Erik Duval** from Leuven made once the comparison that that one also does not use the term "building learning" if a class is taught in a "building".

The fact that E-learning is a pleonasm is due to the fact that almost all teaching nowadays uses some sort of technology and media, it is no more necessary to mention the "E". Teaching with technology and media has become the standard.

I) CAS Systems	II) Problem Solving	III) Interactive Webpages
Mathematica, Maple	Webwork	Javascript DOM
Matlab, Mathcad	Multiple Choice quizzes	Dynamic HTML
Reduce, Macsyma	Personal response systems	Java applets
Magma, Pari, Octave	Gateway exams	Flash pages
IV) Multimedia	**V) Databases**	**VI) Communication**
Graphics	Online Encyclopedias	Email, ICQ
Movies	Online Courses	Online Discussions
Animations	Problem Databases	Taped lectures online
Slideshows	Chatbots	Electronic conferences

3 Benefits of media and technology

Before we distinguish more detailed aspects of media and technology, lets look at the benefits and risks in general.

Long before computers have entered the class room, media have been used to spice up lectures. I myself had very few teachers who were not useing slide projectors, overhead projectors, book projectors, TVs in the classroom. Many science classes also featured live experiments like chemistry experiments or labs. Even some of these classes happened more than 30 years ago, I still remember many of the special presentations or events. In college at ETH in the early 80'ies when graphing calculators were still appropriate, geometry teachers would use them or even bring PC's like the Commodore in the classroom to make demonstrations. This was 25 years ago and things have become much more easy.

The impact of media on learning has been studied since a long time. Already in 1912, the American psychologist **Edward L. Thorndike** recommended pictures as a labor saving device for instruction. [1].

Looking back, these special technological modules were successful in a lecture not only because of their instant effect. They had the **long term benefit** that the lecture entered to the **long term memory**. If a tool has been used in moderation, the lecture has become special.

Teachers use technology to

- shake up old paradigms
- rethink the subject
- illustrate real life applications
- explain things better
- tackle real life problems
- add a discovery component
- add color to the subject
- break the monotonicity of a lecture
- use audio-visual channels
- share teaching tools with other teachers
- better organize a lecture
- have students become more involved
- mine other interests of students

4 Risks of media and technology

There are general problems to be aware of:

Methododical

- danger to recycle old material again and again
- use of outdated technology
- use of emerging technology which is not ripe and error prone
- overuse and monotonicity (power point)
- risk of hardware failure
- use of undigested material

didactic

- didactic difficulties (small fonts, time loss)
- teachers unable to handle the complexity
- teaching style does not match the teacher
- aesthetically pleasing but irrelevant
- lose focus on learning goals
- expectations of les mental effort [3]

The question, how a teacher should enrich the class room experience for students is difficult. It is much easier to list some pitfalls.

I) Technological challenges	II) Illustrating the obvious.	III) Overuse
Technology should not be used for the sake of using technology. Here are examples of pitfalls: • teacher is not comfortable with technology • cable forgotten, projector compatibility not tested. • application crashes, machine needs to reboot • projector needs adjustments, picture not sharp • overhead projector using slides which are unreadable	Enrichment which focus on **simplistic concepts** only offend the intelligent mind. Examples: • Applets illustrating the "rate of change" using the tangent. • Interactive matrix multiplication • Animating the Riemann sum • Animating a function like traveling wave	Too much technology can be like adding too much salt to a well prepared dish. • A teacher is proud about a specific software program and spends time explaining the inner details of it. • Online problems which are routine and boring and of the same multiple choice type. • Students sit behind computers in classrooms. No class-time left to cover essential material. • Every computation is done on a pocket calculator
IV) Too much Complexity	**V) Big brother**	**VI) Laziness**
A in class or online demonstration should be memorable, fun and still easy to use. • Assignments in CAS, which need serious programming from the student. • Assignments which challenge the CPU of the computer too much and don't run on older machines. • Assignments with unnatural problems. • Assignments requiring too much background knowledge in other fields. • Lecture examples in which the teacher gets bugged down.	Technology can be used to gauge and monitor the learning progress of students. • Monitored online homework can be as stressful as an exam. • Computer security is known to be lax at educational institutions. • Students fear that scores are used for grades and letter of recommendations. • Plagiarism software takes away the author right from the student.	Technology can enhance but not replace the direct student-teacher interaction. Pitfalls: • Using technology to save human resources. • Automated grading does not reveal key obstacles. • Series of lectures in powerpoint format. • Too much information on overhead. • Reusing problems for exams, especially for online tests.

In the above table, CAS is an abbreviation for computer algebra system, CPU an abbreviation for computer processing unit.

VII) Lack of time to prepare

Preparing a class using technology needs lots of time and often eats time for didactical preparations or being physically available to students. Using technology needs serious preparation:

- Authoring the tool or learning to use a given tool.
- Testing equipment and program before class.
- Having alternative in case of failure.
- Embed the module with didactic merit.
- Try out many many things and throw what does not work.

VIII) Outdated/emerging technology

Languages for the web like SVG,VRML,AIML, MathML, Flash are evolving and changing fast.

- Emerging not yet fully standardized technology does not yet work.
- Older technology is often no more supported.
- Even simple programs need attendance.
- Plugins get outdated (example: Adobe flash plugins)

Everybody who has used technology in the classroom knows of immediate risks. Here are some more concrete examples.

Hardware failure

- Laptops or projectors can fail.
- Sound or video Cables can break.
- Internet connection like blind spots for wireless.
- Projection software projects on wrong screen.

Software failure

Even after having used a software for many years, I found it necessary to test things before class. Many things can go wrong. For computer algebra systems, we can have:

- The software password might have expired or updated.
- The correct syntax of a command is not remembered. Tiny mistakes can kill things.
- The software is keyed and needs internet access to work.
- The software works on an older operating system but not a newer one.

Incompatibilities

- Java applets can still depend on browser and operating systems. Not all combinations work
- There are different versions of Flash. The correct plug-in has to be present.
- Webpages are designed to work for specific browsers only.
- Content is not accessible for students with disabilities.

Demonstrations

- Even if tested, an experiment can go wrong (it **will** - by Murphys law)
- Interesting experiments can be dangerous, even in a mathematics class.
- Experiments for the sake of experiments, especially if overused can be boring.
- An inappropriate page from the history is displayed during lecture.

Preps

- Danger of having an accident
- The demonstration can fail didactically.
- Essentials of the experiment can not be seen from the back of the room.
- The show distracts from the essential things.

Movies

- Statements about political events.
- Copyright issues.
- Inappropriate clips
- Religious stuff

Webpages

- Webservers are not available.
- Databases are off-line.
- Webpages are outdated.
- The teaching is impersonal.

5 Computer algebra systems

At the ETH Zürich, before being an undergraduate course assistant for the calculus program, I had been a course assistant for a computer algebra system laboratory. The systems included "Reduce", "Macsyma" (which still exists an open source program "Maxima") and "Cayley" (which now has evolved to become "Magma"). Because people at ETH like **Roman Mäder** were actively involved in the early development of Mathematica, we had access to this particular system even before the first versions of Mathematica were rolled out in 1988/1989. So, because I had used such systems intensively since 1985, I take teaching with a computer algebra system for granted. time. It should be an integral part of any calculus course.

Computer algebra systems were also essential for my research. Of course, I was eager to use it when doing my first independent steps as as teacher: I used computer algebra systems extensively at Caltech, first when teaching a course on dynamical systems in 1994 and also for illustration purposes in probability, geometry and calculus courses. Caltech had a laptop and a portable overlay for the overhead projector. At the university of Arizona, the setup was more sophisticated: there were classrooms, where every student had access to computers. I taught a course on differential equations in such a classroom. The 90'ies were an exciting time for the development of technology in the classroom. Calculus was rejuvenated (and partly overdone) by the so called "calculus reform". One of the characteristics of this "revolution" was a more aggressive use of technology.

Also at Harvard, the use of technology already had a culture, when I arrived in the fall of 2000. My experience with technology in the classroom had certainly helped for being hired. Mathematica was used years before I started to teach there and it was relatively easy for me to continue this tradition. Harvard has a site licence for various computer algebra systems. For calculus, we often use Mathematica. But Computer algebra system projects usually have a low priority and are done within a project. Many students use the system throughout the semester for example to check their homework or experiment. Other students just do a project which can be done in a few hours. Like this, the focus is still on the mathematics and not on the technology as it should be.

6 Benefits of computer algebra systems

What benefits does a computer algebra system bring to the calculus curriculum?

- It allows to do proofs in class with the help of computers.
- One can spice up some homework. Students can check more complex homework.
- It allow exploration and experiments. The computer algebra system is what is the microscope is to the biologist or the telescope for the astronomer.
- One can do more creative assignments with more realistic problems.
- Many students are already familiar in the use of such systems from high school classes.

As a teacher, I found it crucial that the installation of a computer algebra system is painless for the student. it is crucial that the first steps are easy and that help and support is available. One teacher has to be "email help line" during submission of projects. I find it important that no external libraries need to be loaded to do basic things. For example, no additional modules should be loaded in order to solve basic linear algebra or calculus problems. This has constantly improved throughout the years. As every programmer knows, libraries can be a major source for frustration in any programming language, especially in the long term when different versions of the library coexist.

7 Risks of computer algebra systems

It is good to anticipate problems and pitfalls, when enhancing a course with a computer algebra system. Guidelines for using computer algebra systems in the classrooms exist for a long time (i.e. [2]). Here is a list:

- Technological glitches are not anticipated. Complex software systems often are imperfect.
- No testing of hard and software is done before class.
- The teacher is unfamiliar with the algebra system and can not proceed if things deviate from the scripted path.
- Small default fonts are used for presentations. As with overhead slides, only a few lines should be visible on the screen.
- The teacher dwells on programming subtleties, which can not be absorbed nor appreciated by the students.
- The computer algebra system is used for trivialities like plotting a parabolas, which can much better be done on the blackboard.
- Obvious things are illustrated, while difficult issues are skipping over. Dwelling on trivialities insults an intelligent mind and takes time from more important issues.
- The software seduces a teacher to give too hard assignments. Especially for experts of a system, it can be hard to imagine what students know.
- The tool can is overused. Overexposure to a any teaching aid can become a problem.

8 Video in the classroom

Video can be used or complement well the classroom. Certain things can be visualized well with a little movie clip. Video can help so to spice up a certain topic.

Mathematics appears in many movies. I personally like to collect movies with mathematical or pedagogical content. Some clips can be seen my personal website. Having a library of movies available can help to spice up some lectures. Here are some examples, where I used video directly in the classroom:

- "The Core" (Divergence theorem, gravity inside the earty)
- "The beautiful mind" (How can $curl(F) = 0$ imply that F is not a gradient field)
- "Good will Hunting" (linear algebra in graph theory)

Sometimes in a metaphorical context

- "The Good, the Bad and the Ugly" (unique, no or infinitely many solutions)
- "Shrek" (integrals have layers)

Or to use as parts of presentations

- XXX (in linear algebra for special class of X matrices)
- "Dodecahedron deformation"
- "Dancing turkey"

9 Benefits of video in the classroom

The reason to use one or two minutes of the time for a movie scene are:

- to stimulate memory: students associate the scene with a mathematical concept. It is used as a memnonic trick.
- to breaks the routine. Especially for a 90 minute lectures, a little movie clip can be a fresh start.

10 Risks of video in the classroom

- First of all, the material needs to be appropriate. Explaining things using a scene of "Bikini calculus" is not recommended for example.
- I found it also important that not too much time is spent on such gimmicks. Students expect to learn something, not to be fed with movies.
- Do not show video for the sake of showing a video.
- Technological glitches are terrible. They can destroy the entire lecture.
- As with any medium, overuse can make it negative. The change is important.

In doubt or time pressure, I skip any video presentations in class.

11 Benefits of video on the web

I use video on the web primarily for entertaining purposes. For galleries, for presenting slides or when doing a podcast. Video is great to spice up some aspect of the course. In the time of "You Tube" it is easy to share video on servers. Entire lectures can be made available.

12 Risks of video on the web

I made once a movie of a thanksgiving turkey dancing to some music for example. One of the student feedbacks on Google video had been: "this guy has much too much time on his hands".

There are **copy right** issues and **privacy** issues, if pictures or movie captures of students are shown on websites.

13 Authentic media

Besides computer algebra systems and multimedia, there is the old fashioned demonstration in the classroom. Examples:

- Vortex gun
- Blow gun
- Helium zeppelin (often used by a collegue Dale Winter)
- Resistor network
- One sheeted hyperboloid
- Chemical experiment
- Photography and optics
- Models from the department surface gallery
- Coupled pendulum from Harvard media room
- Double pendulum
- Catastrophe machine

14 Benefits of authentic media

Again, it helps to make a lecture memorable. Students can associate a lecture with the demonstration and will less likely forget it or recall it better. I still remember most classes or talks in which props had been used (even in research lectures, I have seen Marsden, Devaney lectures which I still remember). From the time as a student, there were some lectures (linear algebra by Specker for example, or physics demonstrations), where preps had been used. I still remember that lecture from the hundreds of lectures.

15 Risks of authentic media

- Demonstrating the obvious.
- Danger of failing the experiment (it needs practice and possibly support)
- Accident. Dagger hitting metal (accidents)
- Not being familiar with the details (a mathematician might not know all the physics)
- Using an unfamiliar subject (for me it would be baseball for example)
- Being distracted from the real things (there is often time pressure even to cover the essential material)

16 Web based teaching

Web based learning has gone through a steady progress since the web exists. Not everything was successful. Not all web based courses in mathematics have succeeded. Since I used websites first for courses in 1994, the number of features which typically appear on a website have increased dramatically:

- basic websites with syllabus, homework exams, handouts etc.
- collaborative websites (Toolkit and now ISites at Harvard)
- wikis
- blogs of the teacher
- online discussions of the class
- electronic homework (webwork from Rochester)
- interactive tools (java, flash)
- quizes (javascript, database driven like placement tests)

17 Video in teacher training

Videos of classroom lectures provide an excellent opportunity to learn to teach.

- Clips from Hollywood movies
- Teaching videos from Harvard

18 Risks from video in teacher training

- Privacy of the teacher
- Privacy of the students
- Teacher becomes an actor

Too many different things can also produce a complexity which is overhealming for beginning teachers. On the other hand, the curriculum as well as the structure of calculus courses requires to go along some well defined path.

Bringing movies to the classroom, doing Mathematica experiments, group work, showing some demonstrations, and still preparing a well structured lecture which is adapted to the current knowledge of the class and fits into the global picture set by the entire course is already not easy.

19 Conclusions

The most important factor for a successful lecture remains the teacher. The interaction with the students and the clarity of the expositions can be far more important than any ideological parameters. A wide variety of teaching styles can work and can coexist in the same course: some used technology, others do not use it at all, some teachers are more formal, others prefer to be more informal.

- What works for one teacher might not work for an other teacher.
- Using technology is like telling jokes: some can deliver, others better do not.
- It is helpful to be aware of the variety of tools which are available.
- Benefits and risks can be close together.
- Using technology can improve a lecture but also increases the risks of a failed lecture.
- A marginal but valuable increase of the lecture quality comes with the risk to lose the entire lecture. Rule of thumb: you can increase the benefit by 20 percent and lose 80 percent. But the 20 percent are worth fighting for.

The art of teaching in the classroom can be compared to the skill of preparing a meal in a restaurant, where the teacher is the cook and the students are the guests. The best efforts of teaching, the most skillful use of technology and the finest pedagogy can be ruined by a tiny mishap. The best meal, using the best recipes, the freshest ingredients can be spoiled by adding too much salt for example. Besides that, there are tasty things which are not healthy or menus which are difficult to prepare well. Simple menus are easier to prepare and still can taste good. Complex menus can please a gourmet but the chef has to be experienced enough to prepare it.

There is also the danger of overuse. Even the best meal, when served repetitively looses its value. Eat lobster roll twice a day for a week and see what happens. At Harvard, where our group often organizes a calculus course with dozen sections, there is also the challenge to coordinate a course with a dozen different sections. In the restaurant metaphor, the course head is a chef, who also has to make sure that the other cooks can prepare a tasty menu. In this restaurant, both experienced cooks as well as newly apprenticed teachers work together. Using a wide variety of always fresh ingredients can help the digestion.

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