The Power of Integration: Assessing a Recent Best-practice Method for Large-class Instructional Materials Generation & Presentation

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Abstract

Computers are used in nearly all modern university classes of a certain size. The stated rationale for their uptake includes an increased efficiency and consistency in course delivery; presenting in a way that appeals to a 'digital-youth'; and enhancing the overall student experience. However, experimental evidence reviewed in this paper suggests that the most common platforms for this purpose do not increase student performances, and in some cases are not students' preferred method of instruction. This paper analyses what is going wrong with common presentation software and practice, from the perspective of *cognitive load theory*, and then introduces and assesses a recent software solution (LaTeX 2_ε–Beamer) which relies on a fundamentally different philosophy of practice. Preliminary quantitative and qualitative measures are presented from a trial of this new system across a very large first-year quantitative course. While concluding that the system is a vast improvement on standard methods, and can be adapted to meet many of the experimentally verified requirements for enhanced student learning, it is concluded that the system is not (yet) the silver-bullet to be used in every instructional context.

KEYWORDS: LaTeX 2_ε, BEAMER, LARGE-CLASS, NOTE-TAKING, PROJECTION, COGNITIVE-LOAD-THEORY, PowerPoint

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"With a chalkboard, at least the lights were on and you didn't fall asleep."

Student comment regarding PowerPoint,
reported in Young (2004b)

Introduction

Whilst education committees the world over have delivered high-powered computing and projection facilities into the hands of the large-class instructor, it seems that, whether due to inadequate training or the ubiquity of dis-intelligent software, many instructors may indeed be embracing such technology but not actually using it to effectively improve student learning. Indeed, some time ago, Goodyear (1998) noted that,

> "The design and implementation of [computer-aided learning resources], for which we can use the shorthand term 'courseware, continues to prove a major obstacle to the widespread exploitation of computer technology in support of learning." (Goodyear, 1998, p.145)

Whilst Goodyear spoke specifically to the Generic Tutoring Environment (GTE)-type systems, his comment is as relevant to any 'courseware' component today as it was then. Today, we see the major players in the instructional materials generation and presentation realm (e.g. *Microsoft*'s PowerPoint, *Apple*'s KEYNOTE) continue to find willing adopters from the high-powered boardrooms of corporations and marketing departments to the halls of government. Nevertheless, the experience of these technologies, as applied to the university instructional environment have been mixed, to say the least. However, to those who have ever interacted with computers and been brought to audibly 'gasp' at what they are capable of in the right hands, one is prompted to yet ask, 'what is the current best-practice technology available to the university instructor?'

This paper will report on one such technology, or rather, on the marrying of an established technology – the widely used professional document preparation language LaTeX 2_ε (Lamport, 1985) – with a recently designed and very beautiful projection system called Beamer (Tantau, 2003). The salient difference that this combined LaTeX 2_ε–Beamer system offers as compared to the standard projection software is that it is set up with the fundamental rule of computer programming in mind – 're-use, don't duplicate'. From a single document containing the information for the lecture, the intgrated system enables the facile production of projector slides, class notes, a full lecture book, worked-solutions to examples, definition compilations, etc. This powerful underlying philosophy, combined with the $\LaTeX\,2_\varepsilon$ professional document preparation language means that where common projection software falls down (e.g. making revisions, changing styles, mathematical nomenclature and figures), the combined system not only overcomes them, but enables the production of additional learning materials and tools that previously would have been prohibtively time-consuming to generate.

In what follows, we first re-visit the characteristics of standard presentation software from the perspective of evidenced-based instructional science, especially with an emphasis on *cognitive-load theory.* Second, the integrated $\LaTeX\,2_\varepsilon$–Beamer system is introduced and assessed based on its use in a large numerical lecture section at a major Australian university. Finally, we finish with a discussion of the technology with an eye to future developments in this area.

Note-taking & the Lecture

> "Somewhere between the lecture and their notebooks a dialogue had quietly taken place. This internal dialogue is often as stimulating as, and more open than, any classroom discussion. Moreover, the internal dialogue always focuses on just those issues that interest us ... It always concerns itself with what bothers us most." (Bergman, 1983)

Although the large-class lecture might appear out of date given the recent rise and rise of electronic (i.e. remote) means of communication especially amongst students (Kennedy et al., 2006), there are some good reasons why it is still the predominant form of teaching in most modern universities. Bergman's quote above surely uncovers a major component of the lecture's continuing appeal. Put more prosaically, Saunders and Welsh (1998) recalls Angell's comparison of the student's mind to 'the interior stadium', that is, the 'interior game – baseball in the mind'. The internal dialogue that each student is propelled into during a lecture is that which the instructor must direct, inform, challenge and at times, compete with. In its best expression, both the instructor and student will be playing *the same game*, this silent dialogue exciting the student not only to learn, but to retain what they have learnt. In the same paper, Saunders and Welsh (1998) provides several reasons why a lecture is still a relevant mode of teaching. The lecture provides for a 'social facilitation' or *collective learning environment* – students can simultaneously witness the expressions of others who are thinking the same thoughts at the same time, being stimulated by the very simultaneity of this response. The large-class lecture is also a *flexible* means of teaching since the instructor can directly respond to questions, or puzzled faces, asking them which component of the material they are having difficulty with and so tailoring the presentation to their current understanding. Additionally, but not insignificantly, the lecturer can give a *'live model of a person thinking'*, the very act of thinking out-allowed in an enthusiastic way can provide a stimulating model for a student's own working dialogue.

But what makes a *good lecture*? Saunders (1998) suggests 'four generally accepted propositions' that should guide instructional design:

1. A listener's limited capacity to process information (Miller's (1956) 7$\pm$2);
2. The importance of prior experience or 'learning set' (how much does the student already know?);
3. The importance of motivation (e.g. an enthusiastic teacher, aiming to instill 'intent to learn' in the student); and
4. Dominance of visual over verbal means of communication.

Of these principles, only (1) and (4) are directly applicable to the preparation of lecture materials. The former is explained under the heading of 'cognitive load theory' and shall be discussed presently. The latter, that of visual (imaginal or pictorial) representation dominating verbal to facilitate memory (by factors ranging from approximately 1.5 to 3 according to studies by Bower and Hilgard (1981, p.5)), should encourage the instructor to rely heavily on thought-experiments or tangible thought-illustrations, or the direct representation of a concept in pictorial form.

Cognitive load theory (CLT) argues that despite the apparent appeal of traditional theories of instruction such as 'authentic learning theory', where learning tasks based as much as possible on real-life tasks are the 'driving force' (Merrienboer et al., 2003) behind educational effort, the basic *cognitive capacity* of the learner can be easily over-whelmed in any context and thus must be of first-order priority when considering instructional design. Moreover, the activity of *note-taking* is a far from trivial task in itself. Studies reviewed by Piolat et al. (2005) note several salient points regarding note-taking, foremost of which, is that note-taking is *cognitively hard work*. The attention of the note-taker is divided between listening, watching, cognition (both memory and synthesis), and their own page, the combination of which often causing the note-taker to undertake a variety of note-taking short-hand such as abbreviating procedures, syntax transformation, physical formatting, or pre-determined strategies (e.g. the 'seven-question' method). Piolat et al. notes that such abbreviation is mandatory given that average writing speed trails average speaking speed by approximately an order of magnitude (0.2 to 0.3 words per second (wps) versus 2 to 3 wps respectively). Actual comparisons of the cognitive load endured during note-taking in relation to other learning tasks can be gained by the standard 'dual-task' experimental paradigm. These studies indicate that note-taking from a lecture ranks in the first-tier cognitive tasks that have been studied, alongside 'Planning', 'Revising', 'Composing a text', 'Translating', and 'Playing Chess (experts)' (see Fig. 1). Piolat et al. conclude (p.306) that note-taking, 'is a unique kind of written activity that cumulates both the inherent difculties of comprehending a message and of producing a new written product'. Indeed, strategies the note-taker employs to deal with this cognitive load are to either emphasise *comprehension* (listening or reading and rarely taking notes); or emphasising *transcription* ('getting down' as much as possible, without processing the content).

⇐ **Fig 1 about here**

In which case, it is argued by authors such as Merrienboer et al. (2003) that traditional approaches to instruction will fail unless the student is afforded *scaffolds*, that is, 'all devices or strategies that support students' learning' (Merrienboer et al., 2003, p.5). Scaffolds may include (in increasing order of complexity) worked-out examples, a completion task, a goal-free task, or a reverse-task. Merrienboer et al. suggests that just-in-time information delivery (higher detail information revealed only when a student needs it) is also helpful. In a similar vien, Renkl and Atkinson (2003) supports the effectiveness of the 'fading principle', where pieces of a worked solution are gradually taken away from the student such that eventually the student can undertake the problem from start to finish on their own. For lecture note-taking Piolat et al.'s review finds that non-linear note-taking strategies (e.g. with an outline (skeleton) or matrix framework) are all preferable to linear (non-scaffolded) methods of note-taking. In particular, graphs, figures and concept-maps foster 'the selection and organization of information' (p.295). Furthermore, studies note that students not only learn when they review their notes but when they make the notes (known as the *generation effect*), which schools against handing out direct facsimiles of an instructor's presentation.

But what of the newer multi-media methods afforded by modern courseware? Mayer and Moreno (2003) argue that CLT applies equally to pictorial (or other) information presentation as it does to textual presentation. They combine a 'dual channel' model of multimedia learning with standard CLT, where it is supposed that humans possess separate information processing channels for verbal and visual material. Ergo, by CLT, if either one (or both) of these channels is overloaded, the student's capacity for learning drops dramatically. The authors detail five common problems that might arise in multi-media presentations and suggest solutions. They argue that the *amount* of information on a slide (or other media) should be small (their term: 'weeding'); that the material be broken down into 'bite-sized' segments and introduced sequentially (pre-training); that signalling helps to induce information processing (e.g. standardized formatting and styles); that *verbal* communication should be preffered to textual presentation; and, that if using pictures or figures, text should be aligned and synchronised to the pictorial representation (i.e. over-coming the split-attention effect (Sweller, 1999)).

It should be noted that many of the above studies and reviews consider almost exclusively 'ideas'-based instruction (i.e. non-numerical education). As it turns out, numerical instruction further increases the difficulty for the instructor and the student alike. Indeed, Becker (1998) suggests that mathematical notation be used *sparingly* in the teaching of Economic concepts. And, if using notation, the instructor should be at pains to ensure that it coheres with standard notation principles used elsewhere in a student's learning experiences (e.g. the Mathematics Department) [1]. Furthermore, any mathematical figure used (e.g. graph or plot) should be correctly labelled, with units and a scale. Notation should be clear, easy to read and unambiguous. With reference back to CLT, it seems that Becker is really arguing that when using mathematical notation, nothing should *surprise* the student, other than that which is being taught – a lack of information, or the inclusion of ambiguity simply takes up another element (or several) in the student's limited short-term memory which should be wholly given over to the new concept or technique.

Clearly, the principles of good instructional design reviewed above require a flexible and somewhat powerful presentation system to accomplish them in the classroom. In the next section we shall briefly review current main-stream instructional technologies given the overview of sound instructional design made above.

> "In lectures, the computers should be as transparent as possible. Nothing distracts a student more thoroughly from the conceptual point at hand than the words 'FILE NOT FOUND' appearing on the screen when the teacher has said, '`Open c:\brilliantinsight.new`.'" (Murray, 1999, p.316)

The quotation from Murray brings out the worst in any kind of fragile technology. For the instructor, however, such fragility is magnified by the expectations of a hundred or more students. A brief survey of the literature concerning current projection technologies shows (unsurprisingly) that although popular software such as PowerPoint have been adopted by many instructors, few are able to reflect in glowing terms on the experience.

For instance, Parks (1999) notes that since '[his] handwriting is not readable (even by [Parks]), PowerPoint was a better medium.' His teaching system used PowerPoint slides for presentation and a hand-out which was a simple printing of those slides three to a page. Under 'the Bad' Parks writes that more prior visual aid creation was required (compared to simple notes) and so afforded less flexibility in the lecture tiself, plus the preparation was far more time-consuming. Further, he found that handing out printed copies of the slides induced 'passivity in some students' which he reasons is because they 'have no need to take notes when they have the printed copy', which echoes the research findings reviewed above. Not only were students not actively engaged during the lecture, but they missed out on the *generative* effect of note-taking. Under 'the Ugly', Parks writes that equipment trouble plagued his early years, though over time this went away, and that 'at least as ugly as equipment failures is slide overload'. This reflection again matches aspects of CLT theory, and is a major danger of pre-prepared slide instruction; there is an high tendancy to speed up and 'click' one's way through the material, forgetting to engage meaningfully the students at all.

Experimental studies support several of Parks' reflections. In a trial involving medical student instruction using either PowerPoint or over-head transparencies, Ricer et al. (2005) found no significant effect on short- or long-term retention due to PowerPoint. The trial used a 'good teacher' for both sections and the over-heads were made by printing the PowerPoint slides directly (which may say more about the organisation of information under PowerPoint than about a comparison between the media). Similarly, three studies on students taking introductory Psychology courses by Hardin (2007), Bartlett and Strough (2003) and DeBord et al. (2004) find mixed support for the PowerPoint technology. Hardin finds that it is the *instructor*, not the technology that is most crucial to student learning outcomes [2]. Bartlett and Strough studied the effect of both a course-outline and the use of multimedia (PowerPoint slides, along with video-tapes and classroom activities) and found significant improvement to student performance where a course-outline was afforded, but no significant gain on this when multimedia was added. The authors conclude, however, that despite non-proven gains of the multimedia approach, the teaching method increases efficiency for multi-section teaching, and might be especially useful for early career teachers. Finally, and in contrast to the other studies DeBord et al. again compared PowerPoint slides with over-heads and found a 'preference' amongst students for PowerPoint, but no significant difference on grades. The qualitative student response to the use of PowerPoint is in line with these findings. Two brief reports in *The Chronicle of Higher Education* (Young, 2004a,b) suggest that many students quickly find weak-spots in the use of PowerPoint such as instructors moving too quickly through the material, or simply reading the slides out verbatim, although are prepared to commend instructors who use the technology effectively.

Systems other than PowerPoint are available, but are far less reported on in the literature (presumably due to the ubiquity of PowerPoint). For instance, Stone (1999) reports positively on her combination system for instruction which includes computer graphics, assisted (skeleton) notetaking, video, sound and the World Wide Web. These are integrated with the *Asymetrix* Toolbook software. Stone calls this kind of approach, 'Computer Based Lecture design' or CBL. Or in a different, but related context, Erwin and Rieppi (2000) report on a first-year Psychology trial using a 'multimedia classroom' versus a 'traditional' classroom. However, a number of factors were potentially confounded in this study, as the class-sizes differed substantially in each treatment (28, 38, and 38 students for the traditional classes, but 64, 95 and 37 for the multimedia classes), and the multimedia classrooms had a range of tools available including standard computers (loaded with Toolbook for graphics display, and MICROSOFT Word for lecture note display), video-disc/tape and CD-ROM players, audio-tape player and keypads for dynamic feedback. Nevertheless, the study found very strong evidence for improved mean performances under the multimedia classroom treatment (80.46 versus 61.66, $t = 6.1$) despite no statistical difference in pre-class aptitude testing.

Summary

With the brief literature surveyed above, it is possible to draw up something of a 'wish-list' for effective large-class instructional technology. We will make this effort here, and so be able to assess the new LaTeX 2_ε–Beamer approach discussed below;

1. The system should provide the student with some structure for note-taking that relates to the material;
2. That structure, however, should not be *complete*, since space for generative note-taking by the student must be allowed;
3. The system should utilise a *consistent* typography and style which effectively signals learning-cues to the student;
4. The system should not be too complicated to learn or generate materials with;
5. The system should allow as flexible as possible presentation of the material within the lecture to respond to student needs and questions;
6. The system should employ graphics (in the form of figures, plots, schematics, mind-maps etc.) as much as possible to convey ideas;
7. However, these images should be built up gradually and feature associative labelling with text;
8. The system should afford sequential revealing (or hiding) of information to (from) the student;
9. For numerical subject material, the system should present clear, unambiguous type-setting and nomenclature of mathematical statements, with any plots or figures annotated with appropriate and consistent labelling;
10. The system should provide any other means of scaffolding possible such as sectioning, a contents page, or other navigational aids.

LaTeX 2_ε–Beamer: An Integrated System

The system to be presented presently is due largely to the hard-work of the open-source community concerned with professional document preparation, and in particular to the efforts of Till Tantau who has developed the

Beamer class. To begin, one of the distinguishing features of this novel system is its departure from all common document preparation and presentation systems in use. Namely, that the LaTeX 2_ε–Beamer system utilises the fundamental principle of *content-reuse* to achieve its diverse outcomes. In any 'by-hand' lecture materials system, if the instructor wishes to create a new media format to enhance their teaching (e.g. lecture hand-outs), they must build this from scratch, or, if feasible, they can make a facsimile of one format to shift it to another (e.g. photo-copying overhead transparencies to give to students) (see Fig. 2) [3]. Whilst the dilligent instructor will make these changes, it is not uncommon for many course materials to be seldom revised. Alternatively, an instructor may keep their course flexible and up to date, but revise only their own notes, and thus not provide the student with the benefits of other materials to enhance the learning experience. ⇐ **Fig 2 about here**

For PowerPoint equivalent users, this situation is slightly improved, since these software allow the user to produce slight variants of the slide view when format shifting (e.g. $n - up$ printing per page, or printing lines for working beside slides). Additionally, notes may be added to each slide which can be separately printed, although this feature seems more aimed at producing notes for the instructor rather than the student. Since the systems provide no opportunity to re-format the content in a systematic way, notes (or any other format shift) cannot be made to have any specific learning aids relevant to their format.

In contrast, the LaTeX 2_ε–Beamer system to be assessed here, takes advantage of the simple principle that authors should concern themselves with content, not style when putting down their ideas. [4] To achieve this, it requires that the author place small 'tags' in their text (see example listing in Fig. 3) which can be recognised by the document preparation language, and formatted accordingly. For example, line 8 of the listing shows the use of the `\mode<beamer>{ ... }` command, which indicates that the enclosed portion (here, the actual proof) should only appear on the screen (slide mode) and not in any other format. Similarly, line 4 of the listing indicates that the 'theorem' class is being called. Note that the instructor need do no more 'manual' formatting – the system will automatically apply the specific 'theorem' formatting class appropriate to the format being generated (e.g. 'handout', 'beamer' (presentation), or 'note' mode). In almost all cases, the default formatting is both attractive and elegant and needs little further adaptation by the author. However, should the author wish to customize stylistic elements, the interpretation of these tags need only be changed *in one place* at the beginning of the document; such changes will be carried through anywhere that the tag (and the information it pertains to) is found.

The Beamer package [5] is one of many add-on packages that extend the basic LaTeX 2_ε mark-up to provide a range of extremely useful tools for giving presentations. In practice, this means that the instructor need write only *one* core document from which standard outputs such as attractive slides for presentation, or an article for hand-outs, or a full Lecture Book can be created (see Fig. 4). Additionally, because of the tag-based philosophy, it is possible to automatically produce very helpful organisational tools for the student such as an index of key terms, or a compendium of definitions, worked-solutions, or proofs.

⇐ Fig 3 about here
⇐ Fig 4 about here

A more elaborate example is given in slide form in Fig. 5 and corresponding Lecture Book form in Fig. 6. Again, it is stressed that these formats were produced from the one source document with simple commands as in the listing in Fig. 3. In terms of pedagogical advances, the basic slide and document mode has many valuable features to be discussed presently.

⇐ Fig 5 about here
⇐ Fig 6 about here

Scaffolding tools As discussed above, from the perspective of CLT, scaffolding is a vital part of enhancing student learning (Merrienboer et al., 2003). The present system offers a number of scaffolding tools. First, sectioning commands given throughout the document appear at the top of each slide (i.e. 'Introduction', 'Limited Growth', and 'Logistic Growth'). Note that the level of detail can be controlled, with the subsection 'Logistic Growth Defined' visible in the Handout mode, not shown in the slide mode. Thus, during the presentation, the student is aware of where the presentation is up to, linking the present slide with a meta-concept or idea. Second, in this (standard) presentation mode style, slides within a main section are indicated by an unfilled circle such that the lecture's progresses can be followed in this area. Moreover, the system causes these headings (and circles) to become *hyperlinks* such that the instructor can navigate in a non-linear way through the presentation, revisting a prior (or future) point with ease. Third, a constant stylistic typology is easily maintained, with a 'Definition' and 'Example' class shown in the top and middle slides from Fig. 5 and their counterpart lecture book format can be seen in Fig. 6. The content is the same, but appropriate (and helpful) stylistic presentation differs across the formats.

Engaging the student and avoiding Cognitive Overload Again, as discussed above, avoiding placing too much on one slide at a time is a key aim for effective communication of ideas. The present system provides simple 'overlay' techiniques, with syntax as found in the example listing (Fig. 3) such as `\item<4-> ...`, or `\visible<3-4>` to set a point to appear only on and after the fourth 'click', or during the third and fourth clicks only. This technique was used in the bottom slide of Fig. 5 to reveal each curve and equation in sequence. Furthermore, the example also shows the use of the `\mode<...>{...}` command, with the *Example* class allowing the solution to be shown in the lecture (Fig. 5) but not in the Lecture Book (Fig. 6). Of course, the instructor can easily set such an example as an 'in-lecture' task, and reveal the solution after an appropriate time, which can be a very effective way to give feedback both to the instructor and the student (Bligh, 1971). In both cases, the system encourages student participation by providing 'skeleton' style notes for them to fill-in, annotate, highlight and question as they follow along with the instructor.

Precise quantitative communication In the quantitative sciences, the ability to accurately portray mathematical symbols and plots is of paramount importance (Becker, 1998). At present, presentation software simply cannot do either effectively, with plots, in particular, normally having to be imported from a third party software, costing both time and in-lecture control over the content delivery. In contrast, due to the native ease with which the $\LaTeX\,2_{\varepsilon}$ document preparation language handles mathematics, formulae are clear, and precise in both formats. Furthermore, as shown in the bottom slide of Fig. 5, with the aid of the widely-used add-on pstricks package, accurate mathematical curves can be drawn by actually entering the formula itself, on a real set of axis [6].

Further tools for navigation and revision Again, due to the $\LaTeX\,2_{\varepsilon}$ language that supports the system, the compendium of notes (e.g. a Lecture Book) can include elements such as a Table of Contents, Table of Figures and a Table of Tables. These are automatically produced straight from the source-material, due to the use of `\section{...}` and `\subsection{...}` (etc.) commands within the document. Additionally, by use of the index package, keywords of interest for student attention and revision can be added in a simple index covering the whole course. An example of this usage is given in the extended example, with the keyword phrase '`\key{logistic growth equation}`' causing different font and colour styles in each format and for the phrase to appear in the index pages of the Lecture Book. Of course, other tools such as chapter references to textbooks (e.g. `\chap{HPW 3.2}`), or marginal indications for revision, attention or caution can be constructed and used throughout the materials development process.

Assessing the System

In Theory

With reference to the 'wish-list' for an instructional system based on current pedagogical evidence and as presented above, the system introduced in the preceeding section does very well, but not perfectly. Certainly, on many items, the combind $\LaTeX\,2_\varepsilon$–Beamer system clearly out-paces present presentation software. Key components such as directing *some* material to the notes (2); producing a *consistent* typography and style (3); allowing non-linear presentation by hyperlinked section-headings (5,10); and creating correct and clear numerical equations and plots that can be gradually revealed (7,8,9) are present in this system, and are almost impossible to feasibly reproduce in common presentation software reviewed above. Other elements such as providing students with a structure for note-taking related to the material (1); and employing graphics where possible (6) are presently afforded in other presentation software.

Remaining from the list is that the system should not be too complicated to learn or generate materials with (4). For some instructors, this is a non-trivial point. The great benefit (and presumably part of their enduring use) of common presentation software is the ease with which the user can 'drop' images into a slide, and in some cases, even have these automatically arranged, or snapped to a reasonable grid. Furthermore, a variety of default backgrounds and styles are available, which if used correctely can achieve a small number of the benefits of the present system. In contrast, the strength of the present system – that the instructor must employ the 'tag-based' document preparation philosophy – may also present as a major downfall for those not used to such a structured approach. However, it can well be argued that the very requirement that the instructor employ sectioning, stylistic, and other tags within the document, causes them to pay close attention to the overal structure of the document, and think first to what *kind* of information they are conveying, and then to how best to express it within the stylistic modes available. For those instructors who already write within the $\LaTeX\,2_\varepsilon$ document preparation language (e.g. for research communication), the transition costs (as found by this author) were small indeed. This is especially so given the gains in both efficiency and student learning outcomes made by the enormous range of (previously unachievable) pedagogical tools that are provided by it.

In the Field

The present system was trialled by the author in a large first-year quantitative course, 'Quantitative Methods A' (QMA) during the first semester of 2006. The course includes a variety of topics and tools in mathematics that students require for their further studies in the Faculty of Business. Topics include financial maths, linear algebra, linear programming, and calculus (up to constrained optimization in several variables) and so rely heavily on the explanation and demonstration of mathematical concepts. Typical class sizes ranged from 180 to 400 students. Due to the positive response from students and instructors alike, the system is now used across all 5 lecture streams in the main QMA session, thus engaging 4 different instructors, and around 1200 students.

Unfortunately, the author had not previously taught in this subject, and so direct comparative data are not available. However, instructors in other sections (four in total) teaching concurrently in the 2006 semester and in previous years employed a combination of overhead transperancies and traditional 'chalk and talk'. Standardized testing was conducted on the present author and yielded the scores shown in Table 1.

Table 1 Proportion of students who claimed to 'Strongly Agree' or 'Agree' with each statement. Numbers in parenthesis indicate break-down into (Strongly Agree, Agree).

Statement	S1, 2006	S2[a], 2006	S1, 2007[b]
This lecturer communicated effectively with students	95 (57,38)	90 (40,50)	98 (71,27)
This lecturer was well prepared	95 (70,25)	93 (50,43)	100 (77,23)
Overall, I was satisfied with the quality of this lecturer's teaching	95 (68,28)	89 (55,39)	99 (80,20)
n[c]	237	151	280

Notes:

[a] QMA S2, 2006 is a repeat off-session class, where in this session > 50% of students were repeating the course.

[b] Survey run *online* for the first time in 2007.

[c] n represents number of students who responded to the survey.

Whilst these scores do not directly measure the impact of the lecture presentation and materials system, each is no doubt significantly affected by such a system. As can be seen, students responded extremely positively to the instructor's use of the system as evidenced by the results in significant areas such as 'communication' and 'preparation' which surely are heavily impacted by an instructor's mode of instruction. Furthermore, through refinements to the system over 2006, the author received an over-whelming response due to two large sections taught in semester 1, 2007, with 71% and 77% respectively answering 'Strongly Agree' to the communication and preparation aspects of the instructor's teaching. These compare with 39% and 47% respectively on the same questions for aggregate data taken across the 2230 students sitting in classes from the same Department at that time.

An richer indication of this impact is given by qualitative responses to a question asking students to mention 'the best features of this lecturer'. In S1 2006 when the system was first introduced, of the 237 respondents, 48 (20%) specifically mentioned the slides and/or lecture notes as part of their commendation. To place this figure, it ranked as the second highest rate of mention, with only 'explanations (good/clear/in-depth)' at 66 (28%) mentions out-scoring the presentation related statistic.

Furthermore, a brief survey of verbose comments made by students regarding the new system clarifies what exactly they found appealing:

- *"Lecture slides were detailed and informative - nice layout";*
- *"Lecture notes are very clearly set out and easy to follow";*
- *"Really detailed lecture notes, that allow spacing for examples";*
- *"Systematic, good use of colour and highlights, places to work in sheet are awesome, excellent lecture notes";*
- *"Very good tailor-made lecture notes consist of definition, graphical illustrations, [and] application of the theory learned";*
- *"Lecture slides were appealing, easy to read and understand";*
- *"[The instructor] prepares organised lecture slides with both definitions and practical examples, which makes it easier to learn concepts and how to work related problems";*
- *"The lecture notes aided in the learning process and provided us with materials for revision";*

- *"The self-explanatory slides ... were easy to follow."*

Significantly, these comments support the 'in theory' benefits of the present system. Students clearly picked up on the implied structure of notes and slides; the space left for active participation in the lecture by incomplete lecture materials; the consistent stylistic/typographic classes employed (e.g. for Definitions, Examples); and the overall clarity and appealing layout of both formats.

Although the qualitative and quantitative data from the field presented above are by no means conclusive, they do indicate tentative support for the positive pedagogical claims made regarding the system and so warrant further investigation of this system in a more rigorous manner.

Discussion

This paper began by presenting a critique of current and wide-spread presentation software for medium to large-class teaching. It argued that present software, whilst possibly able to increase efficiency in course delivery and having some facility for helpful pedagogy (e.g. slide-transitions etc.) overall failed to deliver an integrated instructional system. In particular, under the weight of CLT, it was identified that although student learning can be greatly increased by visual means of communication (a benefit of present software), these gains can be lost if the student is overwhelmed in one or more information chanels, and particularly, if the student is attempting to simultaneously note-take. Experimental evidence has suggested tools (e.g. skeleton notes, sequential revealing, semi-worked problems etc.) that do enhance student note-taking in itself, and as a *generative* activity to enhance the recollection of both information and meta-concepts.

A system based on the relatively new LaTeX 2_ε–Beamer technology was then presented and assessed in the first instance against the 'wish-list' constructed due to evidence-based educational theory, and then in a preliminary way, in terms of a field trial of this approach in a large first-year numerical setting. Again, whilst it is noted that the field results are not rigourous, they indicate a substantial and positive response to the system and give very encouraging grounds for further trials of this system.

As has been stressed above, in this author's view the success of this system rests largely on the fundamentally different philosophical approach that it employs to that of more common commercial software (compare Fig. 2 and Fig. 4). This approach emphasises content *re-use*, through a truly *integrated* architecture. The ability to 'direct' certain content to the slides only, or notes only, or some other format only, or a combination of formats, with simple commands in the same document encourages the instructor to be clear in their preparation about how good pedagogy will inform their instruction. Furthermore, since the underlying LaTeX 2ε language is a professional document preparation tool, the instructor is again caused to be *structured* in their approach, breaking the instructional content into sections and sub-sections, with beneficial scaffolding tools such as a Table of Contents, index and keyword references being available automatically.

Of course, the very nature of this approach will be a significant draw-back to some instructors. Whilst the present author was fluent in LaTeX 2ε before employing Beamer in Lecture preparation, this will not be true for many users. In this case, it is noted that third-party software (e.g. SCIENTIFIC-WORKPLACE) that provide a more common Graphical User Interface (GUI) for LaTeX 2ε document preparation could be an adequate bridging step.

Furthermore, since the present system encourages a thorough preparation (including requiring the slides and hand-outs to be 'compiled' as per a software program), they do not allow for flexible content management 'on the fly'. It would be almost impossible for a user to feasibly edit a slide during a lecture using the present system since such editing would require first, opening and changing the source-file, second compiling the document with the appropriate engine (e.g. pdflatex) and then re-opening the `.pdf` document for display. This is not an uncommon problem, and a shorter, but still disruptive edit procedure would be needed for users of (say) PowerPoint. To this author's knowledge, the most recent development that might overcome this problem would be to give lectures by using a webpage created by the increasingly popular 'wiki' tools [7]. The present author knows of at least one instructor who employs such a tool to lecture, and encourages students to edit their 'Lecture' (a webpage open behind him) during the lecture for factual errors, or to add commonly useful links or text. Whilst this presents an as yet, unstudied development in the delivery of a lecture, it clearly has a great benefit in potentially creating a highly non-linear delivery environment. However, further infrastructure (e.g. universal student access to laptops) and a willing student body (the instructor teaches within a Computer Science and Engineering context) are presumably required for this method of instruction to be feasible. So whilst the present system is inflexible in terms of content on the short-term, a redeeming feature in terms of delivery is that the integrated system is far more flexible in terms of presentation than equivalent presentation software, due to the novel hyperlinked navigation areas on each slide.

To conclude, the present system potentially delivers to the instructor a range of extremely helpful pedagogical tools with sound instructional science backing. Preliminary trials of this system have yielded extremely encouraging results and warrent a closer inspection by the instructional community. Its main use, as identified above for that of PowerPoint, may again be for large-class lower year teaching, where students need significant help to adjust to the lecture style of a modern University context and so stand to benefit greatly from the integrated presentation approach. However, this author is aware of at least one upper year course instructor who has embraced this new approach to initially positive student feedback.

Endnotes

1. For Economists, this is a non-trivial exercise, since (as Becker notes), by convention Economists will place the dependant variable on the x-axis, and the independant variable on the y-axis (e.g. when plotting consumption as a function of income, income will turn up on the y-axis).

2. The reference makes no mention of notes used alongside either technology, or no-technology based instruction.

3. 'Brain' graphic obtained with permission from the *Suggestive Contour Project*, Princeton Graphics Group (`http://www.cs.princeton.edu/gfx/`).

4. For an introduction to LaTeX, see `http://www.latex-project.org/intro.html`.

5. For an introduction to Beamer, see `http://latex-beamer.sourceforge.net/`.

6. For example, the top curve in the slide, $y(t) = \frac{4\frac{1}{2}}{1+20e^{-1.2t}}$ is drawn with the command:

```
\psplot{0}{9}{\a 1 20 2.71828 -1.2 x mul exp mul add def
4.5 a div}
```

that is, on the domain $[0, 9]$, we first define the denominator 'a' (for simplicity) and then obtain the curve by '$4.5/a$'. The notation used is actually Reverse Polish (postfix) as is implemented by the PostScript language.

7. For an introduction to 'wikis' see, `http://en.wikipedia.org/wiki/Wiki`.

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Figures & Captions

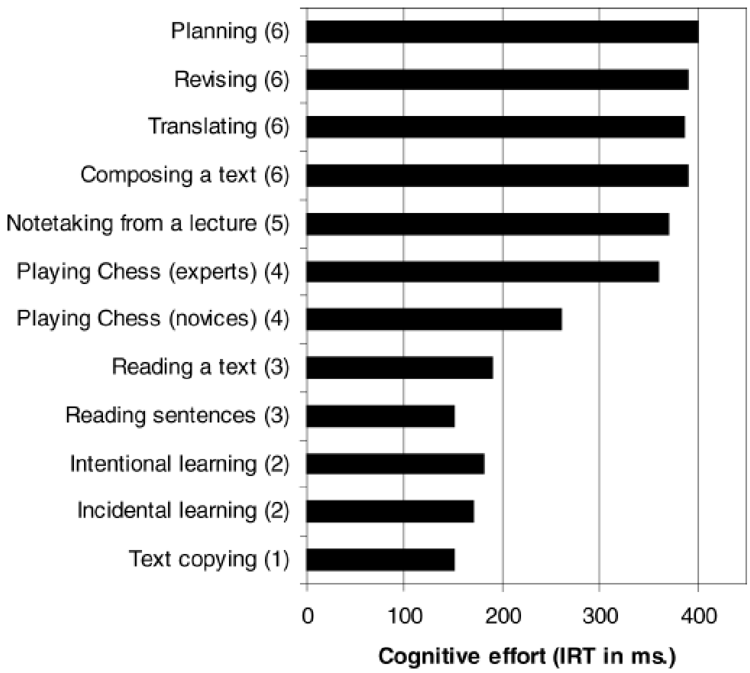


Figure 1 Cognitive effort (Interruption Response Time in ms) in different processing information tasks. Numbers in parenthesis indicate studies cited in Piolat et al. (2005). Reproduced from (Piolat et al., 2005, p.299)

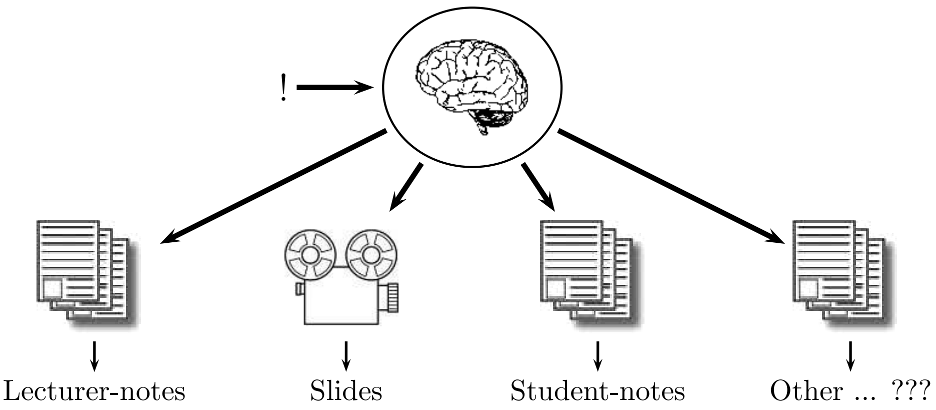


Figure 2 The orthodox approach to Lecture materials means any revision must be carried out for every instance.

```
\begin{frame}
  \frametitle{There Is No Largest Prime Number}
  \framesubtitle{The proof uses \textit{reductio ad absurdum}.}
  \begin{theorem}
    There is no largest prime number.
  \end{theorem}
  \begin{proof}
    \mode<beamer>{
      \begin{enumerate}
        \item<1-> Suppose $p$ were the largest prime number.
        \item<2-> Let $q$ be the product of the first $p$ numbers.
        \item<3-> Then $q+1$ is not divisible by any of them.
        \item<4-> Thus $q+1$ is also prime and greater than $p$.\qedhere
      \end{enumerate}
    }%
  \end{proof}
\end{frame}
```

Figure 3 Example listing showing a basic frame construction in $\LaTeX\,2_\varepsilon$–Beamer. To users of $\LaTeX\,2_\varepsilon$, this will appear very normal indeed. See text for further explanation of features. (Example drawn from Beamer User Guide (Tantau, 2005).)

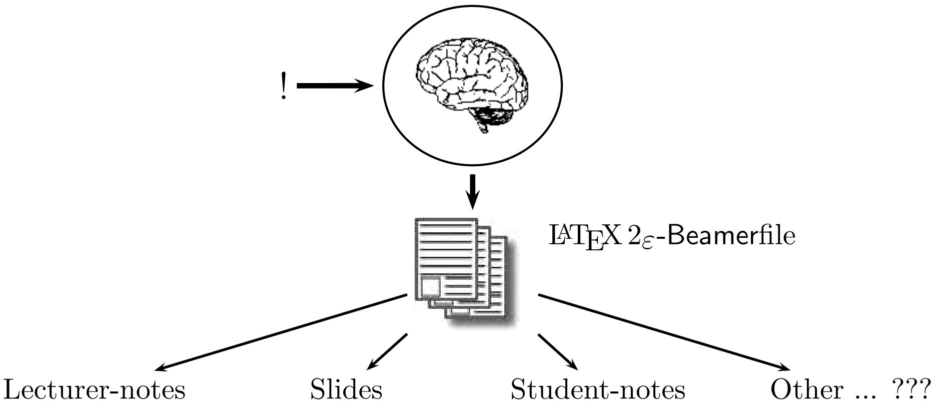


Figure 4 The $\LaTeX\,2_\varepsilon$–Beamer approach to material generation emphasising single content creation, maintenance and re-use, with one-step revision. (Compare Fig. 2.)

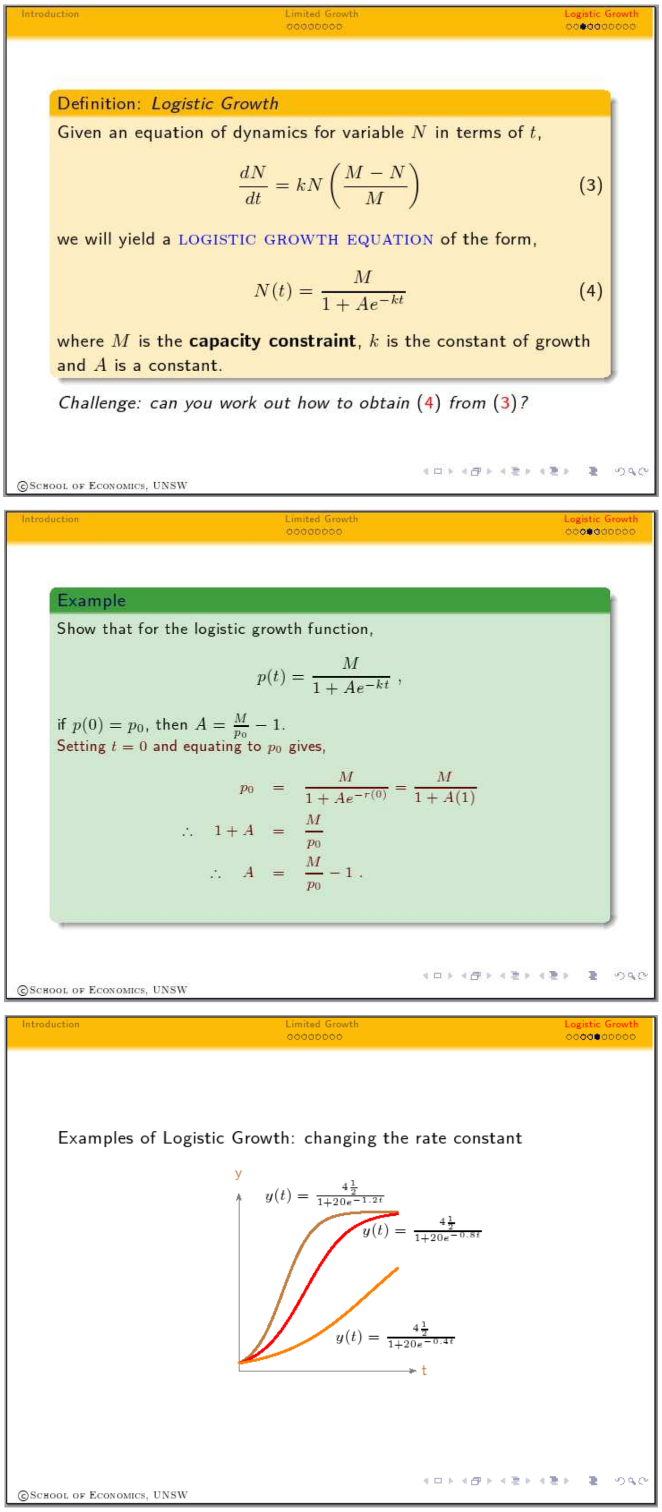
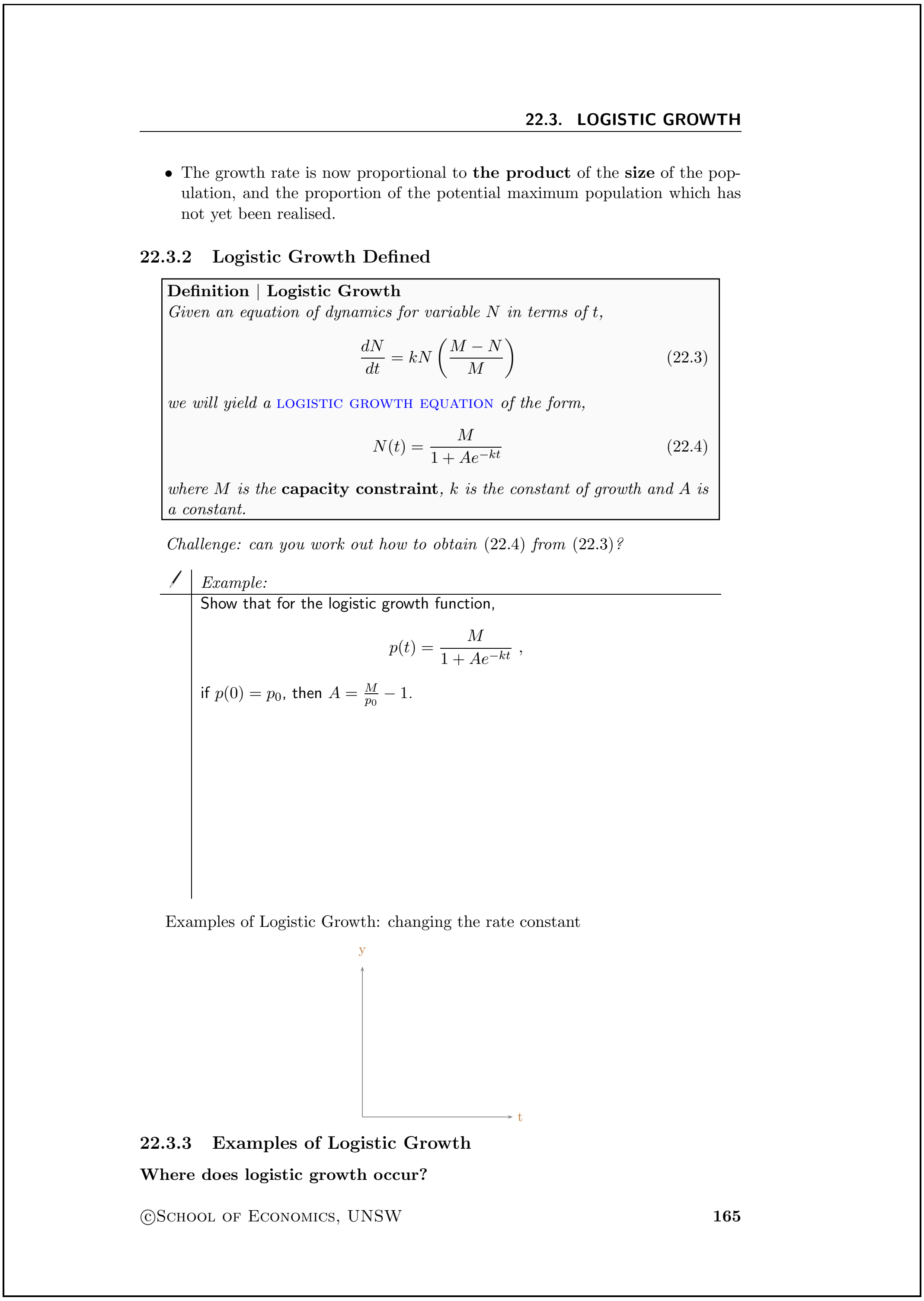


Figure 5 An example sequence of three slides (source-file available on request). Various pedagogical features are referred to in the text. Compare student-handout (article) mode as generated from the same source document in Fig. 6.


22.3. LOGISTIC GROWTH

- The growth rate is now proportional to **the product** of the **size** of the population, and the proportion of the potential maximum population which has not yet been realised.

22.3.2 Logistic Growth Defined

Definition | Logistic Growth
Given an equation of dynamics for variable N in terms of t,

$$\frac{dN}{dt} = kN\left(\frac{M-N}{M}\right) \tag{22.3}$$

we will yield a LOGISTIC GROWTH EQUATION *of the form,*

$$N(t) = \frac{M}{1+Ae^{-kt}} \tag{22.4}$$

where M is the **capacity constraint***, k is the constant of growth and A is a constant.*

Challenge: can you work out how to obtain (22.4) *from* (22.3)*?*

Example:
Show that for the logistic growth function,

$$p(t) = \frac{M}{1+Ae^{-kt}} \ ,$$

if $p(0) = p_0$, then $A = \frac{M}{p_0} - 1$.

Examples of Logistic Growth: changing the rate constant

y

t

22.3.3 Examples of Logistic Growth

Where does logistic growth occur?

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Figure 6 Example page from a Lecture Book produced from the same source file as the slides in Fig. 5. Various pedagogical features are reffered to in the text.