

INCORPORATING LyX AS STANDARD TOOL FOR WRITING MATHEMATICS - EFFECTS ON TEACHING AND LEARNING

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We report on the experience of half a decade of teaching mathematics in the South Pacific region, incorporating LyX as a standard tool for the students in the preparation of their submitted assignments. LyX is a What-You-See-Is-What-You-Mean graphical frontend to LaTeX, the most widely used mathematics markup tool for publishing mathematics documents. We briefly survey the current state of affairs of software used in common practices relevant to the teaching of mathematics, and then concentrate on the advantages offered by LyX. We describe the practicalities of adopting LyX as part and parcel of the course tools and aims, and we then discuss the immediate and longer term effects thereof, and contemplate on the pedagogical efficacy and relevance of LyX as a communication tool.

Keywords: LyX, LaTeX, mathematics writing, mathematics communication.

INTRODUCTION

Communication in writing is at the heart of learning and teaching – a statement so patently obvious that one may find curious the need to state it at all. But indeed, there is a curiosity to be resolved. Students in all taught subjects expect all written communication from the lecturer to be readable, clearly typed, and professionally presented. Similarly, teachers expect students to hand in written assignments which are well-prepared, with attention and care given not just to the content but also to the presentation thereof. In fact, the ability to present ideas and results in a fashion conforming to the subject standards is generally considered part of the competency buildup of a study program. In mathematics students still expect no less than professionally typed material from the lecturer, while the students themselves are allowed to submit handwritten solutions which are far removed from being professionally typed and are often barely readable.

This asymmetry, unique to mathematics teaching, is unfortunate from several perspectives. The written material presented to the students serves as a beacon of mastery. A standard of presentation to appreciate, enjoy, and to strive to achieve. A failure to guide and nurture such a vital communication competency should be viewed as suboptimal design. Further, particularly in mathematics, typing up one's thoughts into a readable, coherent, and beautifully presented document, even if consisting of just a few lines of text, significantly heightens one's understanding of the material due to mathematics' unique feature of being communicated as a mixture of a natural language, typically English, and a formal language, typically set theory formalized to a certain degree of comfort. Students often find making the distinction between the formal and the natural components very difficult, especially when writing their own solutions on a piece of paper. The pen-and-paper's permitting nature, giving the student complete freedom, serves to further blur the line between the formal and the natural aspects in their answers. Lastly, we mention an important psychological effect related to this issue. It is quite disheartening if after solving a difficult problem, all that the student has to show for it is a few sheets of scribbled paper which, even if marked as a full 10/10, cannot be considered anything even remotely close to a document. It simply does not look impressive. If, instead, part and parcel of obtaining full marks is to present the solution as a professionally typed document, the end result becomes truly something to strive for; a readable piece of work, elegant in content and in form. Further work, opinions, and discussion on the importance of communication competencies along these lines can be found in Pugalee, D. K. (2001), Quinn, R. J., & Wilson, M. M. (1997), Baxter, J. A., Woodwar, J., & Olson, D. (2005), and Bicer, A., Capraro, R. M., & Capraro, M. M. (2013).

Various software solutions exist for typesetting mathematics formulas within a document. Perhaps the two most worthy of mentioning are MS Word's equation editor and LaTeX. The former is mentioned due to the widespread use of MS

Word, while the latter is without a shadow of a doubt the publishing standard for professional mathematicians. Most mathematicians probably never even once invoked MS Word’s equation editor, and are thus reluctant to prescribe usage of it as part of their teaching. On the other hand, LaTeX is not a word processor, and using it requires quite a bit of preparation with some non-trivial hurdles to surmount. For that reason, lecturers are reluctant to introduce LaTeX early on, resorting to allowing handwritten submissions.

The aim of this paper is to report on the experience of using LyX as an alternative solution while the author taught mathematics courses at the main campus of the University of the South Pacific in Fiji from 2011 to 2016. The plan of the paper is to first give the reader a quick taste of LaTeX, not shying away from its unpleasant features, in order to appreciate what it does and why it is not the case that students can be expected to simply start using it without significant guidance. There follows a glance survey of LyX, emphasizing its key aspects for the purposes of this report. Then the author’s experience is recounted, including a brief description of the common practice in sufficient detail to allow mimicry for those interested. The observed effects are reviewed, followed by a discussion and concluding remarks.

THE LaTeX FEAR FACTOR

LaTeX, unlike Word, is a document processor rather than a word processor. It is used to produce professional looking documents by means of a markup language typed in an editor which then compiles to produce the end result. All formatting decisions are made by LaTeX during compilation, leaving the writer to concentrate on the content. There are numerous LaTeX editors and compilers, each with its own set of extras and special features. The examples below were all created using Valletta Venture’s TeXpad. Figure 1 is a snapshot of typical work in progress, cycling through editing and compiling phases. Already the brief description above is sufficient to send tremors of anxiety down the spines of many brave souls. There are many books dedicated to imparting the mysteries of LaTeX, e.g., Gratzner, G. (2016) or Mittelbach, F., Goossens, M., Braams, J., Carlisle, D., & Rowley, C. (2004), but often such texts serve to further deter curious newcomers, making one seek the comfort of the familiarity of a word processor rather than all this business with weird looking commands, editors, and compilers.

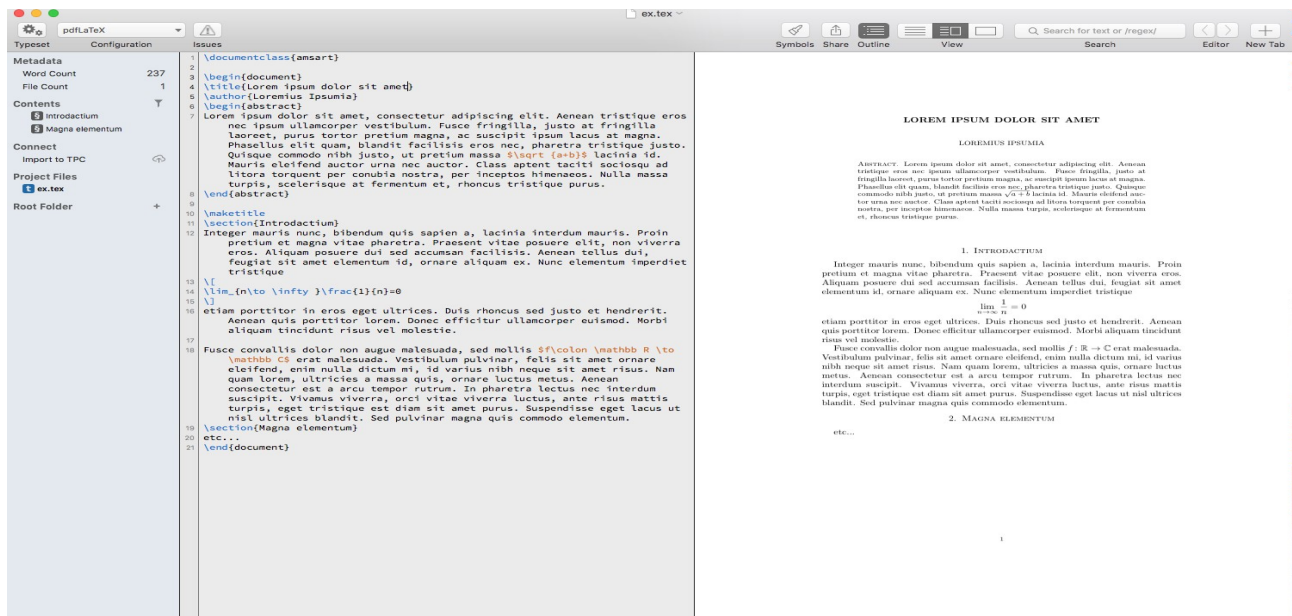


Figure 1: TeXpad session showing LaTeX code on the left and the compiled result on the right.

On the left-hand-side of Figure 1 is the LaTeX code one must type in in order to produce what is displayed on the right-hand-side. A particularly deterring feature of LaTeX is its unforgiving nature to the slightest of mistakes, coupled with its tendency to deliver most cryptic errors when one, unfortunately inevitably, types incorrectly. For instance, if in the

LaTeX code presented in Figure 1, the line reading “\begin{abstract}” were to be replaced by “\begin{abstrat}”, an innocent enough typo, the LaTeX compiler is known to respond quite harshly and unintelligibly, producing output as shown in Figure 2 and errors as shown in Figure 3.

The fact that virtually all professional mathematicians use LaTeX to communicate their research, given the non-

Errors	Output
<pre> /Library/TeX/texbin/pdflatex -file-line-error - interaction=nonstopmode -synctex=1 -output-directory=/ home/weissi/Documents/OddsEnds/Lyon2017/.texpadtmp errors.tex This is pdfTeX, Version 3.14159265-2.6-1.40.17 (TeX Live 2016) (preloaded format=pdflatex) restricted \write18 enabled. entering extended mode (./errors.tex LaTeX2e <2016/03/31> Babel <3.9r> and hyphenation patterns for 83 language(s) loaded. (/usr/local/texlive/2016/texmf-dist/tex/latex/amscls/amsart.cls Document Class: amsart 2015/03/04 v2.20.2 (/usr/local/texlive/2016/texmf-dist/tex/latex/amsmath/ amsmath.sty For additional information on amsmath, use the '?' option. (/usr/local/texlive/2016/texmf-dist/tex/latex/amsmath/ amstext.sty (/usr/local/texlive/2016/texmf-dist/tex/latex/ amsmath/amsgen.sty) (/usr/local/texlive/2016/texmf-dist/tex/ latex/amsmath/amsbsy.sty) (/usr/local/texlive/2016/texmf-dist/ tex/latex/amsmath/amsopn.sty) (/usr/local/texlive/2016/texmf- dist/tex/latex/amsfonts/umsa.fd) (/usr/local/texlive/2016/texmf- dist/tex/latex/amsfonts/amsfonts.sty) (/home/weissi/Documents/ OddsEnds/Lyon2017/.texpadtmp/errors.aux) (/usr/local/texlive/ 2016/texmf-dist/tex/latex/amsfonts/umsa.fd) (/usr/local/texlive/ 2016/texmf-dist/tex/latex/amsfonts/umsb.fd) ./errors.tex:6: LaTeX Error: Environment abstrat undefined. See the LaTeX manual or LaTeX Companion for explanation. Type H <return> for immediate help. ... l.6 \begin{abstrat} ./errors.tex:8: Extra }, or forgotten \endgroup. \endabstrat ->\endlist \egroup \@setabstracta \fi l.8 \end{abstrat} </pre>	

Figure 2: Output due to a simple typo.

Suffice it to say that LaTeX has much to offer, but it is not easy to get going. A more user-friendly solution is desirable.

Errors	Output
<pre> errors.tex (line 6) LaTeX Error: Environment abstrat undefined. (\begin{abstrat} ...) errors.tex (line 8) Extra }, or forgotten \endgroup. (\end{abstrat} ...) errors.tex (line 8) LaTeX Error: \begin{document} ended by \end{abstrat}. </pre>	

Figure 3: Errors reported due to a simple typo.

in a snapshot of a LyX session, with the LyX interface on the left-hand-side and the output on the right-hand-side. The resemblance to a word processor immediately dispels any anxiety as one automatically feels at home when working with LyX. It is a familiar environment, there are no odd looking commands, no visible compiling, and no unwieldy errors to cope with. This is all true, but just on the surface. What LyX does very well is hide the code and the compilation, providing convenient graphical features to give one the illusion that the whole thing has nothing to do with LaTeX. But the illusion is easily broken by LyX’s ability to export any LyX document as a LaTeX document, a feature the uninterested user, and certainly newcomers, can safely disregard. Unbeknown to the user, LyX constantly compiles whatever the user is typing, a feature that pretty much guarantees there will never be a need to debug a LyX document. It is worthwhile noticing that some LaTeX editors resort to a similar technique in order to reduce the risk of bugs.

triviality of getting used to using it, should indicate that there is sufficient gain to using LaTeX rather than a word processor. Here is not the place to further expand on that point, but it is certainly the place to remark that it should now be obvious that teaching LaTeX, especially early on, is challenging.

A further difficulty that one meets just a few steps down the road to using LaTeX is the inevitable consequence of writing code, namely the need to debug. A significant difference between an experienced LaTeX user and a novice is that that former mastered working techniques that minimize the risk of bugs, while the latter spends much time searching one’s code for elusive bugs.

Other than the typographical advantages offered by LaTeX, a pedagogically important feature is the need (lest dreaded errors will be reported) to clearly separate text from mathematics content, as can be seen in Figure 1. The unforgiving nature of LaTeX is here a blessing since only 100% correct code will be accepted, forcing the writer to first very clearly figure out on her own precisely what she means to say.

THE LyX SOLUTION

LyX is an open source project providing a freely distributed graphical frontend for LaTeX. It must be emphasized that under the hood of a document produced using LyX is LaTeX code, but that code is automatically produced and compiled by LyX. The LyX interface resembles that of a word processor, in fact so much so that a casual observer is likely to mistake it for just that. Figure 4 illustrates that feature

Still just on the surface, LyX differs from a word processor in its use of environments (a pull-down menu at the top left corner) used to specify different sections or portions of text, and in its highly sophisticated math mode. The latter is LyX's support for typing mathematical symbols, equations, formulas, and so on. It is here that LyX shines when compared to LaTeX. Much thought went into the design of LyX's math mode in order to provide the most novice of users with immediate capabilities.

In short, LyX is a document processor offering all the advantages of LaTeX with little to no disadvantages. It is user-friendly, freely distributed, highly fine-tuned, and constantly developed and improved. It cleverly and efficiently hides all of the mess of LaTeX under the surface, leaving a clean working environment devoid of any scary bits. Such a tool is an optimal choice to be presented to students on their very first day of an introductory class in mathematics.

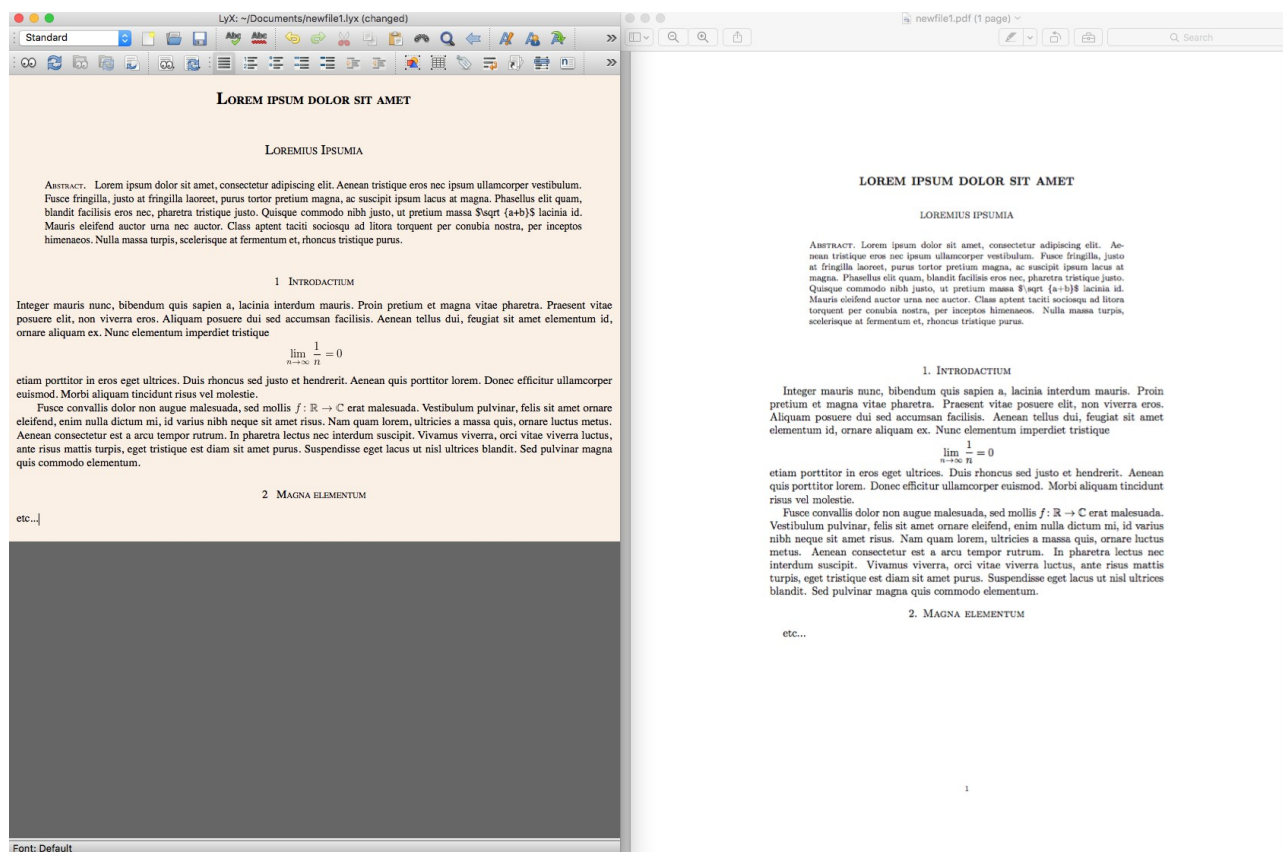


Figure 4: Screen caption of a LyX session showing the LyX environment on the left and the end-result on the right.

HALF A DECADE OF IMPLEMENTATION

I joined the University of the South Pacific as a mathematics lecturer in 2011 and worked there until 2016. During those years, I taught mathematics courses across the undergraduate curriculum, including calculus, linear algebra, abstract algebra, advanced calculus, and discrete mathematics. Some of these courses are proof based (e.g., abstract algebra) and some are of a more calculation based nature (e.g., calculus).

Each course taught, be it a first-year course or a third-year course, would dedicate a one-hour lab session in the first week to teaching the basics of LyX and bringing the students to a sufficient level of mastery to continue using LyX on their own. The visual similarity of LyX to an ordinary text editor was exploited to quickly get the students to produce a simple document. Then the unique features of LyX were discussed, namely the use of environments and LyX's math

mode. Experience shows that the environment pull-down menu of LyX is intuitive enough to allow most students a very smooth transition. The more serious obstacle is typesetting mathematics symbols and formulae, due to the need to find the LaTeX commands for the symbols one requires. Here LyX offers much assistance in the form of automatically suggesting symbols and capabilities in a pane that opens up as soon as one engages math mode. Further, the online tool Detexify (made available by Kirelabs at <http://detexify.kirelabs.org/classify.html>) is a website allowing one to draw any desired symbol and obtain the LaTeX command for it. All in all, after this opening one-hour session over 90% of the students were able to produce a simple looking document, like the one shown above, without any difficulties. Struggling students were typically helped out of their confusion on an individual basis, allowing competency in using LyX to a degree that permits students to immediately start using it to be achieved very early on.

In the first year of the experiment I provided the students with a lengthy hand-in assignment to work on. The assignment consisted of several problems with a preparation time of about six weeks. The instructions were to work on the problems progressively and to use a weekly one-hour lab session to type-up their work as a LyX document. I was then still reluctant to require only a PDF submission, and so declared the lab sessions as highly recommended but not mandatory. When the submission deadline arrived 80% of submissions were printouts of professional looking documents, clearly prepared with LyX. Encouraged by the outcome, in year two I declared that only PDF submissions prepared using LyX will be accepted. The deadline was met largely without any issues, save for a few students who ran into technical problems preventing them from obtaining a PDF. All of these issues were resolved on an individual basis, resulting in a 100% PDF submission of type-set documents.

From year three of the experiment onwards I adopted LyX as a standard tool for students to use in the preparation of all of their mathematics related work. I kept holding a first week induction phase, quickly introducing students to LyX, though this quickly became relevant only for the first-year students. I declared that only submissions of professional looking typeset documents will be accepted for relevant coursework. Consistently, deadlines were met according to the set guidelines with typically 2-3% of students reporting difficulties, all of which were solved on an individual basis. The main source of problems for those students facing difficulties was an inability to export their work as a PDF file, primarily due to installation issues.

To conclude, from the very beginning of the experiment students showed no signs of distress or discomfort with the new technology. Using LyX so naturally builds upon existing word editing competencies shared by virtually all students that a single one-hour lab session is all that was required to bring the students to a level of competency granting them independence in the typesetting of their work. Students were able to immediately start typesetting their hand-in work, requiring very little further support. Technical issues related to installation on students' private computers sometimes led to inability to produce a PDF, a problem usually discovered shortly before a submission deadline. Such problems were typically solved individually by allowing the student to submit the LyX file directly, or suggesting the student re-installs LyX.

EFFECTS ON LEARNING AND TEACHING

Consistently throughout the experiment, feedback from students was very positive, with statements such as “we learned how to produce professional mathematics documents” and “I now know how to produce beautiful worksheets for my own students” appearing often in student evaluations. Retention of LyX capabilities was also very high, and in fact it was often reported to me by other lecturers that they see a significant increase in typeset submissions in their courses too, even though they do not make any efforts to encourage that, indicating that students see the added value of using LyX and choose to do so even when not instructed to. As a by-product, other colleagues' feedback is also very positive since it is much more pleasant to grade a typeset document rather than hard to decipher scribbles on a piece of paper.

Other than these appreciative responses from students and pleasant side-effects for the teachers, positive effects of a pedagogical nature were also observed. The need to enter math mode in LyX in order to type-set a symbol or an equation forces the student to make a clear distinction in her mind between the language and the mathematical content. It becomes much clearer how the surrounding language supports the mathematical content and that the two are truly

very different in nature. The use of LaTeX commands, with their alien look, all starting with a backslash, serves to accentuate that difference even more, generally leading to better understanding and better performance, and since LyX immediately converts the commands to the symbols they stand for, the student is not distracted away from the content she is producing. Particularly in the proof-intensive courses (e.g., abstract algebra) a marked improvement was observed in the students' ability to produce correct proofs, primarily since simply following LyX's mode of operation forces one to pay a great deal of attention precisely to those aspects of one's solution which are crucial to a reasonable flow of ideas and presentation in a proof.

In all of the courses taking part of this experiment students were quite satisfied to be working with LyX, clearly appreciative of the relative ease with which they produced professional documents. Many of my students who were themselves high-school teachers were appreciative of that new capability and reported on considerable time reduction in their own preparation of worksheets for their students.

To conclude, with very minimal adaptation and preparation I was able to successfully and efficiently incorporate LyX as a convenient and powerful tool to empower students in their written mathematics communication, resulting in increased competency when dealing with the material, appreciation of the ability to produce elegant documents, and happier colleagues who now know they too, just like in any other taught subject, have an alternative to allowing handwritten submissions out of inertia.

DISCUSSION

The importance of being able to express oneself clearly, elegantly, and with relative ease as a contributing factor to effective learning is probably widely accepted. However, in mathematics teaching, due to significant initial technical hurdles one must overcome before one can use the most prevalent software solution used by experts, the development of mastery of exposition is deferred to later stages of the study program, and often deferred completely out of existence. The negative aspects of this situation include pedagogical issues, such as increased difficulty in distinguishing between the formal and natural use of language in one's solutions, as well as psychological issues, namely a lack of a neatly looking 'finished product' to be proud of and refer to once an assignment is completed, leading to lack of interest in one's solutions past the immediate need to fulfill a course requirement.

A further complication is the disconnect between software solutions used by expert mathematicians and software used by educators. The latter typically use MS Word, perhaps with the aid of its equation editor, while the former exclusively use LaTeX. This disparity leads to a poor exchange of practices and a general avoidance of introduction of any software solution as a standard tool for students. The solution discussed in this report is using LyX, an open-access software providing a graphical frontend to LaTeX. Among professional mathematicians LyX is very seldom used, primarily due to inertia and the fact that the vast majority of journals require LaTeX submissions (though it is crucial to remember that LyX can export any document to a perfectly acceptable LaTeX file). Thus, LyX emerges as an obvious candidate to bridge the chasm between handwritten solutions and LaTeX typeset solutions by providing a sufficiently familiar working environment allowing students to quickly produce a satisfactory first document and become self-sufficient with minimal time investment in the beginning of a course.

Half a decade of teaching mathematics at the University of the South Pacific demonstrates the efficacy of incorporating LyX as a powerful and much appreciated learning aid, contributing to student success and engagement. Particularly in developing countries, the fact that LyX is distributed completely free of charge is of great importance, and since pricy licenses are an issue for any university, the no extra cost involved with adopting LyX is significant everywhere. Moreover, there is already a well-established dedicated online community of LyX users who are generally very eager to offer assistance to newcomers, all in all manifesting LyX as a very robust and friendly solution to a long-standing problem in the teaching of mathematics. The author intends to follow a similar path introducing LyX in all first-year mathematics courses at the University of Portsmouth, England, in September 2017.

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