Accessibility of Jupyter Notebooks on M269

eSTEeM Final Report

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Contents

Executive Summary

When M269 was rewritten in 2021, all learning, practical work and assessment content was presented by means of Jupyter notebooks rather than having a mixture of theory on the VLE, two printed textbooks and practical work using an IDE.

The project aimed to examine the usability and the accessibility (Web Content Accessibility Guidelines) of this learning approach from the perspective of tutors and students of the rewritten module.

We recruited 6 students and 6 tutors from the 21J presentation and asked them to answer a short questionnaire in the form of diary entries at 3 key points in the presentation. We followed this up with 2 focus groups for the tutors, the student volunteers having dropped out of the study before the second point. We analysed our findings using NVivo.

Our key findings were that while some tutors had adapted well to the new module style, others struggled to find information in the notebooks to help students. The way of working with notebooks, in marking student assignments, was resulting in much longer marking times than before for all tutors. Having to be online to answer student queries was also resulting in much longer response times.

Students were generally positive about the ability to run code examples easily alongside reading of theory, but they struggled to find information from earlier

sections, and some found it tiring working on a screen the whole time rather being able to read a textbook offline.

Our recommendations included that content and index pages be provided for the notebooks and that ways of reducing the time to mark the assignments for tutors be explored.

We followed the study up 3 years later and found that the module team had made significant improvements to the marking guide and processes for marking as well as adding automated testing and making software available on the Open Computing Lab to improve accessibility.

Aims and scope of the project

Introduction

M269 Algorithms, data structures and computability was rewritten for the 21J presentation and now includes all teaching and assessment materials in Jupyter notebooks rather than the OU's VLE interface. These notebooks are an interactive web-based tool that allows a mix of executable practical activities as well as text styled using mark-up language. Both tutors and students need to use Jupyter and install it on their own computers and it was intended that this study would investigate the experiences of both.

The project aimed to examine the usability and the accessibility (Web Content Accessibility Guidelines) of this learning approach from the perspective of tutors and students of the rewritten module. Here, by usability we mean in terms of how straightforward it is to install, run and use Jupyter and achieve the module's learning outcomes.

Rationale

The project built on two eSTEeM projects.

In the first which explored the use of printed materials versus online (An investigation into how STEM students use learning resources in different formats, and how this use develops over time , Alexander, L. and Lansbury, A.), two of the outcomes that emerged were that students prefer a combination of books and digital resources to entirely digital resources, and, module teams should be aware that students meeting an entirely digital module for the first time are

likely to have problems adapting their study methods, particularly if this happens after stage-1.

In the second, which investigated the use of Jupyter notebooks on TM351- Data Management and Analysis (An investigation into the way Jupyter Notebooks enhance learning and teaching on TM351 Dawes, S. and Thomson, C.), it was found that some students find Jupyter notebooks hard to access and search. Furthermore, their use of notebooks limited some students' ability to study when and where they wanted to as a full computer is required, and there were concerns about whether the notebooks should be used to teach theory as well as the practical work. This suggested that notebooks may not be suitable for all learning needs or preferences.

The outcomes from both of these projects indicate that the choice to use Jupyter alone for all learning activities might have adverse outcomes and to an extent this current project investigates whether this is indeed the case. This project also broadens the scope as the outcomes and impact on tutors, for both teaching and assessment when relying upon just digital media is investigated too.

Although the focus of the project comes under the banner "technologies for STEM learning" as it is about the use of Jupyter notebooks; its outcomes address usability and accessibility. In particular we hoped it would benefit students with disabilities and as such it addresses the university's Access, Participation and Success Strategy 2020 - 2025 which provides for disabled students "to access HE and achieve equitable outcomes".

Jupyter notebooks are viewed using a web browser and designing the output from these for accessibility doesn't just benefit disabled students; it benefits everyone, because better accessibility is likely to lead to better usability for everyone. "The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect. " (W3C, 2005)

Activities

6 student volunteers were asked to submit diary entries in October, December and February explaining how the software was supporting their learning, addressing specific questions. We selected the diary-format as it allowed us to see how user-experiences changed over the period of the study. SRPP and HREC approval was sought for this part of the project.

To gather the experiences of tutors on the module we invited 6 participants to 2 focus-groups, again addressing a small number of key questions about their experiences of using Jupyter notebooks to teach the module and incorporated some email responses following these into our research.

We used NVivo to do thematic analysis of the transcripts of the focus-group recordings as well as subsequent emails with the aim of establishing whether guidance in adapting output from the Jupyter notebooks makes them sufficiently accessible and whether any adjustments were necessary to improve usability.

We had intended to analyse the student diaries in the same way but all but one of the students we had recruited had dropped out of the study by December and the quantity and quality of the feedback we received in total wasn't sufficient to pursue this part of the research though some preliminary findings are reported below.

We shared preliminary findings with the M269 module team in April 2022 and produced a project poster for the 2022 eSTEeM conference to inform module teams (e.g. TM129, TM351, TM358, M348, ST374, SM123, SXPS288, S818) as to whether adjustments were needed.

Finally, we followed up our study in December 2024 by investigating what improvements had been made to the module and finding out what the module team and ALs still thought could be improved.

Findings

Student Diaries

Accessing and downloading Anaconda was mostly seen as easy and instructions for this were clear. Students liked that their notes in the notebooks could be personalised and thought this would be helpful for revision purposes.

They said:

- *"I think that the use of the notebooks is very good because it brings the material to life from within the book."*
- *"Running, editing and being able to insert new codes below the ones that exists on the page is so welcome besides reading the page/section."*
- *" Syntax errors and explanations I have read in module materials of what the errors mean have been easy enough to follow."*

However, there was anxiety about the number of tabs being opened in working through the materials and they preferred the way algorithms were written in TM112, as they were much easier to write and follow.

Problems they reported included:

- *"It can be tiring on the eyes looking at the screen."*
- *"There doesn't seem to be a search function, and trying to remember and find which notebook contained the information I was looking for was a bit hit and miss and time-consuming."*

Students did like the TMA question and answers and code all being in the same place, but they would have liked a printed handbook like the one Maths modules provide.

Suggestions and comments they made included:

- *"I do prefer doing practical activities onscreen"* but it would be easier *" to have the activity info on one side of the screen and writing the code on the other side, I don't like scrolling back and forth."*
- "I think I would prefer the concepts and theory of the module materials to be in printed form. " ...but ..."the price of printer ink would have made it too expensive to print all the materials. "

Tutor Focus Groups

Our tutors were representative in terms of platform of the likely M269 population in that between them they covered use of Windows, Mac and Linux computers, using a variety of browsers.

- There were nearly twice as many negative references as positive ones (58 versus 30) by tutors overall. Comments included "I may be missing something, but I can't see the advantage of notebooks", "I like to be in control of where everything is and feel that [it] is not entirely in my control" and "I miss a book with Post-it notes sticking out the top" but "It's great not having to switch out to an IDE. It is very convenient" and "I actually like this. It works for me". One very positive comment was that being able to encourage students to "*play in blank notebooks and print out much more than is required in the TMA to see what is going on*," was a clear benefit of having the notebooks.

Amongst the aspects of using Jupyter notebooks for teaching that tutors liked were:

- Their mostly straightforward installation (though setting the working directory could be problematic for changes to an existing installation)

- The ease of adapting code examples for use in tutorials and being able to send notebooks to students to help explain queries and also the ability to use notebooks interactively during tutorials
- The ability to add markdown as supporting information
- Their support for students following the required TMA layout
- The marks being added up automatically in notebooks for TMAs
- The possibility of accessing the html versions if the notebooks to avoid multiple tabs being open

One tutor also commented on the use of Jupyter "magic" being useful for benchmarking code examples and the ability to produce presentations for use in tutorials by using the RISE extension.

However, tutors were divided on some issues such as:

- The single medium holding all content and code with no separate IDE being needed. However, one tutor commented that "I could be reasonably confident that the Python code I am looking at is the same as the code the student is looking at."
- The ability to find past M269 topics that students might have struggled with. One tutor found the notebooks helped with this, but the majority commented on the difficulty of search and lack of indexing.

The main aspects that tutors disliked were:

- Navigating the notebooks was not helped by the multitude of tabs that could result
- There was no support for stepping through code for debugging purposes
- Opening student TMAs was difficult especially on a Mac and highlighting points in the student's work to provide feedback on or editing the student's code was impossible,
- There was no index or contents that might have been searching easier
- There was no way of fixing code so that experiments did not change the notebooks – important for revision purposes for students

- There were occasional problems with students running functions from the wrong library, which were hard to spot without sufficient knowledge of Python dependencies.
- Leaving notebooks running impacted computer performance
- There was a steep learning curve associated with the Jupyter notebook concept, and this was not helped by the documentation for both Python and Jupyter being in multiple locations.
- Assignment questions could not be read using the OU Study App.
- Shortcuts generally used with Windows and Macs don't work in the same way on Jupyter notebooks
  There was no support for Grammarly or Spellcheck.

For many of these problems, tutors were finding their own independent workarounds.

Lack of support for searching was in fact the problem that was mentioned most of all in the focus groups (20 mentions) and tutors were using pdf versions to avoid switching between the many tabs generated but they disliked the fact that this removed the option to run code.

Accessibility was only mentioned by two tutors as being problematic. Notebooks were in black on white, but tutors and students may have been using an edited CSS file which could change this. Font size was also an issue, especially when displaying files in Adobe Connect.

There were other problems particularly relevant to TMA marking. For example:

- It wasn't always clear which answers were being provided in the mark scheme.
- Setting up files ready for marking and return was very time consuming

- Although highlighting cells in different colours was set up at the top of assignment sheets it was easy for students to delete this by mistake and not straightforward to reinstate this.
- Where students had copied cells with metadata this could lead to duplicate feedback and marks being processed
- The automatic granularity of marks didn't align with that in the tutor notes and made entering marks on the PT3 difficult
- File name length could easily exceed that permitted in the eTMA system given file structure
- The workflow asked, "Which File?" but if the wrong one was selected by mistake there was no Exit option
- The fact that some cells had been made not editable meant that further automation by the tutor wasn't possible

Analysis

While tutors were adept at overcoming problems they encountered when supporting students using Jupyter notebooks there was general consensus that marking in the notebooks was taking far longer than had been the case using the previous version of M269, where there were separate Word documents and code files. An unfortunate consequence of the processes needed in setting up marking meant that some tutors were marking in much larger batches than had been the case before, and waiting till extensions arrived to start marking everything at once, so the TMA return times had lengthened.

Tutors needed to be at their computer to answer the simplest of student queries, where in the past they might have been able to open up materials and TMA questions using the My Study app for example. This meant that response times to student queries were likely to be longer.

As problems searching for content were so prevalent a solution to this needed to be provided.

Impact

Conclusions

While searching across different files is relatively simple for accomplished Mac and Linux users there does need to be good indexing and contents provided to help Windows users and this would benefit everyone. One tutor's suggestion of a JupyterBook for the theory parts of the notebooks might be a solution for this.

Support for debugging could have been provided using JupyterLab which might have helped tutors with excess marking times, however the entire marking process has been improved after the issue that was raised regarding the amount of preparation that's needed before beginning to mark. The M269 module team have been proactive in finding improvements that could be made.

Use of Jupyter notebooks has prepared students for further study in Data Science or AI & ML (though the module materials don't stress this).

Changes to the module

The new edition of M269 had a steep learning curve and it is the module team's view that this may also have led to poor tutor retention rather than solely the change to Jupyter notebooks. It is to their credit however that sufficient changes have been made that the remaining tutors have enjoyed significant improvements.

The original usage of Jupyter Notebooks required tutors to 'prepare scripts for marking'. This required additional software and a complicated series of scripts to be installed and executed in the correct order.

From the module team's perspective:

Improvements made to the module since the first presentation have included:

- The M269 python environment installation and consistent software also being made available via the Open Computing Lab, to aid accessibility.
- Development of the tutor marking tool, providing more automation, including highlighting student cells and tutor feedback cells using colour coding, a marks table, integrity checks and pinning the student's name on the screen to help when scrolling.
- Implementation of automated testing and availability of this for students, meaning higher quality of code submission.

In addition, a WhatsApp group for students helps with support for some 15% of students and has tutor involvement.

From the tutor's perspective

- It is still time consuming to load the software to answer student queries and this is slower than using Word documents but screensharing notebooks to produce live coding demonstrations in tutorials is possible.

- Marking time is much improved from the 3 hours or so from the first presentation because of the improvements to the marking tool but an experienced AL is still likely to take 1 – 1.5 hours to mark a TMA. This is not helped by the fact that the TMAs are very long.

Future changes planned will further help tutors and students by ensuring that local and VCE software installations are identical as well as extending the provision of automated testing and providing more questions that aid the transition of students to a module of this level. A forthcoming move to JupyterLabs also needs to work with the marking tool created for Jupyter.

Dissemination

We presented our initial findings to the M269 module team in April 2022 at which the module chair and other members of C&C were present. We also presented a poster at the eSTEeM conference in May 2022.

References

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University approval processes

- SRPP/SSPP – Approval from the Student Research Project Panel/Staff Survey Project Panel was obtained according to the Open University's code of practice and procedures before embarking on this project. Application number 2021/1951.
- Ethical review – An ethical review was obtained according to the Open University's code of practice and procedures before embarking on this project. Reference number HREC/4079/Dawes.
- Data Protection Impact Assessment/Compliance Check – A Data Protection Impact Assessment/Compliance Check was obtained according to the Open University's code of practice and procedures before embarking on this project. Data Protection registration number 28-04-075