Attitudes Towards Student-Centered Learning
with Jupyter Notebooks in Econometrics:
A Semantic Analysis

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Abstract

Jupyter notebook is an interactive web-based programming environment commonly used in data science to facilitate learning and teaching of programming. By providing a single intelligible and reproducible environment to conduct empirical analyses and simulation studies, Jupyter notebook has only recently been adapted for econometrics instruction. This paper documents the students’ experiences using Jupyter notebook in a postgraduate introductory econometrics course using a qualitative thematic analysis methodology that transcribed and coded 27 one-to-one interviews with ten students throughout the academic term. The results show that: (1) The Jupyter notebook-based learner-centered design pedagogy increased students’ autonomies in the learning process; (2) students developed confidence throughout the learning process; (3) interactive learning tools were effective in supporting students’ econometrics learning.

Keywords: Digital Education, Econometrics, Jupyter Notebook, Thematic Analysis
1 Introduction

The teaching and learning environments are irreversibly shifting towards more digitalised ones due to the rapid development of new technologies [1]. This development was further accelerated when higher education institutions were forced to transit to emergency remote teaching due to the COVID-19 pandemic [2,3]. This transformation not only led to intensified workloads for teachers who needed to rapidly acquire new skills to navigate increasingly complex software to deliver online teaching, but also brought difficulties for students who were not ready for online learning [4–6]. To uphold high-quality education during this transition, we embraced a 'learner-centered design' approach within a technology enhanced student-centered pedagogy, enabling students to personalize routes through their individual learning process in an econometrics course [7–9]. This paper considers changes in attitudes towards learning econometrics within a student-centered technology-enhanced pedagogy during the emergency remote teaching period.

This paper considers Jupyter notebook as the technological platform for student-centered learning. Jupyter notebook is rapidly growing in popularity as a learning and teaching tool across many disciplines. However, there is very little research about its effectiveness as a student-centered technology enhanced pedagogy in econometrics [8,10]. This paper intends to bridge this gap by conducting a preliminary qualitative thematic analysis. It assesses changes in students’ attitudes towards learning econometrics in a technology enhanced setting. For that purpose, the paper hypothesizes that a technology enhanced student-centered pedagogy using Jupyter notebook positively supports personalized learning during a remote emergency teaching period.

Section two discusses the methodology and research approach, section three presents the results, section four is a discussion, section five provides the conclusion followed by acknowledgements.

2 Methodology and Approaches

The methodology of the study is threefold: (1) the design of Jupyter notebook followed the principles of ‘learner-centered design’ approach --- designing for the individual who will be learning and designing the interface around their characteristics [11]; (2) we considered a human-computer interaction based active learning pedagogy within the constructivist framework [12,13] supporting students in co-creating their own understanding of econometrics concepts in a dynamic learning setting; (3) we conducted a qualitative longitudinal study [14] to assess changes in students’ attitudes towards adopting a new technology in learning econometrics [15,16]. We collected data via qualitative interviews and adapted an inductive thematic analysis approach to analyse and evaluate them [17,18].

Course Overview

The course was structured around ten lectures and 5 seminars where Jupyter note-
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book was deployed to support the lecturer (first author)’s teaching by demonstrating ad-hoc interactive theoretical equations, examples, and practices. The organization of lecture and seminar content was adapted from the book called ‘Introductory Econometrics: A modern approach’ [19] and written in Markdown¹ language. The lectures ² were organized in an easy-to-difficult order according to Gagne’s postulate [20]. The seminars were arranged as students’ self-learning sessions where they worked on Jupyter notebook-based practical exercises and received one-to-one technical support from the lecturer and demonstrators.

A ‘learner-centered design’ approach and an active learning pedagogy
We provided a set of Jupyter theme options to help students with impaired vision to personalize their learning material. Images and videos embeddings were introduced to facilitate individual learning pace whilst signposting students to further self-guided learning resources. A Table of contents was integrated as an extension of Jupyter notebook (via nbextension package³) to assist students in tracing down different sections of knowledge with easier navigation [21].

Our pedagogy required students to fully benefit from the interactive learning tools. Since we were aware that students had no prior knowledge of Python, we introduced them to basic Python programming at the start of the semester to help them understand the basic functionalities and commands.

We employed several Python packages to develop dynamic learning tools within Jupyter notebook. The datasets were imported from Faraway [22] and all mathematical functions were written in LaTeX language. We introduced dynamic plotting, self-guided quizzes, multiple-choice questions into Jupyter notebook with the help of Python packages including Bokeh⁴, Plotly⁵, Matplotlib⁶ and iPython⁷.

A qualitative longitudinal study
We recruited students via both classroom on-spot and email invitations. Participants assigned with random IDs were individually contacted and received a copy of information sheet and consent form before the start of the first interview session. They were invited to join three interview sessions spreading throughout the semester (Week 3, 8 and 13). Each interview lasted – on average – ten minutes and was audio-recorded and auto-transcribed. All transcripts were proofread, corrected, and anonymised. The interviews and qualitative analysis were conducted by the second author of the paper. Though the scale of the study is relatively small, we were able to trace each student’s progress in the study in sufficient depth and indicate tendencies [6,23]. We adopted a contextualist approach for the analysis [24] exploring students’ learning experiences and their attitudes towards learning.

¹ https://www.markdownguide.org/
² The lecture content included a probability and statistics revision, simple linear regression, multiple linear regression, inference, asymptotic theory, further issues, econometrics analysis with qualitative information, heteroskedasticity, further specification and data issues, and a revision lecture.
⁴ https://docs.bokeh.org/en/latest/
⁵ https://plotly.com/
⁶ https://matplotlib.org/
⁷ https://ipython.org/
econometrics with Jupyter notebook, as being reflected by different stages of their learning process.

3 Results

Week 3 – Getting familiar with Jupyter Notebook
We observed that students were able to effectively utilize Jupyter notebook in their learning by end of week 3, after some initial set up challenges taking place between weeks 1 and 2: ‘I think the Jupyter notebook is really difficult to set up at first, but my roommates helped me. Now I think Jupyter notebook is making the learning more interesting’ (Participant 3). ‘The whole set up was a bit complicated, but it is all sorted now. And it seems fine.’ (Participant 9).

Nearly all students highlighted a positive interactive learning experience and stated that Jupyter notebook scaffolded their learning progress: ‘The benefit of using Jupyter notebook is that it helped me to acquire a better understanding of the concepts related to how sampling works compared to learning them from the book’ (Participant 3).

Some student highlighted the opportunity to learn Python programming by utilizing the pre-written codes: ‘Jupyter notebook shows that Python is not that difficult and if you actually want to learn, you can learn. Obviously Jupyter notebook grants you some working knowledge of Python’ (Participant 6).

Most students valued the interactive functions. They stated that the direct manipulation of the data strengthened their learning experiences, whilst the dynamic plotting enhanced the data visualization experiences compared to conventional static graphs displayed in textbooks or on PowerPoint slides: ‘I wasn’t able to visualise these key concepts (previously). But Jupyter notebook works really well because it allows you to see what actually happens when you change something yourself. It is super easy to get through everything’ (Participant 9). ‘I like the interactions. I think it is a better way to learn the concepts using dynamic graphs. It is quite easy and good to use’ (Participant 7).

Week 8 – Learning progress and getting ready for the exam
Students expressed an increasing enthusiasm to get engaged with Jupyter Notebook based learning and began to appreciate the usefulness of the technology by week 8. Students were also more confident and creative in their personal learning process: ‘It is a good compliment to my revision in terms of practice. Because econometrics is not only about theories’ (Participant 6). ‘I often use the challenge question (function) in Jupyter notebook. I do it myself first and then double check if I did it correctly’ (Participant 7).

Although Jupyter notebook was rendered useful in the learning process, not all students would choose to use it when preparing for final examination: ‘Revising with Jupyter notebook is tricky...And since this is my first time preparing for exams using Jupyter notebook, I assume the interactions would help me in exams, but I am not sure’ (Participant 2).

A mixed-method approach that integrated the advantages of both PowerPoint and Jupyter notebook was also adopted by some students depending on the nature of
lecture content: ‘In the last few lectures, I used PowerPoints mainly. The key points are clearer, but they are not very detailed. From Jupyter notebook, we can see the whole progress at every step in the regression analysis’ (Participant 8).

**Week 11 – An evaluation of the journey after the exam**

Participants were invited to review their whole learning process with Jupyter notebook in the final interview. Some students mentioned a positive shift of attitudes towards learning econometrics with Jupyter notebook: ‘Most importantly, I feel confident about the econometrics, and I have a deeper understanding of how to use it in a logical way’ (Participant 7). ‘It is a really powerful and helpful tool’ (Participant 8). ‘In general, I am a little better and more confident in using Jupyter notebook compared to the beginning. Looking back at the whole experience, it is a quite different one and using Jupyter notebook was very interesting’ (Participant 2).

Most participants affirmed the efficiency of Jupyter notebook in their personalized learning, and a few, however, may not consider it as an option in future studies as there are other competing technologies that they would prefer such as the R shiny tool: ‘...Jupyter notebook is supporting my learning. Unless compulsory in the future, I might not use it because there are other econometrics software...’ (Participant 4).

**4 Discussion**

**Learner-centered design – Creating an accessible tool for students**

The analysis highlights several advantages for introducing Jupyter notebook during remote emergency teaching in econometrics. Data visualization and dynamic plotting complemented traditional static learning materials, enabling students to self-acknowledge their learning success. The interactive nature of Jupyter notebook further enabled students to learn at their own pace and preferences [16]. In our study, students affirmed the efficacy of step-by-step instructions facilitating their understanding of mathematical equations and statistical models. Students highlighted the dynamic plotting and self-check challenge questions as more useful and helpful in assisting their learning and exam-preparation. Built upon IPython widgets, the ‘the glue’ that connects the educators’ pedagogical objectives to the students, these widgets created a new form of communication between the students and data [25]. In addition, introducing Python language with Jupyter notebook provided an opportunity to cultivate interests for some students who were curious of programming, and supported them to receive some initial training [10]. In addition, as programming has been emphasised as a transferable skill to enhance CV visibility and employability [8], it has benefits beyond the econometrics course itself, and students were favored for this.

**A reflection on student-centered active learning pedagogy**

The occurrences of errors when initially running Jupyter notebook and relevant files on Anaconda were frustrating to some students. To help students mitigate their concerns, we additionally prepared both text and video tutorials, as well as on-spot trouble shooting sessions to help students get familiar with the environment. We
suggest more forms of both online and offline support such as a chatbot could be designed to help students tackle these problems. We also noticed that some students still preferred the traditional forms of learning materials including textbooks and PowerPoints towards the latter part of the semester. We suggest Jupyter notebook materials serving as a substantial notebook for students to consolidating the concepts, whilst a mixed-method approach where traditional textbooks and digital technologies both applied in the teaching should be promoted. This method was also suggested by Hanč et al. who supported the mixed-method approach considering that teachers might not yet be prepared for Jupyter notebook [26].

Future work
Our pilot study qualitatively explores changes in attitudes towards learning econometrics with Jupyter notebook using a semantic analysis methodology. While there are three main findings confirming our overall hypothesis, the robustness of each of them would require a more in-depth quantitative approach. A particularly useful result would be to evaluate the speed of technology adoption in new learning and teaching settings, an avenue for future research.

5 Conclusion
This study explored students’ attitudes towards learning econometrics with Jupyter notebook. Qualitative results demonstrated a subjective positive change in students’ attitudes towards learning econometrics in a technology enhanced setting. First, the study showed that students adopted the new technology in their learning within four weeks of remote emergency teaching, which echoes the past work that reported a positive result (e.g., [16, 27]). This adaptive phase is also similar to Johnson’s report [28]. Second, students’ confidence in learning econometrics with Jupyter notebook, however, would only grow after a longer period of engagement with the new technology. This result is comparable to Gahmi et al. [29]. Finally, the study highlighted that the interactive nature of Jupyter notebook was instrumental in supporting students in their personalized learning, which was also affirmed by other pedagogical evaluation studies (e.g., [16, 27–29]).

Acknowledgments. This research is supported by the NUBS Digital Innovation Fund.

References


Received: February 15, 2023; Published: March 8, 2023