

Use JupyterHub to Enhance the Teaching and Learning Efficiency of Programming Related Courses

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ABSTRACT

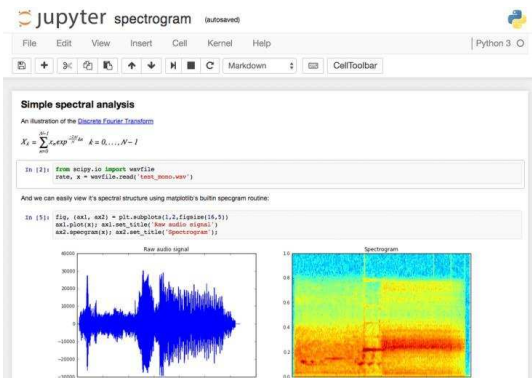
Programming Related Courses (PRC) are highly demanded recently, however there are several challenges about the teaching and learning (TLE) activity of PRC before/during/after class. JupyterHub (JH) and Jupyter Notebook (JN) have grown exponentially popularity due to its flexibility, ease of access through a browser. In this paper, we use an empirical use case to demonstrate how JH and JN help to alleviate the challenges and add convenience to PRC's TLE before/during/after class. The system has been applied in our school for two years and about 430 students in 5 courses have used the system. We design questionnaire and collect feedback from students who have the experience of learning PRC with and without JH/JN, we also interview 4 teachers and ask for their opinion about the usage of the system. From both students and teachers' feedback we can observe that JH and JN can effectively add convenience to PRC's TLE.

Keywords: JupyterHub (JH), Jupyter Notebook (JN), Convenience, Teaching and Learning.

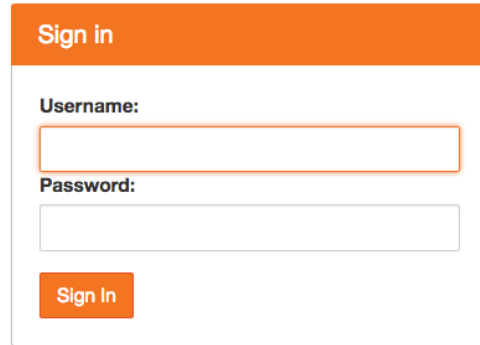
1. Introduction

Programming Related Courses (PRC) are highly demanded in current “Big Data” and AI era. Different to traditional courses, PRC focus more on combining theory with coding practices, which brings challenges to the teaching and learning activity before/during/after class. Before class, computational environment (CE) needs to be set up, configured and updated. During class, teachers have to frequently switch between lecture slides (theory part) and programming environment (coding part) to demonstrate the writing and execution of computer program, making students difficult to grasp the overall picture of the course. After class, sufficient coding exercises are very important for students to sharpen the programming skills they learned in class, however the grading of coding assignments is time consuming since program needs to be loaded and executed by computer and checked manually if exception happens. Due to the above challenges, in practice, coding exercises and tests are not paid enough attention in PRC teaching and this incurs problem that students may get high grade in PRC with weak coding skill.

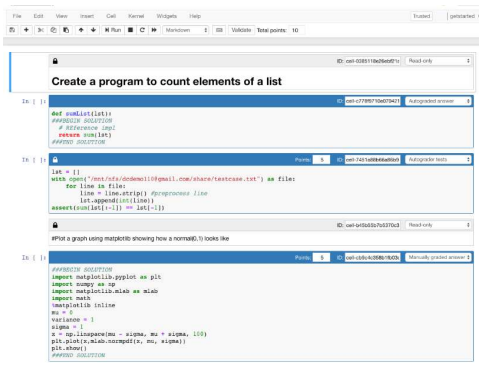
Jupyter Notebook (JN) is an open-source software which has web-based Notebook interface that supports rich documents that combine code and computational results with text narratives, mathematics, images that a modern browser can display. Cardoso, A., Leitão (2018) point out that the high interactivity of JN provides tools to develop and make available narratives anchored in a live computation, which offer the possibility of communicating knowledge and research based on data and results in a readable and replicated way. Figure 1(a) illustrates a Jupyter Notebook sample containing highlighted texts, mathematical formula, Python codes, images, which is used as lecture slides conveyed to students. Note that since code and notebook narratives are integrated into one page, students can easily practice the programming techniques they learned in class by writing and running the code within the page. JupyterHub (JH) is a multiuser version of Jupyter notebook that can be deployed in a centralized server and provides access to any student with internet through web browser. Figure 1 (b) shows the login page of JupyterHub. Once username and password are input correctly, students will enter into their own account where their Jupyter Notebooks are saved.



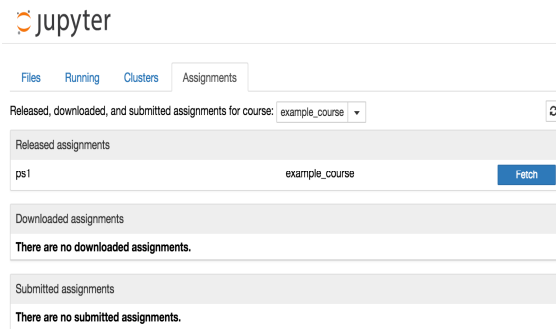
(a) Jupyter Notebook page sample



(b) JupyterHub login window



(c) Create Assignment



(d) Release Assignment

Figure 1: Illustration of JupyterHub and Jupyter Notebook

JupyterHub and Jupyter Notebooks can alleviate above problems. Before class, installation and maintenance of CE can be done by administrator, which save students from the complicated CE installation and configuration. During class, all the lecture notes, mathematical equations, figures, codes can be displayed through webpage, and students can execute the codes and results are immediately displayed in the same webpage which save teachers and students from frequently switching between slides and coding environment. After class, assignments can be created and the *NBGrader* function of JH can automatically grade coding assignments if the input and output are clearly defined, and the centrality of the system makes answer collection and invigilation task of computer based exams much easier.

In this paper, we try to analyze if JH and JN can help improve the convenience of PRC's teaching and learning activity before/during/after class by asking for both teachers and students' feedback.

2. A Use Case of PRC Teaching and Learning

A use case of JH/JN is described as below:

First, JH system are set up by administrators. Students who register the course are added to JH database, and students can then log into their own account through any web browser after entering their ID and password correctly. Teachers upload JN lecture slides as *.ipynb* format (Jupyter notebook file format) to JH and distribute slides to each registered student's account before class. Students can access slides before class for the preview purpose. During class, students can follow teacher's explanation about slides content by reading, understanding, executing and testing the code written on the notebook and even write their own code. Students' modification about the slides can be automatically saved. After class, teacher may leave homework to students by distributing homework notebook to students' account and set the submission deadline. Students put up their solutions in JN and submit their homework through JH. Similar to creating assignments, teacher can also organize (in-class) quiz by releasing question JN at the beginning of the quiz and setting up a submission deadline restricting students to submit their solutions before the deadline. Figure 1(c) denotes a sample question notebook and Figure 1(d) denotes that once question paper is

released and students can find it in JH and “fetch” the question paper so that it can be saved in student’s own account. There is an important component called *NBGrader* in JH which can help teacher automatically grade students’ question notebook, and this is extremely helpful since it can greatly relieve teacher’s workload and also make it possible to assign more programming assignment to students which train students to get more hands on programming skill.

3. Related Work

JH and JN have grown exponentially popularity due to its flexibility, ease of access through a browser and have been widely used for teaching purpose in many prestigious universities like UC Berkeley, Michigan State University, Northwestern University, etc. Existing works have introduced how JupyterHub and Jupyter Notebook are applied in university teaching (Krpán, Mladenović & Rosić, 2015). Cardoso, Leitão and Teixeira (2018) presents the use of Jupyter Notebook as tools that provide a programming environment to develop and share scientific contents and that can promote the access to remote and virtual labs. Hadi and Al-Zewairi (2017) employed Jupyter Notebook for teaching of web scraping. A recent study introduces how Jupyter Notebook is used in teaching Physics by conveniently facilitating the decoupling of the data handling and processing, and allows the students to explore the data in an interactive way, to acquire a deeper knowledge of the data (Urcelay-Olabarria, Lazkoz, Urrestilla, Leonardo & Igartua, 2017). Díaz and Cabrera (2018) provide a guide to implement the entire teaching platform based on Jupyter Notebook for educational purpose. Holdgraf et al. (2017) develop and compare several bootcamp-style models of pedagogy with or without the cloud-computing infrastructure. Hamrick (2016) presents an automatic workflow of assignment creation, distribution, collection, grading and feedback through NBGrader, an open-source auto-grading tool.

Even though JH and JN have been widely used for teaching purpose recently, there has few work analysing the efficacy of applying them to solve the problems existed in teaching and learning of PRC before/during/after class.

4. Research Problem and Methodology

In this paper, we will discuss the validity of JH and JN with respect to improve the convenience of teaching and learning of PRC by solving practical challenges before/in/after class.

4.1 Background

In this paper we define two categories of courses, courses which use JH/JN as the teaching platform and courses which use PPT+IDE as the teaching platform.

4.1.1 JH/JN platform

There are 5 PRC courses opened in our school which are based on python programming language and use JH and/or JN as the teaching platform (see Table 1 for course description). The 5 courses are opened by four different programs, Computer Science, Data Science, Financial Mathematics, and Statistics program. In nowadays Python is one of the mainstream data processing language which is suitable for various data analysis and machine learning tasks. Besides, Jupyter platform supports Python kernel very well. From Table 1 we can observe that around 430 students have used the Jupyter platform since it is first introduced in 2017 in our university.

Table 1: Python related PRC

Courses	Cohorts	Student Number	JH and/or JN
Python Programming language	2	~170	JH + JN
Software Development Workshop 2	2	~150	JH + JN
Data Processing Workshop	1	84	JH + JN
Artificial Neural Networks & Deep Learning	1	20	JN
Financial Engineering Workshop	1	12	JH + JN

4.1.2 PPT+IDE platform

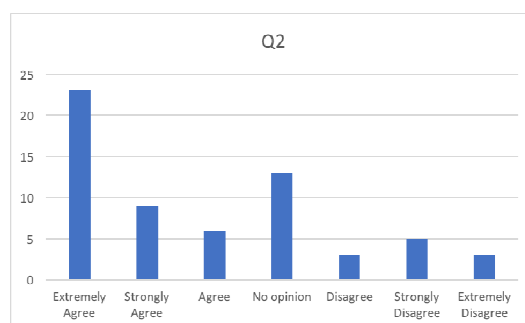
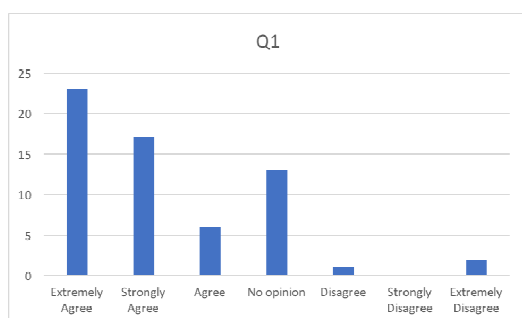
There are multiple PRCs opened in our school which are not based on Python programming, e.g. C/C++/Java programming language, and these courses are not taught with JH/JN platform. Most teachers use Microsoft PowerPoint (PPT) slides as the teaching media to introduce the theoretical parts of the course, and use integrated development environment (IDE) like Visual Studio, Eclipse to demonstrate how program is executed.

4.2 Methodology

4.2.1 Students' Angle

A portion of students have the experience of learning PRC through both two platforms. For example, when they learn PRC based on Python like data processing workshop, they use JH/JN platform, while when they learn PRC not based on Python like C++ programming language, they use PPT+IDE platform. By comparing students' learning experience of using the two platforms, their opinion can partially reflect the convenience of JH/JN system in students' before/ in/after class study. We design questionnaire about how JH/JN facilitate students' study before/in/after class and distribute the questionnaire to students who have used both platforms in their learning of PRC (both python based and non-python based). 62 Feedbacks are collected and most of them come from Year 3 students since most PRC are major required courses which will not be taught in junior or sophomore. Questionnaire questions are listed below.

- Q1:** In Jupyter platform, students access computing environment through web browser. In C/C++/Java course, students access computing environment on their own computer by installing IDE (e.g. Visual Studio) themselves. Do you agree that jupyter relieve the complication of environment configuration?
- Q2:** In Python course, Python code and lecture content are integrated into one Jupyter Notebook. In C/C++/Java course, lecture slides (e.g. written by PPT) and code execution (e.g. by IDE's like visual studio/eclipse) are accessed separately. Do you agree that jupyter notebook perform better in illustrating programming concepts?
- Q3:** In Jupyter platform, students can directly execute python code in the same page with course content, however for C/C++/Java, students need to switch between PPT and IDE back and force. Do you agree Jupyter Notebook make coding practice easier?
- Q4:** Following previous question, do you agree Jupyter platform help you better follow teacher's pace during the class?
- Q5:** Jupyter platform can automatically save your coding exercise during the class. Do you agree this is helpful for your study?
- Q6:** Disregarding course content (e.g. C++ is more difficult than Python, or vice versa), do you agree that the learning experience based on Jupyter platform is better than PPT+IDE (e.g. like learning C/C++/Java)?
- Q7:** If Jupyter Notebook supports C/C++/Java as good as Python, do you agree to take Jupyter platform as your first choice to learn C/C++/Java, instead of using PPT+Visual Studio/Eclipse?



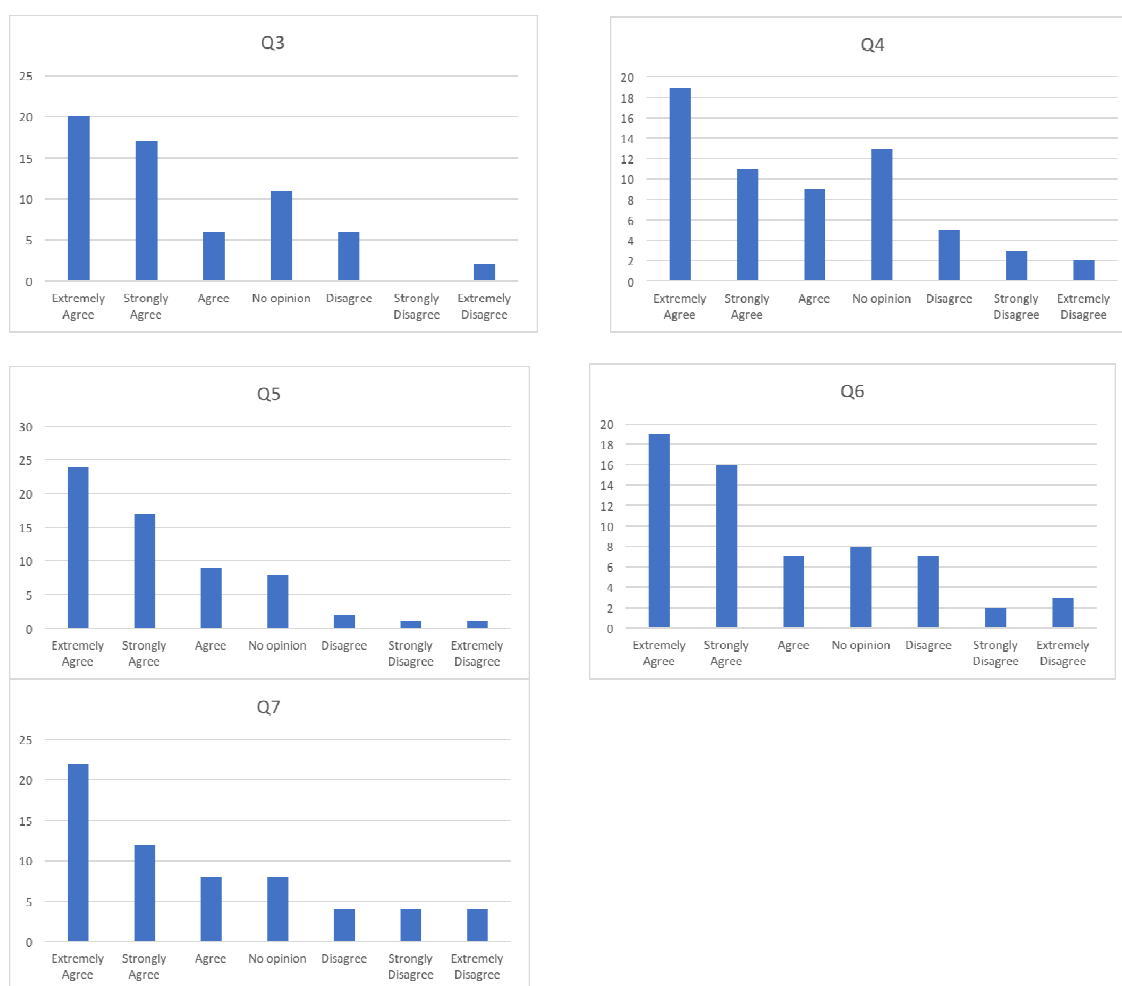


Figure 2: Questionnaire Feedback from students using both platforms

From the feedback above we can find that the majority of students agree that JH/JN can help reduce workload of setting up computational environment (Q1), enhance interactivity so that programming concepts can be better demonstrated and students are more convenient to do coding practice and follow the pace of teachers when they study PRC (Q2, Q3, Q4), automatically save the exercises done in class (Q5), and provide better learning experience (Q6, Q7).

4.2.2 Teacher's Angle

Since the sample size of teacher is relatively small, instead of distributing questionnaire, we use face to face interview strategy to talk with four teachers who have the experience of using both platforms to teach PRC (JH/JN, PPT+IDE) and ask for their opinions if JH/JN add convenience to their teaching. All teachers agree that NBGrader function of JH helps a lot in their teaching since it can greatly relieve the grading workload and make it possible to assign more programming exercises. Besides, it also adds more flexibility to create programming related in-class quiz since questions can be released and collected conveniently online and grading can be automatically done, and this is helpful to push students to follow teacher's instruction. Some teachers think JH/JN are most suited to workshop oriented course since course contents, expected output, demonstration and so on, are clearly presented in JN and students can self-study by reading instructions and executing the codes written in the notebook. Some teachers think the "interactive" teaching mode is helpful since theory and practice can be combined in one JN page. After introducing the theoretical parts of the course, teachers can demonstrate to run the codes and computation/visualization results will be displayed in the same page without requiring teachers and students to frequently switch between slides and coding environment back and force, and this keeps the consistency of TLE.

Overall, all the four teachers believe JH/JN platform add convenience of delivering course content to students and that is why more and more teachers decide to use JH/JN platform to teach PRC since 2017 when JH/JN is first launched in our school.

5. Conclusion

PRC are highly demanded recently, and there has practical challenges about the TLE activity of PRC before/during/after class. JH and JN grow exponentially popularity in recent years due to its high interactivity property. In this paper, we use empirical use case to demonstrate how JH and JN help to alleviate the challenges and add convenience to PRC's TLE before/during/after class. Before class, installation and maintenance of CE can be done by administrator, which save students from the complicated software installation and configuration. During class, all the course content including theory and coding parts can be displayed on JN webpage, where codes can be executed and results are immediately displayed in the same webpage without requiring teachers and students frequently switching between PPT and IDE. After class, the NBGrader function of Jupyterhub can automatically grade coding assignments, and adds more flexibility to create programming related in-class quiz since questions can be released and collected conveniently online and grading can be automatically done.

We have used JH/JN platform in the teaching of PRC for two years and about 430 students in 5 courses have used the system. We design questionnaire and collect feedback from students who have the experience of learning PRC with and without JH/JN. We also interview 4 teachers and ask for their opinion about the usage of the system. From both students and teachers' feedback we can find that JH and JN can effectively add convenience to PRC's TLE.



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Authors' Backgrounds

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	<p>Mr. Junwei Xia is a Teaching Assistant of several programming courses in BNU-HKBU united international college (UIC). He helps to deploy and configure the JupyterHub platform and co-teach several courses based on the platform. Before that, he received his Bachelor's degree in Applied Mathematics from UIC in June 2016. His research interest is in the areas of Machine Learning and Financial Mathematics.</p>