

Teaching and Facilitating an Online Learning Environment for a Web Programming Module

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Abstract— Over the last decade, there has been a gradual increase in the number of learners on Computer Science-based programmes, which in turn has led to a situation where educators have been teaching large classes. This is a challenge, as it can be difficult for educators to provide personalised support for each learner. The pandemic has only exasperated this further, given the online delivery of courses. The work in this paper describes the implementation of a pedagogic framework that was deployed during the delivery of a first-year web programming module. The motivation behind the development of this framework was driven by the need to facilitate an online learning environment for a large class, which adapted existing pedagogic approaches such as problem and project-based learning with the view to enabling learners to develop their problem-solving skills. In addition to this, an online lab co-ordination system was formulated to measure engagement and provide support to the learners.

Keywords— *programming, project-based learning, problem-based learning, online, web technologies*

I. INTRODUCTION

The COVID-19 pandemic unearthed several challenges for higher education institutions [1, 2], however one can also argue that it gave institutions an opportunity to reflect on their post pandemic pedagogic approaches and adapt them to facilitate a productive online learning environment. In the context of Computer Science (CS) programming modules, the adaptation of pedagogic approaches and practical programming environments is essential. This is because programming is a core subject within the area of CS, as it allows learners to develop their problem-solving skills and get hands on practical experience of learning about algorithms [3]. First year programming modules tend to have a significantly larger number of learners enrolled onto them. Facilitating large classes was considered a challenge for educators' during the pre-pandemic period [4], and this has only been heightened during the pandemic. To address this, we devised a pedagogic framework during the online delivery of a first-year web programming module in the academic year 2020/21. The framework was based on the adaptation of existing pedagogic approaches, namely problem and project-based learning, where the objectives was to enable learners to develop their problem-solving skills. Hence, the aim of this paper is to investigate the impact of this pedagogic framework on the performance of the learners undertaking the first year web programming module. This module was designed to equip learners with practical skills and an understanding of the underlying principles of programming the World Wide Web (WWW). The major topics within this module included: Client-side programming using HTML5, Cascading Style Sheets, JavaScript, Server-side programming using PHP and

a firm understanding of the Internet and web servers. Given the online learning environment, we also developed an interactive lab session coordination system, which allowed the module team to provide timely support to learners and be able to get a better understanding of exercises/topics that learners needed support with.

The rest of the paper is structured as follows: Section 2 discusses the related work. Methodology is presented in Section 3, which is then followed up with a description of the framework in Section 4. While Section 5 presents the results that validate the pedagogic framework and evaluates the effectiveness of the lab session coordination system.

II. RELATED WORK

COVID-19 has been seen as the greatest challenge that education systems have ever faced as educators globally have had to adapt their pedagogic approaches due to teaching online [5, 6, 7]. To facilitate this, institutions upgraded their education systems by utilising technologies to deliver online teaching without compromising the quality of education [8]. This also presented institutions with an opportunity to deliver courses to learners who were unable to attend overseas classes due to travel restrictions caused by COVID-19 [9]. However, for many developing countries this was far from an ideal situation, as the learning experiences were impacted by inadequate Internet facilities and nonconductive home learning environments. Learner engagement and interaction has also been a considered a challenge for both learners and educators. This is a view that that has been acknowledged by learners due to the lack of interaction with educators and peers, especially within group projects [1].

During the pandemic, the delivery of online courses was very much dependent on e-learning tools and platforms, which also have the capability to evaluate learner engagement, participation, and attendance. However, it has been suggested that there was a need for comprehensive training for the educators to ensure effective use of these tools to maintain/improve teaching online [10].

Before the pandemic, teaching and organising large classes was seen as challenge for educators due to factors such as learner engagement and pass rate. This has been a growing trend in CS modules, as the number of learners registered in first year programming modules has been increasing in recent years. Therefore, it is challenging for educators to focus on every learner, especially in programming modules which can lead to increases in failure rates [11]. Many educators have tried different approaches to improve learner engagement and pass rates. One such approach was the recording of sessions to complement interactive learning, which was successfully

tested for a cybersecurity module [7] as it helped learners to solve weekly practical assignments. Moreover, approaches such as self-assessment, peer mentoring and group activities can improve the learner's learning and engagement, as this was investigated during the teaching of a software engineering module [9]. Furthermore, dividing a large class into micro classes by replicating the small-class community can also increase learner satisfaction rate and engagement [10]. Collaborative teaching is another approach that can be used through various types of activities such as group projects, group discussions to improve learner engagement. A recent study [8] on collaborative teaching showed that it is helpful for clarifying learner's doubts and enhancing their problem-solving ability. In addition to this, lightweight strategies such as small discussion groups and one-on-one tutoring can have a positive impact on learner satisfaction rates [11].

Project-based and problem-based learning (PBL) are known to be successful pedagogical approaches in computing and engineering education [12]. Integrating PBL into the classroom has shown improvements in critical thinking, in-depth technical knowledge, problem-solving and team working skills [13]. Moreover, PBL provides learners with the opportunity to apply theoretical concepts in a real-world way. As such, the variety of applications within engineering is widespread. For example, one PBL study used a Decision Support System (DSS) to teach one of the most fundamental topics in distribution planning: vehicle routing. Yet, in this PBL method, learners solved a typical vehicle routing case without any knowledge of the theoretical background as a prerequisite or introduction to the theory. The key learning outcome was in raising concerns about how DSSs must be adapted for implementation in every business scenario [14]. Another study used PBL within the Lean Six Sigma classroom. The study findings were; the learners who took enhanced courses developed a better understanding of theory to implement in real-world situations, and the impact of green belt certification in recent graduates in terms of transition to the workforce, gain more credibility and fasten their careers [15]. One research study used PBL to teach learners about writing A3 communication reports. The study found that the combination of A3 communication reports with PBL significantly improved the learning practices in the classroom, and their problem solving while allowing the communication of obtained results [16]. In summary, there are many examples of PBL applications within the engineering classroom, yet, those proven the most successful have an adequate amount of support provided by instructors, tutors, and teaching assistants [17, 18]. The next section will showcase the methods to measure engagement and provide support to learners working on PBL assignments.

III. METHODOLOGY

The development methodology used for the pedagogic framework was the *Technical Action Research Model*, which assessed how the module was delivered in the previous year, with a view to making the module delivery more efficient and effective [19]. This was very important, as the module team wanted to learn from their experience of delivering this module during the first lockdown in March 2020, where they had to adapt the content and assessment within days to accommodate a new way of delivering this module online. Through this process, it was discovered that the following challenges needed to be addressed during the academic year

2020/21 (where the module was going to be delivered online again):

- Create a learning environment within the live online lecture sessions that would enable learners to get hands on experience with coding exercises that would also reinforce what they have learnt.
- Revise the assessment structure of this module, so that the learners can keep a track of their progress while they learn new concepts and apply their learning to their assessment.
- Facilitate an online laboratory environment, where it would be possible to measure learner interaction and engagement.

IV. FRAMEWORK

The aim of this first year web programming module was to provide learners with a basic understanding of the operation of the World Wide Web (WWW) and teach them practical skills for programming the Web. The pedagogic framework applied for this module was an adaptation of problem and project-based learning, where the motivation was to provide learners with hands-on experience of web programming languages and technologies. In terms of delivery, the module was delivered through a combination of online (synchronous) lectures and lab sessions, which were supported by a comprehensive set of self-study (asynchronous) materials provided on the learning management system. This material included interactive H5P (HTML5 Package) videos that learners were expected to engage with before and after the live online lecture sessions. These videos had embedded questions (figure 1) that were used to measure the learner's engagement with the asynchronous content. This was useful, as the module team used this engagement data to identify learners who were not engaging with the content.

The online (synchronous) lectures were used to introduce both the theoretical and practical aspects, while the lab sessions provided learners with an opportunity to reinforce the content covered during the lecture sessions as well as providing support for the weekly lab exercises and assessments.

A. Problem-Based Learning

One of the objectives for the online (synchronous) sessions was to provide the learners with an opportunity to reinforce what they have learnt within the synchronous session. This was done by adapting a problem-based learning approach where the educators instructed the learners to solve in-class coding exercises that would be based on a concept that had been covered by the educator within the lecture session. For example, the educator would explain to the learner how loops work in JavaScript, which would then be followed up with a coded example, followed by an exercise based on loops that learner would need to code (i.e., solve). The learners were then encouraged to share their coding output (in the form of screenshots) with the rest of class by posting it on a dedicated Microsoft Teams channel. This approach was effective, as when the learners posted their screenshots it also encouraged their peers to do the same. To determine the level of difficulty of the weekly in class coding exercises, the educators conducted a survey/poll in week 1 of the module that asked the learners to rate their initial level of understanding about the core web technologies (i.e., HTML, CSS, JavaScript, and PHP) that would be covered during the module.

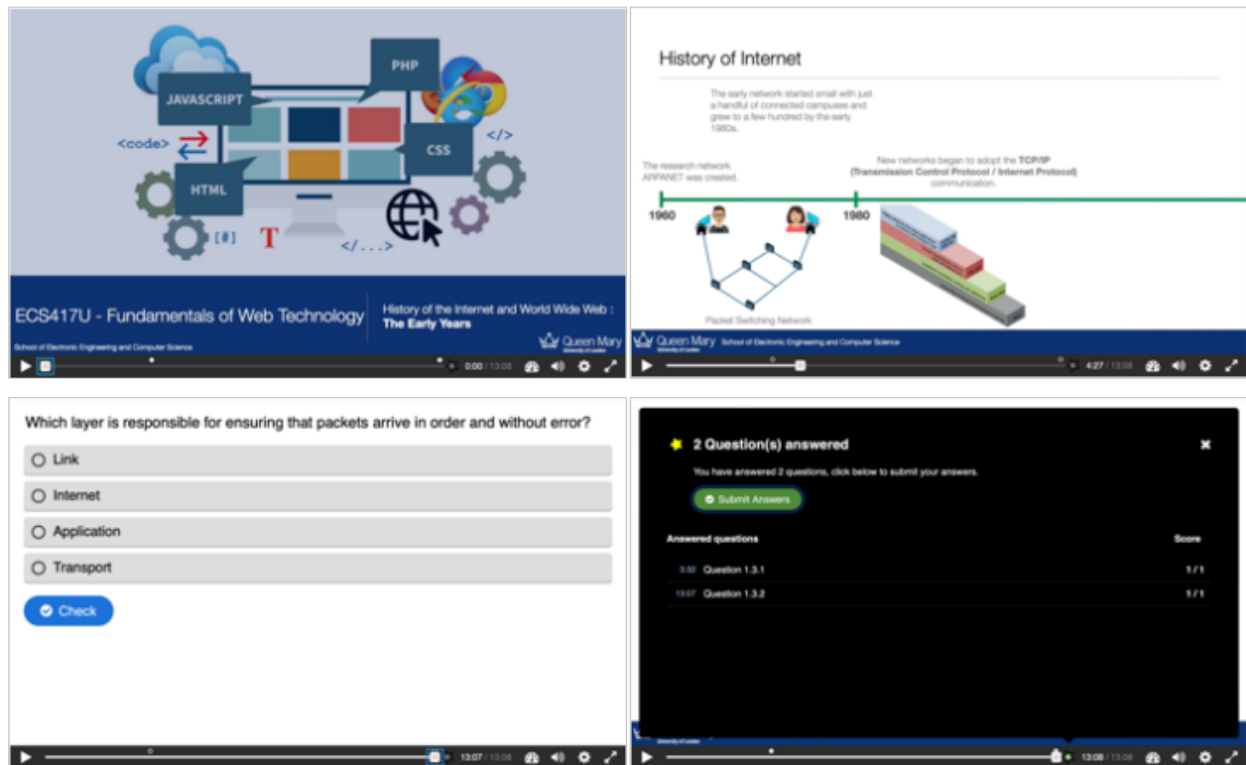


Fig. 1. Example of an Interactive H5P Video

B. Project-Based Learning

Given that the module was going to be delivered online, a project-based learning approach was adopted where the learners were expected to complete a project (also known as a mini project) over the course of the module, where the output of the project was the development of a portfolio website that served as platform for the learners to showcase their skills to external audiences (i.e., potential employers). The site also needed to include a tool for writing and reading a weblog (blog), where the main user would be able to add text entries to the blog. To complete this project, the learners were required to work on the mini project on a weekly basis, as the content they covered in the lab sessions would enable them to build their portfolio website progressively over the 12 weeks of this module. During the lab sessions, learners were provided with weekly formative and summative lab exercises that were designed to support the learner's development in acquiring the core module skills that were fundamental in enabling the learners to develop a portfolio website for the mini project assessment. The portfolio website had to be developed using the core web technologies covered in this module. Specifically, HTML5 and CSS was used mainly to create the structure and layout of the website pages. JavaScript was used to achieve extended validation of the forms and client-side interaction on the site. While PHP was the server-side programming language used for access control, basic database connectivity and generating dynamical web pages for the blog. An assessment requirement was that learners needed to deploy their websites on the OpenShift application platform which needed to have a webhook to the learner's GitHub repository.

The benefits for the learners in engaging with this mini project were two-fold. Firstly, it allowed the learners to keep a track of their progress while they learnt new concepts and applied their understanding of these to their mini project. Secondly, from an employability point view, it provided them with a platform to demonstrate to potential employers their skills through projects that they have worked on while at university. This is something that is vital for learners within the area of Electronic Engineering and Computer Science, as throughout their degree programme they get many opportunities to demonstrate their skills on a wide range of coursework assessments and projects. Hence, an online portfolio is an ideal platform for students to provide evidence of their skills acquired throughout their degree programme.

C. Interactive Lab Co-ordination System

In addition to providing support and guidance to the learner, the lab sessions also allowed the module team to assess the summative lab exercises. The coordination of these lab sessions was a monumental challenge due to the number of learners on the module (285 learners), as the module team had to ensure that a system was formulated, which was able to track learner engagement, provide learning support and assess weekly tasks. In addition to reinforcing the content covered in the lecture sessions, the labs sessions provided the learners with an opportunity to:

1. Ask demonstrators for clarification/support on the weekly lab exercises and mini project.
2. Get their summative lab exercises assessed by a member of the module team.

Week 4 - Interaction Form - Group 1

Interaction with the module team will be done using this online form, where you will be able to initiate contact with them. Once you have filled in this form (during your lab session) to request support or confirm that you are ready to be assessed then you will be contacted by a member of the module team via Microsoft Teams. Hence please ensure that you have downloaded this application and your are logged in.

Hi, Usman. When you submit this form, the owner will see your name and email address.

* Required

1. What would you like to discuss with the module team? *

Select your answer ^

Request for Support

Ready for Assessment

☐ Send me an email receipt or my responses

Submit

Start time	Completion time	Email	Name	What would you like to discuss	What question would you like to ask	Which topic	Response time	Response	Comments
38	2/16/21 11:03:13	2/16/21 11:03:54		Request for Support	Connection between the html and css file / switch topic3			Yes	
39	2/16/21 11:03:14	2/16/21 11:03:54		Request for Support		Topic 3		Yes	
40	2/16/21 11:03:51	2/16/21 11:03:59		Ready for Assessment		Topic 3		Yes	
41	2/16/21 11:03:46	2/16/21 11:04:04		Ready for Assessment		Topic 3		Yes	
42	2/16/21 11:04:04	2/16/21 11:04:11		Ready for Assessment		Topic 4		Yes	
43	2/16/21 11:03:52	2/16/21 11:04:17		Ready for Assessment		Topic 2		Yes	
44	2/16/21 11:04:11	2/16/21 11:04:25		Request for Support	assessment criteria			Yes	
45	2/16/21 11:04:17	2/16/21 11:04:27		Ready for Assessment		Topic 2		Yes	
46	2/16/21 11:04:44	2/16/21 11:04:50		Request for Support	Exercise 3/4 Week 3			Yes	
47	2/16/21 11:04:27	2/16/21 11:05:04		Ready for Assessment		Topic 2		Yes	
48	2/16/21 11:05:16	2/16/21 11:05:24		Ready for Assessment		Topic 3		Yes	
49	2/16/21 11:05:09	2/16/21 11:05:26		Ready for Assessment		Topic 2		Yes	Human will assess
50	2/16/21 11:05:29	2/16/21 11:05:38		Ready for Assessment		Topic 2		Yes	
51	2/16/21 11:05:33	2/16/21 11:05:57		Ready for Assessment		Topic 2		No	No answer at second attempt either
52	2/16/21 11:05:55	2/16/21 11:06:07		Ready for Assessment		Topic 2		Yes	Human will assess
53	2/16/21 11:06:17	2/16/21 11:06:24		Ready for Assessment		Topic 3		Yes	
54	2/16/21 11:05:32	2/16/21 11:06:57		Request for Support	Topic 2			Yes	
55	2/16/21 11:07:39	2/16/21 11:07:47		Request for Support	Topic 2			Yes	
56	2/16/21 11:07:56	2/16/21 11:08:02		Ready for Assessment		Topic 3		Yes	
57	2/16/21 11:07:54	2/16/21 11:08:03		Ready for Assessment		Topic 3		Yes	
58	2/16/21 11:08:02	2/16/21 11:08:12		Ready for Assessment		Topic 2		Yes	
59	2/16/21 11:08:05	2/16/21 11:08:13		Ready for Assessment		Topic 2		Yes	
60	2/16/21 11:07:39	2/16/21 11:08:19		Request for Support	Topic1			Yes	*Human - student will need to work
61	2/16/21 11:01:30	2/16/21 11:09:11		Ready for Assessment		Topic 2		Yes	
62	2/16/21 11:04:27	2/16/21 11:09:17		Ready for Assessment		Topic 2		Yes	
63	2/16/21 11:01:00	2/16/21 11:10:26		Ready for Assessment		Topic 3		Yes	
64	2/16/21 11:06:52	2/16/21 11:11:22		Ready for Assessment		Topic 3		Yes	
65	2/16/21 11:11:13	2/16/21 11:11:23		Ready for Assessment		Topic 2		Yes	Human will assess
66	2/16/21 11:09:45	2/16/21 11:11:28		Ready for Assessment		Topic 2		Yes	
67	2/16/21 11:09:44	2/16/21 11:11:38		Request for Support	Can you see if I did the topic 3 right?			Yes	
68	2/16/21 11:12:04	2/16/21 11:12:28		Ready for Assessment		Topic 2		Yes	
69	2/16/21 11:12:33	2/16/21 11:13:04		Ready for Assessment		Topic 3		Yes	
70	2/16/21 11:12:41	2/16/21 11:13:46		Request for Support	Lab Topic 3 Q4			Yes	
71	2/16/21 11:11:35	2/16/21 11:14:44		Ready for Assessment		Topic 4		Yes	

Fig. 2. Lab coordination system, which includes the form and a live spreadsheet for each lab session group

Interaction with the module team was done using an online form, where the learners were able to initiate contact with the module team. Once the learners had filled in the form (during their allocated lab session) to request support or confirm that they were ready to be assessed then they were contacted by a member of the module team via Microsoft Teams. Hence the learners needed to ensure that they were logged in and ready for a member of the module team to call them to provide support or assess them.

The lab coordination system was created by formulating a methodology that made use of Microsoft Forms and live spreadsheets (figure 2), which allowed the learners to locate themselves in the queue. This was very important, as it managed the learner's expectation in terms of when they would be contacted by someone from the module team to provide them with support or assess them. This interactive approach not only facilitated learner support queries, but also allowed the module team to get a holistic view of the topics that learners were struggling with.

It can be seen in figure 3 that a large proportion of the learner's interaction with the module team was based on assessment requests. One of the reasons for this was due to the fact there were several summative assessments, which

contributed towards the final grade of the module. In addition to this, we gave a flexible submission period where the learners could get their weekly tasks assessed over a few weeks, as opposed to having a fixed weekly deadline. This was done to facilitate the different learning styles of the learners. Week 5 had the highest number of assessment requests, as during this week learners could get topic 3, 4, 5 assessed by the module team. Table 1 provides a breakdown of the weekly lab exercise and their flexible assessment periods.

TABLE I. ASSESSMENT PERIOD FOR THE WEEKLY LAB EXERCISES

Topic	Assessment Type	Assessment Period in Weekly Labs
2	Summative	Week 2, 3, 4
3	Summative	Week 3, 4, 5
4	Summative	Week 4, 5, 6
5	Summative	Week 5, 6, 7, 8
7	Formative	Not Assessed
8	Formative	Not Assessed
9	Formative	Not Assessed

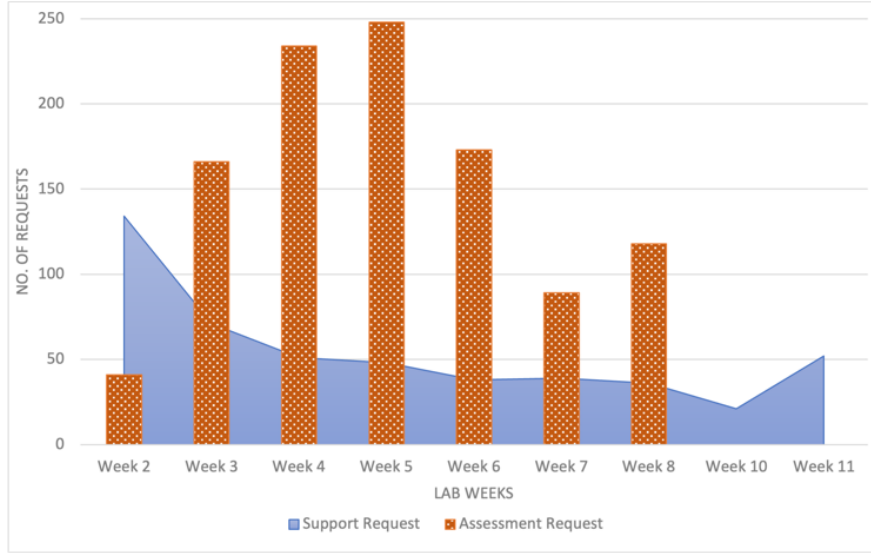


Fig. 3. Learner engagement measured by learner interaction with the module team based on requests for support and assessment. Note: There were no lab sessions in week 1, while week 9 and 12 were assessment only sessions for the mini project.

Another interesting observation in figure 3 is that the request for support gradually decreased as the semester progressed. One of the reasons for this was that many learners initially had issues in the first lab session (week 2) to setup the deployment environment. However, there was a slight increase in week 11 as there were many support requests about the mini project that had submission deadline in week 12.

V. RESULTS

In this section the following research questions have been addressed to validate the effectiveness of the proposed framework and the interactive lab coordination system:

RQ1 - What is the difference in performance of learners undertaking this module with previous cohorts (pre-pandemic)?

RQ2 - Can the proposed framework be implemented in a post-pandemic learning environment, where institutions may adopt a hybrid learning environment (online and face-to-face)?

To address *RQ1*, we have compared the performance of the current cohort to the cohort that studied this module before pandemic. This is because the pedagogic approach within the lecture sessions and assessment had changed since then. Given this we can conclude that the proposed framework yielded positive results as 285 (229) learners attempted all assessments (including the mini project). 95% (84%) of these learners passed this module with an average pass mark of 72.9 (59.74)*.

*Note that the number in the bracket () indicates the module pre-pandemic statistics.

In order to evaluate the interactive lab coordination system, descriptive surveys were carried out with the learners and the module team. The feedback received from learners (48 responses) was positive (Figure 4), as many of the learners felt that the lab interaction forms were easy to use, and they were able to locate themselves within the queuing system. It was

also very pleasing to see that the learners felt that they were well supported by the module team during the lab sessions.

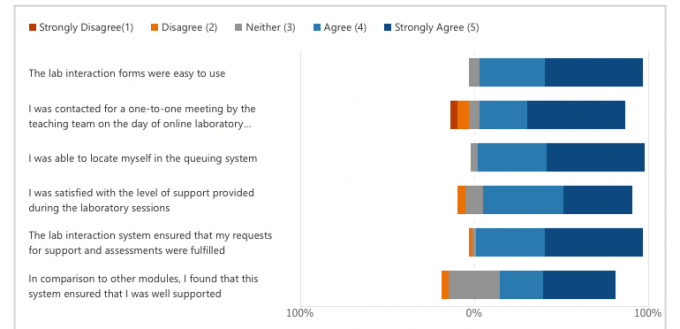


Fig. 4. Interactive Lab Coordination System – Learner Feedback

In addition to the learners, it was also important to capture the views of the module team, namely the teaching assistants who facilitated the lab sessions by providing support and assisting with the weekly summative assessments. For this module, there were two educators (lecturers) and 17 teaching assistants of which 11 had provided feedback (figure 5) about the lab interaction system.

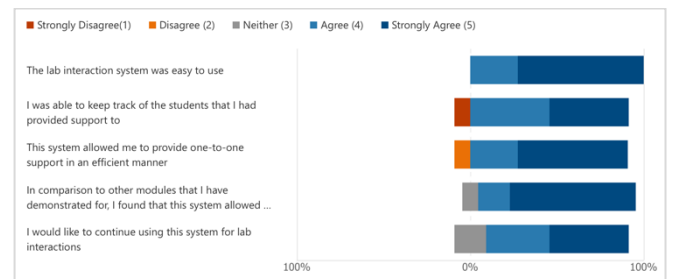


Fig. 5. Interactive Lab Coordination System – Module Team (Teaching Assistants) Feedback

Like the learners, the module team provided positive feedback, as they also felt the system was easy to use and facilitated an environment where they could provide support

in an efficient manner. It was also encouraging to see that most of the module team would like to continue using this system. Hence, we intend to continue to use this system for the next academic year. To conclude, this leads to the answer for RQ2: *Can the proposed framework be implemented in a post-pandemic learning environment, where institutions may adopt a hybrid learning environment (online and face-to-face)?* We believe it can, as lot of the good practices (in class problem solving exercises, the mini project, and the lab coordination system) can be deployed in a face-to-face (on campus) and online delivery of this module.

VI. CONCLUSION

Teaching larges classes during the pandemic can be challenging, however the proposed pedagogic framework (based on problem and project-based learning) allowed the module team to facilitate a learning environment that enabled learners to acquire practical web programming skills. In addition to this, an interactive lab coordination system was formulated that had a positive impact on learner's performance on this module. Given the results, it is evident that the proposed framework and interactive lab interaction system will be a benchmark to demonstrate good practices that can be deployed by other educators teaching programming.

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