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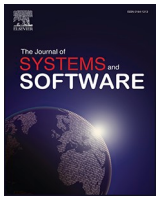

Delivering computing module for the large part-time software development class from pre- to post-pandemic: An online learning experience

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ABSTRACT

Introduction: Covid-19 pandemic brought dramatic changes to higher education settings, particularly for curriculum delivery, moving quickly to online learning. This paper discusses teaching experience covering practices of technology-enhanced learning for the MSc Computing Foundations module (20 CATS) for a large class studying part-time Software Engineering course at the School of Electronics, Electrical Engineering and Computer Science (EEECS), Queen's University Belfast (QUB) during 2019–2022 academic years. We compare on-campus learning with the abrupt shift to online learning during the pandemic and with sustainable online learning a year later. The objective of this study is to answer how part-time software development students perceived their technology-enhanced learning experience from pre- to post-pandemic and to evaluate the impact of the shift to online learning for the part-time class

Methods: This study is based on data collected during 2019/2020, 2020/2021, 2021/2022 academic years. Methodology types employed in this study include online observation with statistics collected from the virtual learning environment (VLE) Canvas, quantitative analysis, individual student surveys on teaching techniques and module content

Results: This study provided an effective online teaching method for Computer Foundation module, reviewing the impact of different curriculum items and online educational activities starting with content delivery – both synchronous and asynchronous – and moving on to VLE Canvas discussion forums, ungraded formative quizzes, in-term formative assessment in the form of mock exam and, finally, to online summative assessment delivered on VLE Canvas. We investigate positive and negative aspects of technology-enhanced learning from pre- to post-pandemic according to part-time adult students studying the MSc software development program and focus on how this effective learning environment contributes to education practice with a view what developments are worth retaining post-pandemic and what did not work well. Analysis of the data from individual student surveys on teaching techniques and module content for the Computing Foundations module allowed us to conclude that students perceived very positive their technology-enhanced learning experience after shifting to online learning. We also found out that changing the module delivery format (from face-to-face to online) did not affect the results of the students' performance.

Conclusion and implications: Adaptation of the MSc Computing Foundation module to a new model of distance learning has proved to be successful, so we can conclude that this delivery format is appropriate for this target audience. This study explored the effectiveness of the pedagogical approach while also gaining valuable insights into the software development student experience of learning in the VLE. The findings from this study may contribute to developing effective teaching practices in software engineering education and adult learning, and improve the preparation of future software professionals in the IT industry.

1. Introduction

The rapid shift to online learning during the Covid-19 pandemic led to widespread migration to online delivery, although online education is not new and many universities around the world were implementing it long before. However, the online learning and teaching experiences that

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students and universities have had during the pandemic contrast sharply with the best practices and research in this field (Stewart and Lowenthal, 2021).

Existing literature on the transition from face-to-face learning to other types of learning (blended or online learning) examines these shifts on the basis that changes in learning are carefully planned by academics (Brown and Green, 2015). A switch to a new model of delivery would normally take place after a period of consideration of module specifications, providing a rationale and justification for changes which can be accepted by faculty, and curriculum review. In truly unprecedented times of the Covid-19 pandemic, it was required to make this very significant shift under crisis conditions that demanded from educators to challenge their assumptions and perceptions, as well as provided them with an opportunity to reimagine the experience of teaching and learning for large cohorts (Alon et al., 2023; Lee et al., 2022).

As recent studies and surveys show, the key trend in higher education after returning to campus has been the rapid digitalization of all processes, which is primarily manifested in the growth of online education (UNESCO, 2021), with a hybrid mode considered to be the most popular form of education. The main conclusion that universities have made after the pandemic is that they should provide flexible learning pathways through recognition of all types of learning (UNESCO, 2022).

Surveys conducted in the UK, both among students and university staff, showed that the two categories adapted quite well to the transition to online learning, despite the fact that at the initial stage, such transition has become a shock for many academics and learners (PWC, 2021). According to a survey conducted in 2021 by the Student Futures Commission (UPP Foundation, 2021), about 66 % of students would prefer to combine face-to-face and online teaching. 45 % of students indicated that they would like face-to-face learning to be complemented by online classes at least once or twice a week, while 21 % of students want to study mainly online, with in-person classes once or twice a week.

It should be noted that the effectiveness of online learning (achieving learning outcomes) depends on many factors, such as the university infrastructure, academics, their teaching methodologies and educational program, students and their technical and psychological readiness for online classes. According to the data of The National Student Survey (an annual survey of UK students) conducted in 2021 part-time and mature students were less affected by the pandemic and were more satisfied with their courses taught online (Office for Students, 2021). Scientific research suggests that the online delivery format is more suitable for master's and postgraduate students (Toti and Alipour, 2021; Yu, 2021), as well as part-time students (Fiorini et al., 2022), as they are more motivated and self-regulated than undergraduate's students.Part-time student cohorts comprise both adults and young people, who usually work full or part-time to fund their education, and they usually have different social and pedagogical needs than other student cohorts such as full-time undergraduates enrolled after secondary school. A majority of such students preferred online or hybrid mode to face-to-face delivery for reasons of flexibility, time and cost after the end of the pandemic (Flynn et al., 2022; Gardner et al., 2022). Adult students, in addition to the lack of time associated with work, have family responsibilities (parenting or caring for parents), which also influence the choice of study mode. Relatively younger and single adult students are less likely to choose online learning, while adult learners in employment, with dependent children, higher levels of prior education, and women are more likely to enroll in programmes taught online (Gardner et al., 2022). Most studies examining the phenomenon of adult education and its pedagogical features that emerged during the pandemic period are typically based on investigating the experiences of students from various disciplines, therefore, they tend to be of a generalising nature without specific reference to a particular educational domain (Fiorini et al., 2022; Flynn et al., 2022; Gardner et al., 2022).

The effectiveness of online learning also largely depends on the nature of the subject taught online. As studies show, teaching technical subjects online is more demanding, including software engineering where the practical nature of lab sessions made it particularly difficult to move online while maintaining the same level of effectiveness (Mbunge et al., 2021; Toti and Alipour, 2021). At the same time, when redesigning their modules for online delivery, academics working in computer science perceived themselves as being significantly more prepared, confident, held a good working knowledge of the relevant technologies and felt supported by their institution than those in other disciplines (Crick et al., 2020; Toti and Alipour, 2021).

Despite the numerous advantages of online education, the learning outcomes of software professionals are still being studied. Existing research examining satisfaction with the transition to online or blended learning for software professionals during the pandemic and post-pandemic period is mixed (Alon et al., 2023; Crick et al., 2020; Giray, 2021). Computer Science students, despite the theoretical advantage when it comes to learning online, experienced the same kind of struggle with the sudden transition to emergency remote teaching; undergraduate's students were particularly affected (Toti and Alipour, 2021). For example, the e-learning experience of computer and software engineering undergraduate students regarding on-campus and e-learning was measured by responses to an online questionnaire. The participants rated their perceived satisfaction from e-learning as 2.85 out of 5-point Likert scale (Giray, 2021), although, this result can be supported by the fact that only data from emergency online learning during the 2019/2020 academic year were considered. A study of undergraduate students' experiences in a large information science course that switched from online learning to blended learning in the post-Covid period yielded mixed outcomes, with results showing that students preferred blended learning to online learning (Alon et al., 2023). At the same time, research shows that the use of innovative teaching methods by the instructor can make the online course interesting and successful for the students on different levels of study (Adeliyi et al., 2021; Gill et al., 2022).

The research shows that the majority of existing studies are focused on the analysis of the advantages and disadvantages of the transition to online education as a result of the pandemic (Gardner et al., 2022; Lee et al., 2022) and based on the experience of teaching software engineering in the second half of the 2019/2020 academic year and in the 2020/2021 academic year, i.e. in times of crisis transition (Crick et al., 2020; Giray, 2021; Toti and Alipour, 2021). At the same time, there is a gap in research aimed to compare teaching and learning experiences before the pandemic, during the pandemic when remote education emerged and technology-enhanced learning in the post-pandemic times.

Due to the generalising nature of studies examining the experience of adult students transitioning to online learning because of the pandemic, this research focuses on the specific experience of mature part-time students in a particular subject area, namely, those studying software development. We will focus on analysis and synthesis of teaching experience for the Computing Foundations module for a large class studying part-time Software Engineering course at the School of Electronics, Electrical Engineering and Computer Science (EEECS), Queen's University Belfast (QUB) during 2019–2022 academic years, i.e. we will compare on-campus learning with the abrupt shift to online learning during the pandemic and with sustainable online learning a year later. We will discuss the benefits we have gained and the challenges we have faced during the transformation and adaptation of the module to the existing conditions arisen as a result of the pandemic impact and post-pandemic conditions.

The objective of this study is to answer how part-time software development students perceived their technology-enhanced learning experience from pre- to post-pandemic and to evaluate the impact of the shift to online learning for the part-time class. To achieve this objective, student satisfaction, instructor support, student interaction and collaboration, and course design in a virtual learning environment were important factors to be considered. We aim to answer the following research questions:

RQ1: What are the positive and negative aspects of technology-enhanced learning from pre- to post-pandemic according to part-time adult students studying the MSc software development program?

RQ2: What is the satisfaction of part-time software development students with the module delivered in the VLE after shifting to online learning?

RQ3: Is there a difference in students' performance while shifting to online learning?

By answering these research questions, this study aims to explore the effectiveness of the pedagogical approach while also gaining valuable insights into the software development student experience of learning in the VLE. The findings from this study may contribute to developing effective teaching practices in software engineering education and adult learning, and improve the preparation of future software professionals in the IT industry.

The rest of this paper is organized as follows: Section 2 provides a background on the impact Covid-19 has had on teaching methodology and students' learning experience in Software Engineering (SE) fields and adult learning for software professionals. Section 3 describes the research methodology, including participants, data collection procedures, metrics and data analysis process. Section 4 presents the description of teaching methodology based on the conceptual framing for effective online courses as a frame of reference for pedagogical redesign. Section 5 presents the results of the study that allow us to answer the research questions. These results are discussed in Section 6. Section 7 lists the limitations of the findings discussed. Finally, we draw our conclusions and describe the implications of our findings in Section 8.

2. Literature review

2.1. Impact of the pandemic on adult students

The Survey of Higher Education by UNESCO National Commissions highlights that many countries were affected "digitally, i.e., the pandemic has also brought digitalization to the fore, as many sectors have moved to work remotely (UNESCO, 2021). This transition has created an increased demand for professionals with information technology skills. With the government plan for growth, Build Back Better highlighting a skills gap in basic digital skills, ensuring students and graduates can use digital services and technology professionally that will contribute to growth in this area (Universities UK, 2022). At the same time, the survey conducted in Northern Ireland by the Department for the Economy (DfE, 2020) evidences a lack of digital skills in the adult population.

The impact the pandemic has had on adult education cannot be underestimated. The reduction in public spending on adult education and apprenticeships during 2009–2019 in the UK was accompanied by a gradual decline in adult interest in education and reached its lowest level in the entire history of observations (1996–2022 years) – in 2019, the rate of adult participation in learning was 33 % as a whole in the UK and only 22 % in Northern Ireland (Learning and Work Institute, 2022a). As the data from the Adult Participation in Learning Survey 2022 in the UK (Learning and Work Institute, 2022b) shows, the pandemic has given impetus to an increase in the participation of adult students in the educational process. In 2021, there was the highest participation rate (current or recent learning) in recent years – 44 %, 11 % higher than the 2019 rate and more in line with that seen in the 2000s. Although this indicator fell slightly in 2022, to 42 %, it still shows the interest of an adult audience in getting an education.

The higher education system in Northern Ireland is still not producing sufficient numbers of graduates in STEM subjects, particularly Engineering and Technology; Mathematical and Computer Science; and Physical Environmental Sciences (OECD, 2020b). It has resulted in the UK Government's action to actively develop and implement various financial programs to get adults involved into life-long learning, including Northern Ireland Assembly's (regional UK government) short-term funded university courses to provide individuals, facing redundancy or furlough, the opportunity to reskill in the area of software development. This initiative was driven in part by the long-standing need to provide highly qualified software engineers to satisfy industry demand for computing graduates, which has steadily increased over the past several years (McGowan et al., 2022).

Adults see work and other time pressures as the main barriers to learning (24 %). This is followed by lacking the confidence to learn (14 %), cost (13 %), and being put off by tests and exams (12 %) (Learning and Work Institute, 2022b). It can be concluded that flexibility, accessibility and affordability of education are vital criteria, but not sufficient in terms of the inclusiveness of the developed programs, that needs to be increased. At present, online education is no longer an emergency solution to prevent the spread of the pandemic, so universities and academic individuals have to decide whether they need to develop an attractive course for students while increased competition on the educational market. With this in mind, university representatives understand that it is necessary to invest time and money in the development of IT infrastructure, staff development, and encourage the most active and creative teachers. The risk of not investing in the digital learning market is substantial and could result in a basic online service with little support. Social infrastructure will not be considered as valuable as existing online alternatives – such as massive online open courses – which are on the market at far lower prices (PWC, 2020). Student opinions are important factors to understand regarding the benefits and development of online learning.

2.2. Positive and negative aspects of technology-enhanced learning during and post-pandemic periods

An analysis of the positive and negative aspects of online learning during and after the pandemic allows us to summarize them for adult part-time students studying software engineering.

The main positive aspects can be described as following (Casper et al., 2022; Giray, 2021; Fiorini et al., 2022; Toti and Alipour, 2021):

1. Time and location flexibility and accessibility. Online delivery format offers students the flexibility to access module materials and lectures from anywhere, allowing working professionals and students with other commitments to pursue software engineering education. Attending classes online from home or from their workplace after work reduces stress and the probability of being late for a class.
2. Accessibility of module materials and self-paced learning. The ability to access recordings of lectures and have more time for independent work on module materials. This may be useful for those who need more time to understand complex software development concepts, as well as for non-native English students.
3. Improved student engagement. Enabling and encouraging online chat with instructors, conducting online surveys and real-time quizzes, using interactive technologies allowed the instructors to engage more students than during face-to-face classes.
4. Improved class attendance. There has been an improvement in class attendance, especially during the period of emergency e-learning in the second semester in the 2019/2020 academic year and the 2020/2021 academic year due to the fact that most students stayed at home because of the Covid-related restrictions.
5. Preparation for an online/remote workforce. Virtual communication and collaboration skills were improved. More options were provided to interact with lecturers and classmates via online chats, discussion boards, emails etc. New technical skills requiring mastering software such as VLE, collaboration apps built for hybrid work, etc., were gained.

Negative aspects of online learning falls into the three categories (Casper et al., 2022; Crick et al., 2021; Dhawan, 2020; Giray, 2021):

- Technical and technological problems (such as lack of laptop, old operation system, unstable internet connections etc.). These are considered to be critical just after the sudden shift to online learning, but qualitative results show that their impact decreased over time as students became more technically competent and may have acquired the necessary equipment.
- Lack of personal communication with lecturers and peers. Online learning can be isolating, as students miss face-to-face interactions with instructors and peers. This can affect collaboration, networking, and the sense of belonging to a learning community.
- Lack of presence and non-engagement. Students may not have their cameras turned on during live lectures, making it difficult for the instructor to understand the presence of students in online classes and assess the student engagement; it requires the instructor to use other student engagement technologies. Difficulties with monitoring of inactive or non-engaging students.

Empirical research indicates that only a very small percentage of adult students wanted to return to the entirely face-to-face model that prevailed prior to the pandemic, suggesting that any disadvantages brought about by the sudden conversion to online learning were largely outweighed by its advantages (Fiorini et al., 2022).

2.3. Satisfaction of students' learning experience

Student satisfaction is an important factor to consider while designing the module and the format of its delivery. The satisfaction rate can be used to compare traditional face-to-face and distance modes of delivery. Research conducted before the massive shift online due to the pandemic found out the lower level of overall student satisfaction with online courses, because students considered them simpler, while satisfaction among adult students was higher (Linnes et al., 2022). Online learning during COVID-19 has led to the emersion of new online learning mechanisms and tools, as well as expanding the use of existing information technologies and demonstrating how some of them can be effective and useful. The latter provided an opportunity to introduce online learning for some students, and for others to gain a new perspective on it. According to research (Van Wart et al., 2019), students find that remote learning is somewhat beneficial, even if it is perceived as lacking in social interaction and communication.

By student satisfaction, we will understand the justification of his expectations from the learning process, that is, the student's actual perception of his experience. Most studies highlight the connection between student satisfaction with online learning and the way online courses are designed and delivered.

Shifting to online learning for many students in the face of the Covid 19 pandemic in 2020/2021 led to a great expansion in the use of online resources for learning. This has sparked renewed interest in features of virtual learning environments (VLEs), namely in the mixed learning resources, that can be beneficial to both academics and students leading to improved performance and satisfaction.

The consequence of moving courses to an online environment was the understanding of the importance of all the pros and cons of using VLE. Since the VLE has become the main point of interaction between academics and students, the question arose of how to use its features as effectively as possible. While discussing interaction with software, we pay special attention to usability and user experience (UX). The successful use of VLE by both students and lecturers in online learning depends to a large extent on user experience as it determines how users interact with and perceive the learning platform (Maslov et al., 2021; Tawfik et al., 2022; Zanjani, 2017). Good UX design can lead to higher student engagement and satisfaction, while poor UX design can create learning difficulties and reduce motivation to learn a particular module. At the same time, learners cannot focus solely on UX, today the importance of learner experience as an emerging design paradigm for the field of Learning/Instructional Design & Technologies comes to the fore, which means that "learners' individual, perceived experiences of interaction with learning technologies must also be considered as critically important to the learning process" (Schmidt et al., 2020).

Researchers at the University of Edinburgh, in support of the Learn Foundations project, have conducted several studies examining user priorities for VLEs before and after the pandemic, allowing comparisons between their results (Duncan, 2019; Horrell, 2021). Pre-pandemic studies, i.e. for on-campus courses, showed similar results to QUB. Students paid the most attention to lectures, past exam papers, grades, reading lists/study resources, assignment deadlines. Academic staff, as well as students, preferred the content of the module (lectures, tutorials, reading lists) and assessment. Based on the research, a course template was developed that is recommended for use by the university's schools. Subsequent studies conducted at the University of Edinburgh to examine changes in user requirements for navigating VLE Learn during the shift to hybrid teaching and learning have shown that students were expecting to navigate VLE in the same way they had before the pandemic, that is, the results showed that the developed template remained relevant (Horrell, 2021). Despite learning and teaching being fundamentally different, students were expecting to find things in the same place in VLE, they were not expecting to see a separation of physical and online items, while among the most important tasks for lecturers appeared "Announcements", staff tended to use announcements and/or email even when adding material or information in standard locations (The University of Edinburg, 2021). At the same time, the results of a joint study of the University of Edinburgh and the Royal (Dick) School of Veterinary Studies, conducted in 2020 to study the needs of students of online postgraduate courses showed, that having a recording of a live lecture remains a top priority (1 item), while slides and lecture notes have become less important (5 and 6 items), whereas Discussion boards (3 item) и Reading lists/study resources (2 item) become more important, which can be explained both by the delivery format of the module and by the way that these are postgraduate courses (Duncan, 2020).

The synchronous way of learning seemed more familiar to scientists and was considered more attractive to students, since they could interact with their classmates and teachers during "live" classes (Pick, 2021). However, to attend such a class, it was necessary to connect to the virtual class at a certain time, for which the student needed access to the Internet and a computer with a certain bandwidth (De Guzman and Pastor, 2020). For some students, this has become impossible, primarily those belonging to low-income groups, many of whom may not have the necessary computer equipment (Office for Students, 2020), but has also created difficulties for those with several family members trying to simultaneously access devices and Internet connections.

The asynchronous mode of learning is considered more suitable for MSc students, including adult working students, as they have the flexibility to access study materials at the time and place available to them, since many MSc part-time students have parental and caring responsibilities. Some studies suggest that asynchronous delivery mode facilitates processing and better understanding of information and may improve the quality of learning (Hrastinski, 2008). On the other hand, this delivery method has limitations in terms of supporting interaction and creating learning communities (Pick, 2021).

Active use of technology in the classroom has both positive and negative sides. On the one hand, reasonable use of technology and subsequently arising new teaching methods can become an effective learning tool that improves the soft and hard skills of students; on the

other hand, a balance is needed so that the use of technology does not become an additional source of distraction. Engaging students in software engineering courses is particularly challenging because these courses contain heavy theoretical notions with a few practical work in the classroom (Ouhbi and Pombo, 2020). By student engagement, we mean their attendance in the classroom and participation in the classroom activities. In order to actively involve students and develop their soft and hard skills, Software Engineering academics actively use various modern approaches to learning, such as problem based learning, storytelling, role playing, gamification techniques, flipped classroom, interactive systems for audience response etc. The effectiveness of the use of different approaches depends on the specifics of the module and the prerequisites for its learning. Studies show that when teaching the Computer Foundations module, the most common approaches to student engagement are the use of interactive systems for audience response and flipped classroom, which is due to the specifics of the module, since it is an introductory module (Ouhbi and Pombo, 2020).

The use of a particular learning technology does not necessarily lead to student engagement and interest and ultimately to learning. In order for distance learning to be effective, it is necessary to create a comfortable environment for the student, which includes regular interaction between the teacher and the student, mentoring, monitoring and giving feedback, including remote assistance (Ali et al., 2017). There is a lot of discussion in the literature about the personality of the teacher, which influences the concept of teaching in large classes proving that more active participation leads to better learning outcomes (Long and Coldren, 2006). The role of the teacher is important, but it is not a one-way process. Deep learning in a large class becomes possible when there is a relationship between students and the teacher, leading to increased student motivation (Straits, 2007; Isbell and Cote, 2009).

Assessment and feedback are an integral – and, possibly, the most important – part of learning, therefore monitoring on how students are engaged with formative assessments and perform is considered to be the key factors to facilitate their learning. Studies have shown that online environments can enhance opportunities for immediate and ongoing formative feedback. Online formative feedback supports students to identify their strengths and weaknesses, revise their work, and continuously refine their understanding by reviewing feedback, which supports them towards engaged and self-regulated learning. It is evident that formative online feedback can foster student engagement, improved achievement and enhance motivation to learn (Gikandia et al., 2011). However, there is a consideration that assessment options are limited for the large class audience, and that continuous formative assessment can hardly be achieved because of the nature of teaching in the large class (Snowball and Boughey, 2012), meaning that these can be easily narrowed down to only multiple-choice questions as a main assessment tool (Carless, 2020; Pishchukhina and Allen, 2021). It is also very challenging to provide meaningful feedback to large numbers of students, although in recent years the use of technologies, such as student response systems and online feedback, has allowed the provision of instant and meaningful feedback for a large class (Gikandia et al., 2011).

2.4. Student performance in an online vs. face-to-face

In order to analyse the differences in student performance in face-to-face and online classes, the results of exams such as marks, class averages and pass rates are most often used as an indicator of performance. The research shows that outcomes of on campus and online module delivery are mixed in terms of class performance comparison.

To estimate the overall impact on module outcomes for online module delivery for students studying postgraduate certificate course (Cert) in software development at Queen's University Belfast the authors conducted comparisons between the postgraduate Cert (online) and previous MSc in software development (conversion) course outcomes (face-to-face) (McGowan et al., 2022). The comparison was made between the Programming module which is double weighted, compulsory, and present in both qualifications. Overall score for the class, pass rate, dropout rate, lecture attendance were considered as key performance indicators. Except for the dropout rate, the online course either compared favourably or outperformed the face-to-face, which could be caused by the fact that fully funded (by the Northern Ireland Assembly) courses have a high dropout rate.

The assessment results of students in the 2019/2020 academic year were compared with the test and exam results of students in the two previous academic years 2018/2019 and 2017/2018 (for example, students studying modules "Applied Computing"). The study found that the COVID-19 lockdown had a significant positive impact on student performance. The results show that students scored better in all types of tests that were conducted after the lockdown began (Gonzalez et al., 2020).

A comparative study conducted between Italy, Sweden and Turkey used administrative data from universities in the three countries to estimate the probability to pass exams (pass rates) after the spread of COVID-19 pandemic (and the shift to distance education), with respect to the previous comparable period (Casalone et al., 2023). It was concluded that the pass rate decreased with the shift to online teaching.

3. Methodology

3.1. Participants

This study is based on data collected during 2019/2020, 2020/2021, 2021/2022 academic years. The study was conducted among 309 students studying Computing Foundations module as a part of a conversional part-time MSc course in software development at the School of Electronics, Electrical Engineering and Computer Science at Queen's University Belfast, Year 1. The course was delivered in two formats: as an on-campus face-to-face course in the 2019/2020 academic year, and as a fully online course in the 2020/2021 and 2021/2022 academic years. 72 students out of 309 studied on campus in the 2019/2020 academic year; 237 students studied online (129 in the 2020/2021 and 108 in the 2021/2022 academic years respectively) (Table 1).

In order to collect the data and analyse the student satisfaction with the module and teaching, voluntary and anonymous Module Evaluation and Teaching Evaluation surveys for the Computing Foundations module were conducted. Module Evaluation Questionnaire (MEQ) allows students to anonymously provide feedback on module content, structure, presentation, workload and resources (Queen's University Belfast, 2023). The purpose of Teaching Evaluation Questionnaire (TEQ) is to help staff and the institution monitor the quality of teaching (Queen's

Table 1
Summary information about the participants.

Academic year	N students	TEQ, Number of responses (in %)	MEQ, Number of responses (in %)	Mid-term survey, Number of responses (in %)
2019/2020	72	23 (30 %)	22 (29 %)	–
2020/2021	129	49 (38 %)	46 (36 %)	48(37 %)
2021/2022	108	37 (34 %)	36 (33 %)	34(31 %)

University Belfast, 2023). The number of students who filled out the questionnaires and their percentage out of the total number of students are shown in Table 1.

In order to understand the difficulties students faced during the abrupt transition to online learning in the 2020/2021, it was decided to conduct a mid-term survey. Participation in the survey also was completely voluntary and anonymous. The same survey was conducted in the 2021/2022 academic year. The number of learners who completed the mid-term questionnaires, the percentage and the total number of students are shown in Table 1.

During the research period, the course content and curriculum items remained identical for all aspects of teaching except for the delivery mode. The same instructor taught both versions of the course. It had the same syllabus, basic teaching materials, learning outcomes, and schedule. Students' performance throughout the study period was evaluated according to the same guidelines, summative and formative assessments covering the same portions of the course material. The assessments were administered at the same time during the semester (Weeks 6 &12), and had the same structure and format. Despite the varying delivery mode of the module during the different academic years the characteristics of student cohorts were identical: it was a large cohort of students of different ages, already having a bachelor's degree in various disciplines excluding Computer Science or other similar Computing degree, and studying the three-year MSc Software Development (Part Time) program. We suggested that there was an equitable learning experience for both the face-to-face and online students, that allowed us to compare the research data obtained.

3.2. Data collection procedures

Methodology types employed in this study include online observation with statistics collected from the virtual learning environment Canvas, quantitative analysis, individual student surveys on teaching techniques and module content.

MEQ and TEQ for the Computing Foundations module, comprising open and closed questions are online questionnaires, were distributed among students at the end of each semester to collect data on student satisfaction with the module and teaching respectively. Both questionnaires started with a brief explanation of the objective and anonymity of the study and were collected by the EEECS management. The lecturer has access to the summary of anonymised module evaluation and teacher evaluation data collected for particular semesters in the academic year.

The MEQ consists of a set of items falling into six groups: Module Structure and Learning Resources (four items), Assessment and Feedback (four items), Overall Satisfaction (one item), formed as a 5-points Likert scale, ranging from "strongly disagree" to "strongly agree"; Required Work (one item), formed as a 3-point scale ("less", "similar", "more"); Attendance (one item), formed as an interval scale (0–25 %, 26–50 %, 51–75 %, 76–100 %); Comments. Comments are represented by four open questions: "What did you find most valuable on the module?", "Can you identify any improvements that you would like to see made to the module?", "Can you please give an indication of the total number of hours spent studying this module each week (please include formal face to face engagement, formal online engagement and private study)?", "Please make any further comments that you may have in the space below".

The TEQ consists of a set of items in the form of four groups: The Lecturer/Tutor (8 items) and Overall satisfaction (1 item) formed as a 5-points Likert scale, ranging from "strongly disagree" to "strongly agree"; Attendance (1 item) formed as an interval scale (0–25 %, 26–50 %, 51–75 %, 76–100 %); Comments. Comments are represented by three open questions: "Please identify any good teaching practice that should be more widely adopted", "Please identify any improvements the lecturer could make regarding their current approach to teaching", "Please make any further comments that you may have in the space below".

The mid-term questionnaire consists of 6 items with a focus on technology-enhanced learning that were rated on a dichotomous scale ("yes" or "no"). Participation in the survey was voluntary. The survey was developed by a lecturer and conducted via anonymous Google Forms on Week 6, Semester 1. Specifically, the following questions were asked to the respondents: "Are you satisfied with the quality of lectures?", "Are you satisfied with the quality of advisors and with their availability?", "Do you feel comfortable asking questions during lectures/to advisors?', "Are you clear what is expected of you throughout the module?", "Are you satisfied with the use of live lectures, prerecorded videos and Canvas?", "Please add any additional comments, including any compliments or criticisms of the module". At the same time, students had the opportunity to leave comments with complaints and suggestions if the answer was "No".

The use of VLE features and MS Teams meeting attendance reports during online classes are collected and used to monitor the engagement of students. Reports are available for lecturers to monitor students' access to different curriculum items in VLE (for example, data on the number of students who completed quizzes, passed the mock exam, summative assessment etc.).

3.3. Data analysis

To determine the positive and negative aspects of technology-enhanced learning from pre- to post-pandemic according to part-time adult students, we compared the data related to student satisfaction with teaching and the module (TEQ, MEQ); student engagement (Canvas Discussion Forum statistics and on-campus attendance reports (2019/2020), MS Teams attendance reports (2020/2021, 2021/2022), Canvas Quizzes, Mock exam statistics). To determine the negative aspects of the transition to online learning, we compared the data obtained from the mid-term survey over the 2020/2021 and 2021/2022 academic years. We additionally analysed open-response questions in TEQ, MEQ and mid-term surveys, emails and comments from students during classes to identify problem areas from pre- to post-pandemic while studying the Computer Foundation module.

To assess the satisfaction of part-time software development students with the module delivered in the VLE after shifting to online learning, we compared the data obtained from individual MEQ and TEQ for the Computing Foundations module. Student satisfaction has been examined as an indicator of whether learners are satisfied with their learning experience. The software EvaSys Evaluation was used to represent and interpret the data as a tool for efficiency, but was not used as a tool of conducting analysis or drawing conclusions.

To assess the difference in students' performance while shifting to online learning, we used final course grades for the three academic years, including class averages and pass rates as indicators. Comparisons of final grades between the two cohorts (2019/2020 and 2020/2021, 2019/2020 and 2021/2022) were performed using nonparametric tests for two independent samples (Mann Whitney's U-test and Kolmogorov-Smirnov test). P-values of less than 0.05 were considered statistically significant. To study the samples, static analysis was carried out using descriptive statistics and the Kolmogorov-Smirnov test to test the hypothesis of normal data distribution. A comparative analysis of the pass rates was also carried out.

4. Description of teaching methodologies

4.1. Teaching context

The Computing Foundations module introduces fundamental elements of computer science for students that are studying a conversional part-time MSc course in software development at the School of Electronics, Electrical Engineering and Computer Science, Year 1 (Pishchukhina, 2022). The structure of the part time version of the MSc software

development course was designed to be flexible in order to enable students to continue with current employment (QUB, 2022) and considering the fact, that adult learners in Northern Ireland predominantly take higher education courses on a part-time basis (OECD, 2020a). The part-time large class is taught in the evenings and spread over 3 years to allow students to study while in full-time employment. MSc software development course is one of the largest MSc cohorts in the EEECS with an annual intake of 100+ students for part-time class.

Prior to the Covid-19 crisis, the part-time Computing Foundations module was delivered as a traditional face-to-face module, with lectures in a large lecture theatre, and tutorials in the lab. The module was introduced and became a part of the curriculum in the 2019/2020 academic year and had been taught in person for 12 weeks and finished in February, 2020, before the pandemic started. At the beginning of the 2020/2021 academic year, the Computing Foundations module had to be transformed and delivered online, as a part of rapid transformation made for all programmes taught at the School of Electronics, Electrical Engineering and Computer Science in Queen's University Belfast in response to the pandemic (Pishchukhina, 2022). After delivery in the pandemic year, the part-time module was highly rated by the students and, therefore, retained as a distance module taught fully online over the next 2 years. When it became possible to return to campus in the 2021/2022 academic year, part-time students were given the opportunity to come to the university library or lab and use the university machines to join online evening classes, if they needed to use those resources or have more supportive environment to concentrate on their studies. Some of them used that opportunity, avoiding study from home because of distractions, poor internet connection and / or personal circumstances.

The program is one of the most popular among MSc programs in EEECS with the software development course rated as the highest for overall student experience Computing Master course in the UK (2019) (QUB, 2022). According to Postgraduate Teaching Evaluation Survey (PTES) (2022), the overall satisfaction respondents in Computing PGT had with their studies was 88 %, based on 142 responses; this was 15 % higher than the score for Russell Group institutions (PTES, 2022). Given the nature of teaching of the software development course, we can expect to increase or at least maintain the attractiveness of this program both in the short term and long run.

Since the Computing Foundations module started in 2019, the following characteristics of the target audience have been taken into consideration and affected the development of the structure and teaching of the module:

- The large size of the cohort (100+ students);
- Different background and age of students;
- The module is a full-year round module taught to the 1st Year students in semesters 1 (six weeks) and 2 (six weeks).

At the same time, education provision for the part-time cohort orientates on the following main principles of adult learning: high motivation for learning; conscious approach to learning and setting clear goals; managing the learning process on their own; having their own experience that is involved in learning; focussing on quick application of new knowledge in practice. Taking the above into consideration while teaching this module, we have transformed and adapted it to changing conditions actively involving students in the discussion of its various aspects in order to make it as interesting and useful as possible for this target audience.

A particular challenge was the redesign of the module in response to Covid restrictions. At the beginning of the 2020/2021 academic year academic programmes taught at the School of Electronics, Electrical Engineering and Computer Science at Queen's University Belfast had to be transformed and delivered online that forced all module owners to redesign them to be taught fully online using Microsoft (MS) Teams and the Virtual Learning Environment, Canvas (Pishchukhina and Watson, 2021).

Table 2 introduces a summary of the changes in the teaching of the Computing Foundations module in accordance with the chosen concept of effective online module delivery (Pishchukhina, 2022).

In this paper we will share the experiences of redesigning the Computing Foundations module with a particular focus on how the conceptual framing for effective online courses (Martin et al., 2019) informed the transformation of the module for synchronous delivery and asynchronous online learning environment. The conceptual framework includes the full cycle of an online course with a focus on online course design, assessment and evaluation, and facilitation (Martin et al., 2019). It appeared that effective online learning must account for the design, assessment and evaluation, and facilitation before, during, and after the student learning experience. Under new conditions, it was necessary to redesign a face-to-face synchronous, 20 CAT Computing Foundations module on the MSc software development course, with the module comprising 100+ students, into an engaging online format. For many courses, the online learning environment was traditionally considered as a supplementary source to the face-to-face teaching, e.g., seen as a repository for materials, which has now been transformed to the main source for teaching and learning.

4.2. Module design

While designing the course, the fact that 95 % of the mature audience work full-time and have family responsibilities had to be taken into consideration. In the pre-pandemic 2019/2020 academic year lectures

Table 2
Summary information about the Computing Foundations module.

Item	2019/2020 academic year	2020/2021 academic year	2021/2022 academic year
Teaching format	Face-to-face	Online	Online
Module design	Lectures held in the lecture theatre; practical classes conducted in the lab	Synchronous and asynchronous modes of delivery (short pre-recorded videos based on lecture slides, online live lecture sessions in MS Teams and recorded videos of live lecture sessions uploaded on the VLE Canvas once the lecture has taken place)	Synchronous and asynchronous modes of delivery (short pre-recorded videos based on lecture slides, online live lecture sessions in MS Teams and recorded videos of live lecture sessions uploaded on the VLE Canvas once the lecture has taken place); opportunity to come to the lab
Facilitation and Engagement	Meetings in-person; Canvas Discussion Forum; Communication via emails	Teams chat; Online quizzes during live sessions; Thematic revision sessions; Weekly individual support sessions conducted online; Canvas Discussion Forum; Communication via emails	Teams chat; Online quizzes during live sessions; Thematic revision sessions; Weekly individual support sessions conducted online; Canvas Discussion Forum; Communication via emails
Assessment	Formative: weekly quizzes and mock exam in the VLE Canvas, delivered online; Summative: online tests, delivered on Canvas	Formative: weekly quizzes and mock exam in the VLE Canvas, delivered online; Summative: online tests, delivered on Canvas	Formative: weekly quizzes and mock exam in the VLE Canvas, delivered online; Summative: online tests, delivered on Canvas

and practical classes were conducted face-to-face, and the VLE Canvas was used to deliver online quizzes to conduct formative and summative assessments and as a repository for storing lecture slides and tutorials for practical sessions.

The migration of the module to online environment was supposed to happen before the 2020–2021 academic year, so we were given a leverage for analysing the strengths and weaknesses of synchronous and asynchronous modes of delivery (Sekulich, 2020; Roache et al., 2020), as well as the experience of colleagues who have moved their courses online since March, 2020. Most studies, including those on teaching in large classes, conclude that it is necessary to use both synchronous and asynchronous models (Anzovino et al., 2020; Roy et al., 2020). At the same time, a series of workshops and trainings, dedicated to connected learning model implementation and development of practical skills for working with the VLE Canvas, MS Teams and other online learning technologies, were conducted at the School of Electronics, Electrical Engineering and Computer Science. However, the pedagogical context of organising online classes for a large cohort studying the Computing Foundations module has become a challenge for the instructor.

It was decided to organize the course around weekly topics and assignments, dividing the content and providing clear course-related recommendations that help students learn. Consistency in the structure from week to week allows students to know where they are in the learning process. One important aspect was to introduce students to the nature of the interaction required in an online module. Clarification of expected participation, contribution and engagement standards, and deadlines were clearly explained to them.

The main task of the lecturer was to find and maintain a balance between synchronous and asynchronous delivery modes, as well as how to simplify the tutorials. Mainly due to the class specifics and technology considerations, it was decided to include both modes of delivery. The former involved recording of 15 min videos covering weekly structured material and uploading the videos on VLE Canvas that followed by quizzes to provide feedback, and the latter was delivered through holding live lectures, tutorials and feedback sessions via MS Teams. Another strategy embedded into the module structure was the live delivery of lectures via MS Teams with concurrent recording of the same lecture and uploading it in Canvas afterwards using MS Stream. This appeared to be a good strategy as student feedback was extremely positive and the majority of the class (82 %) mentioned watching of those pre-recorded videos as an effective revision tool while preparing for assessments.

The active use of VLE by students and lecturers has become a positive experience of the pandemic period, with some approaches and teaching techniques still used post-pandemic. In February 2022, the Task&Finish Group of key stakeholders was established to create a “Canvas Course Co-Design Project” at QUB to develop a framework which can be used by schools to ensure a “student-first” approach to course development in Canvas (Zamboglou, 2022). The main aim of the project was to create minimum standard guidelines to ensure all Canvas VLE courses offer a good and consistent digital pedagogic baseline, improving consistency in courses across programmes of study (Gray, 2022). To change the design, it is necessary to constantly take into account the requirements of users. Since VLE was actively used by all participants in the educational process during the pandemic, it can be assumed that the requirements of both students and academics may have changed during this period. In March 2022, a user study was conducted (both undergraduate and postgraduate students and lecturers) to find out what really matters to them when working with VLE. The top tasks methodology was used for the study, a list of tasks generated by key stakeholders was identified, and sample modules from each school were reviewed to identify additional tasks. As a result, a list of 52 tasks was formed, from which students and lecturers had to choose 5 items that they considered the most important (Zamboglou, 2022).

The results of the study show the different views of academics and students on the same components of the module. For example, the students considered most important to provide lecture materials: lecture recordings (1st item), lecture slides (2nd item), lecture notes/outlines/hangouts (3rd item), taking up more than a quarter of the votes. Whereas 3 top tasks for academics are lecture slides (1st item), lecture notes/outlines/hangouts (2nd item), assessment information and deadlines (3rd item), a lecture recordings they placed in the 6th item. It can be concluded that the availability of recorded lectures for students is crucial, which, in our opinion, was a positive consequence of the transition to online during the pandemic and will remain a good practice in the post-pandemic period (Fiorini et al., 2022). Both students and lecturers consider particular importance of posting assessment information and deadlines, assessment marking schemes, assignment submission and assignment feedback, as well as the information necessary to prepare for practical sessions that is course materials and content. At the same time, we see that, with regard to assessment, it is interesting for students to see, in addition to quizzes, mock exams and past exam papers as part of the module, while academics give them less importance. However, the staff considered the presence of “Announcements” to be an important task, while the students were more interested in information about “Class time” and the composition of groups during group work.

Based on the results of this study, the minimum expectations that students have when accessing their courses in Canvas have been determined and based on this a suite of Canvas VLE Templates has been created by the Centre for Educational Development in collaboration with Instructional Designers at Instructure (Canvas Supplier) (Gray, 2022). The use of these templates became possible in the 2022/2023 academic year. The developed template for EEECS includes the following main sections: Modules, Announcements, Discussion, Collaboration, Assignments, and Grades.

To summarise, we can make a conclusion that it is not necessary to give priority only to the requirements of students, the module delivery format should be convenient for both the lecturer and the student, taking into account the learning objectives, the specifics of the module, the audience and the lecturer experience. As part of the Computer Foundations module, it is planned to use templates developed for EEECS in the 2022/2023 academic year, taking into account the results of the study and the personal observations of the module owner based on his teaching experience for this target audience.

4.3. Facilitation and engagement

Effective student-centred learning, regardless of class shape or size, requires clarity, well-organized structure, balance between complexity and simplicity, personalization and interaction. By facilitation, we mean the process by which the owner of the module organizes interaction with students in order to achieve their learning outcomes. The task of the facilitator is to improve the usability of their online course for all students, taking into account the specifics of their audience.

In our opinion, one of the most difficult tasks during the pandemic turned out to be holding lectures. During the face-to-face teaching period, teachers could “see” the students and “measure” their attention and the extent to which they are engaged with material, even in a large class, which made it difficult to arrange in an online format. We understood that the lecture should not be limited to a monologue presentation, so planning an online lecture session took more time than planning a face-to-face class, since it was necessary to think over the logistics of the engagement with students in greater detail.

Teaching in a large online class in terms of student engagement was another challenge for the instructor. While having a class size of 100+, the decision had to be made on how to build such relationship during (and beyond) live classes in a virtual environment. Queen’s University uses the virtual learning environment Canvas and MS Teams tool to deliver programmes online that also was considered as a supplementary source to engage with learners (Fig. 1).

To facilitate student engagement during live sessions in MS Teams, we used the Chat function for learners to ask questions. Another

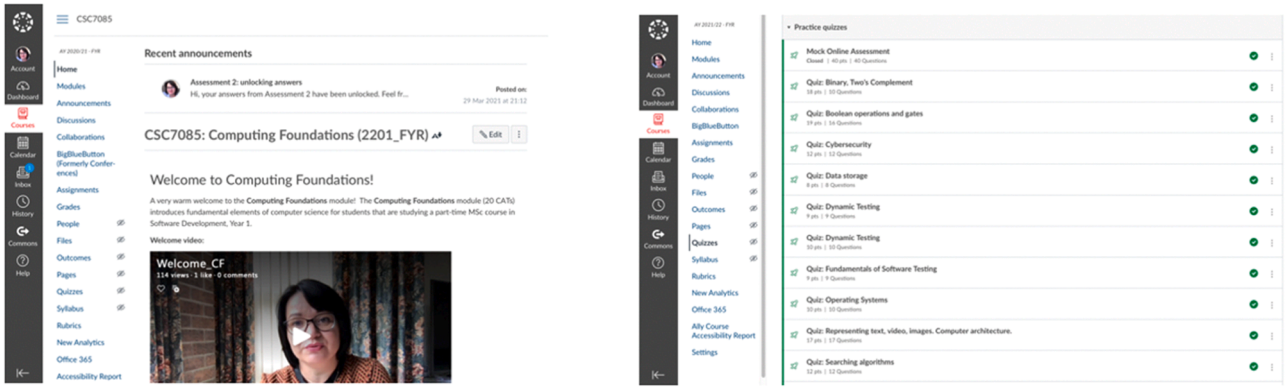


Fig. 1. Computing foundations module on Canvas.

technique that was employed to engage with them was a poll asking students to indicate their mood using cartoon and funny animal scales, as well as responding on lecturer's brief funny remarks etc. This usually worked well at the beginning of the class as an "ice-breaking" technique helping them to relax that normally got a lot of responses. Such a "human" and engaging approach has become an integral part of the successful teaching of large classes in a pandemic (Farrell et al., 2021). The above was very well received by students and they commented positively on the Computing Foundations lectures that because of such an inclusive approach and encouraged participation, they felt as a part of the lecture, which is really important in an online learning context.

Another point to consider during online lectures was the difficulty of measuring student engagement and understanding of the material during live synchronous classes. To measure the level of engagement, several MS Teams Forms quizzes were included at regular intervals of 15 min after a short block of information. This gave students the opportunity to shift their focus and avoid monotonous presentation, as well as to receive some formative feedback on their new knowledge in a relaxed informal way. Additionally, these Forms quizzes have been added as learning tools for students at the end of each section to engage them in the material.

To avoid monotonous and "monologue-type" delivery during live sessions, YouTube videos illustrating some computer subjects concepts (such as sorting / searching algorithms, number systems, etc.) were offered to learners to enhance their learning. In addition to polls in MS Teams and engaging learning activities, Discussion forums on Canvas were included after the relevant topic was covered during live lecture classes. That helped to provide engagement and a learning tool for the entire class, as questions received from students via email or Teams were uploaded with explanations and answers onto the Canvas board.

The comments and requests from the class, provided by student representatives at Student Voice Committee meetings, were also taken into consideration. Student feedback and suggestions had helped to adjust ways of teaching in the 2021/2022 academic year and get a sense of class satisfaction.

4.4. Assessment and evaluation

Assessment allows both educators and students to track progress towards learning objectives and can be approached in a variety of ways. *Formative assessment* provides feedback and information during the instructional process, while learning is taking place, and while learning is occurring. With this type of assessment, the lecturer measures the progress of students, and can also evaluate their own progress as an instructor. The focus of formative assessment is to identify areas that need improvement, namely misconceptions, struggles, and learning gaps along the way and assess how to close those gaps. These assessments are generally not graded and act as an indicator of student progress and determine teaching effectiveness.

In contrast, *summative assessments* evaluate student learning, knowledge, proficiency, or success at the conclusion of a module. The final exam is not the end of student learning, but an opportunity to receive feedback on their growth in understanding. Summative assessment is more result-oriented and assesses the final result, whereas formative assessment focuses on the process towards achieving the result (achieving learning outcomes).

At the initial stage of module design, the development of a student assessment system, both summative and formative, given the size of the cohort, has become a challenge for the instructor.

Since this module is taught for adult learners in the first and second semesters of the first year of study in software development programme, there are some specifics of the mature audience that have to be taken into consideration while designing formative and summative assessments for such a type of learners. In the literature, it is widely noted that "adult" students often ignore the difficulties associated with the assessments (Brown et al., 2022), i.e. they cannot quickly adapt to the fact that they will be assessed, which manifests itself in the form of time management problems, stress, anxiety, etc. The above had to be considered carefully, given the fact that the students studying MSc software development programme had not had prior experience in taking exams for a long time, mostly for 10–15 years after completing their undergraduate degrees.

4.4.1. Summative assessment

When developing a format of summative assessment, the following features have been taken into account:

- Large class;
- Lack of recent experience in taking exams, which caused anxiety in students;
- Need to provide transparency of the process for external and internal moderation.

Taking into account the above factors, it was decided to organize a summative assessment in the form of an online exam, organized with the help of the VLE Canvas. Students were required to take two in-term computer-based assessments weighted 40 % and 60 % respectively.

In the 2019/2020 academic year, the online exams were conducted in the form of tests delivered on the VLE Canvas, but students were sitting the exam in the lab under the invigilation of teaching assistants. In the 2020/2021 and 2021/2022 academic years exams could be taken from home and were held online at predetermined times in the form of online timed assessments. To prevent the possibility of cheating, students were required to record their screen activity during the exam and send it to the instructor on request.

In the 2021/2022 academic year, when students were able to return to campus, they were given the opportunity to take exams online, but in the university lab. Surprisingly, students did not make a use of this

option and preferred taking the exam from home.

There were no modifications made to the summative assessment model compared to the face-to-face delivery: the students took 2 in-term assessments delivered on VLE Canvas in the form of online tests containing multiple-choice, short open-response and larger open-response questions.

4.4.2. *Formative assessment*

Since it was decided to conduct the final assessment in an online environment, in addition to the main goals an additional goal of formative assessment was to familiarize students with the VLE Canvas. To date, there are many methods of formative assessment that are actively used in the online environment: self-test quiz tools, discussion forums and e-portfolios, mock exams, etc.

Managing the large class and providing qualitative and timely feedback on their knowledge and skills became a challenge. To address that, possible online formative assessment options and applications were searched for, and, subsequently, a series of weekly formative online assessments in the form of Canvas quizzes have been designed and a mock exam has been added.

4.4.2.1. Online quizzes design. Self-test quizzes are one of the most popular formative assessment methods today. Formative assessments were designed in the format of online self-test quizzes in the VLE Canvas virtual learning environment that hosts the delivery of teaching and learning activities. Online quizzes, covering topics on a weekly basis and containing questions of different types, were not limited with the number of attempts and were used by students for self-directed learning purposes and to provide immediate automated feedback on student knowledge and skills.

The inclusion of quizzes in the structure of the module allowed the collection of valuable data for the instructor that resulted into creating more personalised learning experience for students, despite the fact that the quizzes score do not count towards the final mark.

Because of the size of the class, and the need to provide automated feedback as the main form of formative feedback, the questions were designed in several formats to develop students' reflection and self-assessment, as well as encourage them to further study the theoretical material before they answer a question.

Each quiz covers a weekly structured topic and contains up to 20 questions of the following types (Pishchukhina and Allen, 2021):

- Multiple-choice questions with single-right answer and multiple-correct option answer to evaluate broad understanding of the subject.
- Match questions in which the students are asked to match phrases and terms to evaluate their knowledge of terms and definitions.
- Fill in the blank questions to evaluate students' computing skills and challenge their critical thinking.
- Open-response (scenario) questions to evaluate their problem-solving skills.
- Examples of multiple-choice, open-response and match questions with automated feedback are presented on Fig. 2.

The automated "correct/incorrect answer" feedback has been complemented by the instructor's personalised comments provided individually for students in VLE Canvas. The most common type of errors in the computing domain, such as incorrect formatting, wrong simple calculations or typos were identified by the system. Every submission and individual feedback with wrong and correct answers are visible to a single student in Canvas so they could use it to review answers at any time, show them at a support session or just email through to the lecturer to ask for extended manual feedback.

Online graded quizzes with an unlimited number of attempts have become an integral part of weekly formative assessment. Such a type of formative assessment helps students to get immediate online feedback by seeing their responses, a correct answer and instructor's comments after quiz submission. Correct answers were disclosed immediately to memorize them. The designed online quizzes with an unlimited number of attempts provided an opportunity for repetitive practice in solving problems in computing, e.g. "find a way to sort this list faster than a bubble-sort does". This mode of assessment allows an individual learner to follow trial and error as a way of building their computing experience and facing common errors as computing subject is an extremely practical domain requiring explicit examples and access to practical challenges.

All formative quizzes were designed using the summative assessment criteria, i.e. formative automated feedback was invaluable to students in terms of preparations for the final exam. Multiple-choice questions required general knowledge of the subject concepts and critical thinking, whereas open-response questions required algorithm development and problem-solving skills. Using online formative quizzes followed by personalised feedback and focusing on repetitive practicing in problem solving have helped students to apply their knowledge in practical aspects of fundamental computing theory on such topics as binary calculation, Boolean operators, data storage, sorting and searching algorithms. After online quizzes implementation, it was also noticed that the volume of general queries from students was much reduced from 35 to 50 support queries per week to 5–10 individual requests, especially the very large number of queries with regards to low-level easily made errors, such as calculation or logic errors.

Practicing with quizzes was reflected in student exam results. Exam marks statistics taken from the VLE Canvas show an association between the formative quizzes with the highest number of attempts/scores and

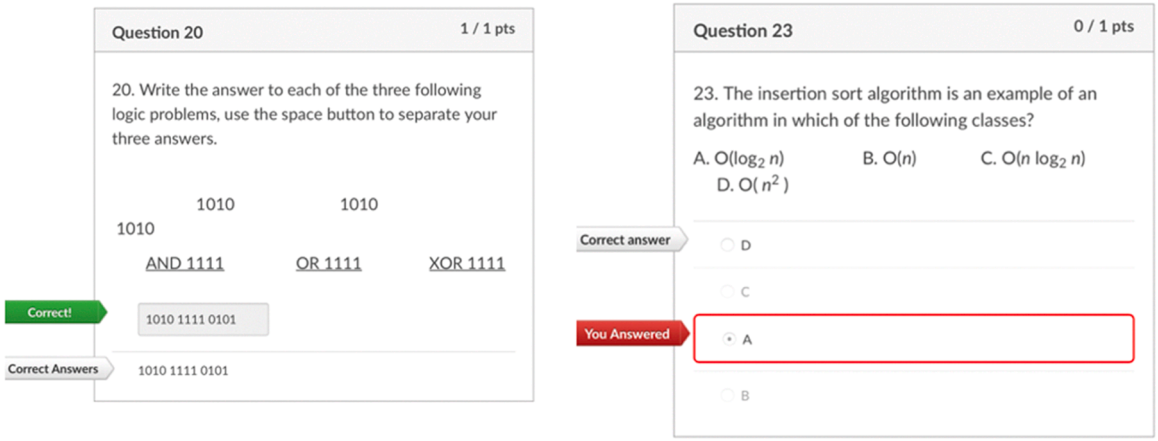


Fig. 2. Formative quiz design and automated feedback format.

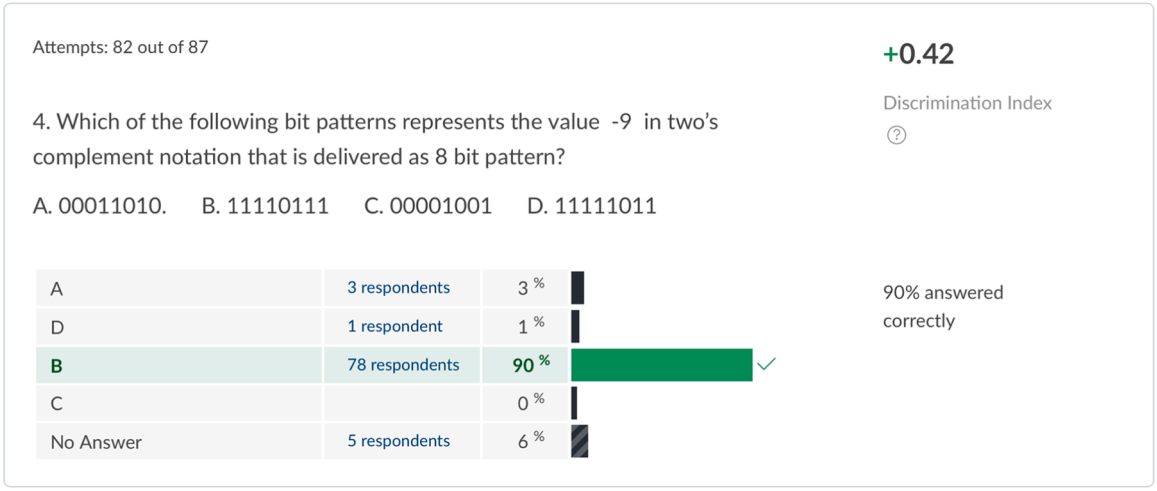


Fig. 3. Question breakdown: attempts and success rate.

the highest scores on the exam, and vice versa. Two, not equally sized, groups of students have emerged: those who worked frequently on their formative quizzes and those who did not, and consequently passed the exam with the lowest grades or did not pass at all. Those data are consistent with the taking of formative assessment quizzes, i.e. the group of students who had ignored formative quizzes got the lowest marks and another group of students who had been diligent in their self-training while formative assessment got the highest marks on the exam (Pishchukhina and Allen, 2021). An added benefit to formative quizzes was the instructor's ability to see in real time the number of formative quizzes attempted, completed and abandoned in VLE Canvas to get it helped to acquire an overall impression for how the students were progressing towards the exam. Quiz statistics on VLE Canvas alongside with the question breakdown were also used to inform real time adjustments to the teaching and shape the teaching trajectory (Fig. 3).

Normally, extra time was spent in class to repeat and focus on heavier computing topics when it had been noticed that quiz scores on these specific topics turned out to be less than expected 75 % success rate.

For example, after covering in class sorting and searching algorithms, the lower 48 % success rate was observed at quick sort and binary search aspects. Therefore, the instructor's decision was to take extra time in-class to debrief on the quiz with the suggestion to re-take the sorting and searching quiz afterwards. The latter has resulted into an improved success rate of the class up to 82 %.

4.4.2.2. Mock exam: design and implementation. The mock exam option, as one of the possible tools to stimulate and engage with students in a large class, has been highlighted in the recent reviews adding to the fact that analysis of the results of mock exams allows an educator not only to assess the level of knowledge gained by students, but also to understand the gaps in their knowledge (Gikandia et al., 2011; Wiliam, 2013). The mock exam results, analysed by the instructor, allows to reflect on student performance and correct the pace and chunks of content delivery, highlighting the most noticeable areas in learning causing difficulties to students.

Along with the preliminary performance evaluation of the class, the mock exam introduces a simulation of real assessment as one of the ways for a student (1) to prepare for the final assessment and (2) being adapted to its conditions. The mock exam, covering topics taught during the semester and containing questions of different types offered an unlimited number of attempts and was used by students for self-directed learning purposes and to provide immediate automated feedback on student knowledge and skills.

The mock exam contains questions of the following types: *multiple-choice questions* with single-right answer and multiple-correct option answer to evaluate broad understanding of the subject; *fill in the blank questions* to evaluate students' computing skills and challenge their critical thinking; *open-response (scenario) questions* to evaluate their problem-solving skills (Fig. 4.).

The mock exam was designed using the same assessment criteria as for the summative assessment, i.e. formative automated feedback has

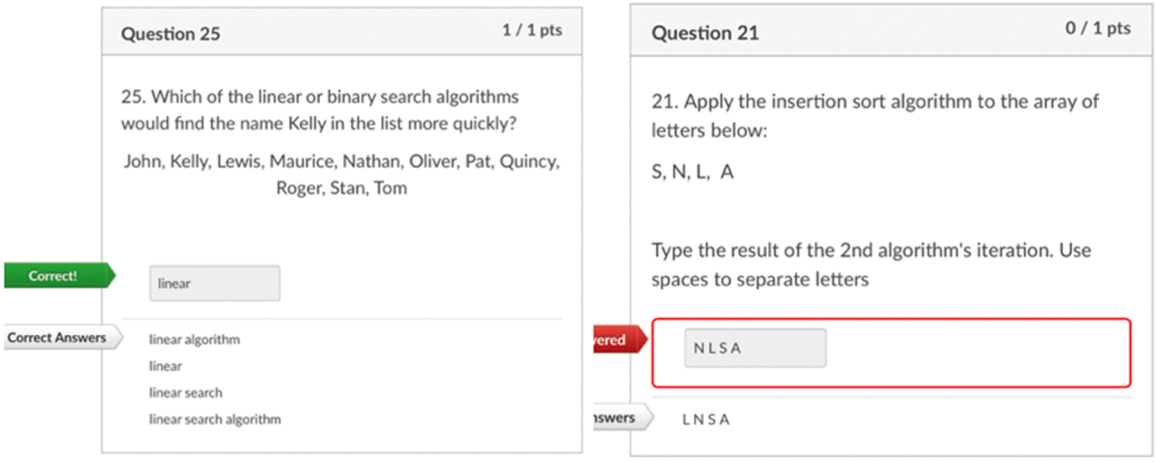


Fig. 4. Mock exam questions and feedback on correct and incorrect answers.

given insights to the students in terms of the topics to revise and general understanding on how to prepare to the final exam.

We will provide some statistics for the 2021/2022 academic year.

The mock exam, covering the material for Assessment 1 and similar to its format comprises 40 questions; 18 multiple choice and fill in the blank questions, each worth 1 point (total 18 points); and 22 short open response questions, each worth 1 point (total 22 points). In total, 106 out of 108 part-time students set two exams for the Computing Foundations module delivered as timed online assessments in the 2021/2022 academic year. 99 students took the mock exam and 106 students took Assessment 1, for which the mock exam was designed and implemented, i.e. 93 % of students taking Assessment 1 took the given opportunity. 96 students took Assessment 2, for which mock exam was not offered.

Practicing with the mock exam was reflected in student exam results. Exam marks statistics taken from the VLE Canvas show a direct correlation between the mock exam with the highest number of attempts (scores) and the highest scores on the exam, and vice versa. Figure A.1 in Appendix A represents the part-time postgraduate class results of taking the mock exam. In the summary graph, skewed left, the x-axis indicates the scored percentages, and the y-axis indicates the number of students who received each percentage. It corresponds to the class exam grades (Assessment 1), also skewed left, represented on Fig. A.2 (Appendix A), where X-axis represents student performance, Y-axis represents a number of students taking the online assessment. The graph for Assessment 2, offered to the students without mock exam practice, shows the student performance, that is a little lower compared to Assessment 1 results (Fig. A.3 in Appendix A). The best results were shown for the mock exam with the average of 72 %, the second-best for Assessment 1 with the average of 71 % and, finally, for Assessment 2 with the average of 70 %.

The standard deviation shows how close the exam scores were to the average exam score. A lower number indicates that students generally scored close to the average, while a higher number indicates that scores varied widely. We observed the standard deviation that is higher for the mock exam, however, the highest score and lowest score for the mock exam are outstanding numbers. It was noted that 99 students took the mock exam, although for Assessment 1 and Assessment 2 only 1 attempt was given, while the maximum number of attempts to pass the mock exam was unlimited. We concluded that 58 % of students in the class made 2 attempts, 29 % - 3 attempts, 3 % - 6 attempts, i.e., on average the majority of students made 1–2 attempts (Fig. 5).

An added benefit of using statistics was the item analysis carried out by the instructor, which has led to improvements in exam design, changes to some of the questions, and adjustments to the marking scheme. For example, the VLE Canvas provides 18 different metrics to analyse multiple choice items, although special consideration has been given to the following indicators reflecting the complexity of Assessment such as the difficulty (difficulty index), discrimination (discrimination index – point biserial of the correct answer) and item distractors (Instructure Community, 2018; Lee, 2022).

According to (Instructure Community, 2018), the difficulty index shows how hard it is to answer the question correctly. The index is computed as the proportion of students who answered correctly. Proportions range between 0 and 1. Canvas makes this calculation with the point biserial. A point biserial is a correlation coefficient that relates observed item responses and is especially used when one set of data is dichotomous, meaning it can take multiple values based on correct and incorrect responses. In addition to the point biserial of the correct answer, the same calculation is created for the distractors (also known as a distractor efficiency). Ideally, all of the question's incorrect answers should be equally appealing to the students who miss the question. Scores for this range from −1 to 1.

The discrimination index attempts to look at a spread of scores and reflect differences in student achievement. This metric provides a measure of how well a single question can tell the difference (or discriminate) between students who do well on an exam and those who do not. It divides students into three groups based on their score on the whole quiz and displays those groups by who answered the question correctly. Student groups are generally divided into the top 27 %, the middle 46 %, and the bottom 27 %. Ideally, students who did well on the exam should get the question right. If students do well on the overall exam but not on the question, the question itself may need to be revised (Instructure Community, 2018).

Analysis of distractors for multiple choice tests shows how incorrect answers act as distractors from the correct answer. Ideally, all of the question's incorrect answers should be equally appealing to the students who miss the question. Scores for this range from −1 to 1. When distractions are ineffective and obviously wrong, they become ineffective in assessing student knowledge. An effective distraction will attract subjects with a lower overall score than those with a higher overall score (Lee, 2022).

The statistics on the mock exam items (questions) are shown on the Fig. 6, where the abscissa shows the numbers of questions, and the ordinate shows the number of students and indices. As shown on the Fig. 6 there are several questions with a high difficulty index, e.g. questions №3, 15, 27, 28, 30, 31, and a low discrimination index, e.g. questions №5, 15, 18, 27, 31, 32, suggesting that a special consideration has to be given to those questions in terms of re-shaping or reformulation. For example, question №31, given the difficulty index, seems too easy (4 out of 75 students answered it incorrectly), while the discrimination index is 0.05.

If the discrimination index is negative, it means that, for some reason, students who scored low on a test were more likely to give the correct answer. With this pattern, the high-performing students are getting the answer wrong, and the low and/or mid performing students are getting it right. Researchers have recommended removing items that have a negative point-biserial (Balogh, 2016). Values of 0.15 or higher mean that the item is performing well, good items typically have a point-biserial exceeding 0.25. Items with incorrect keys will show

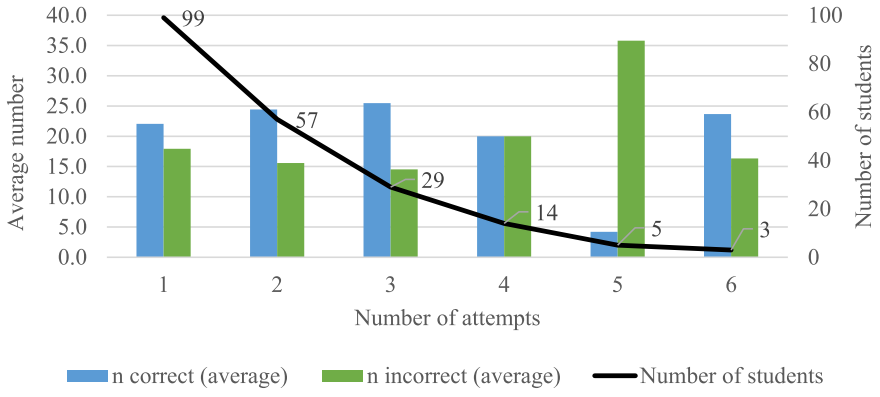


Fig. 5. Mock exam: number of attempts.

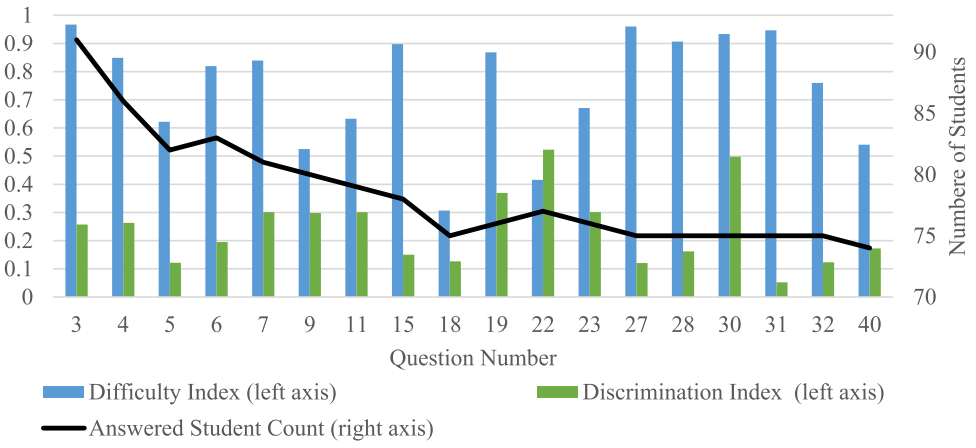


Fig. 6. Statistics on the mock exam questions.

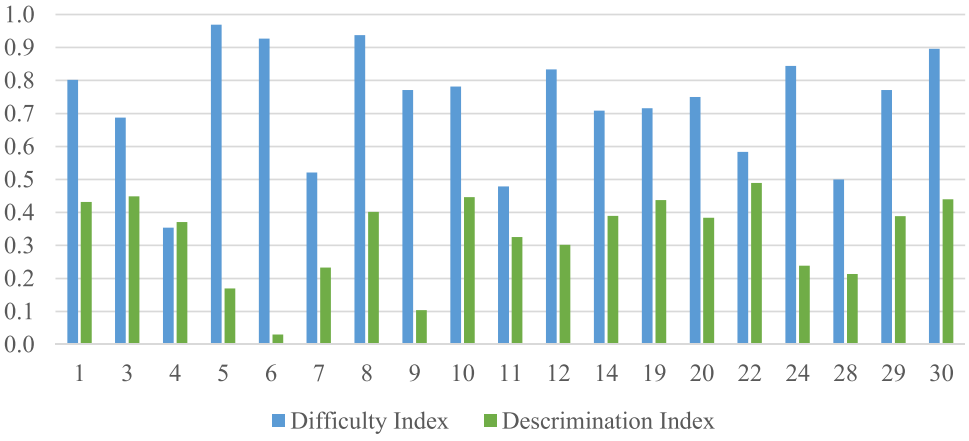


Fig. 7. Statistics on Assessment 2 questions.

point-biserials close to or below zero. As a rule of thumb, items with a point-biserial below 0.10 should be examined for a possible incorrect key (Balogh, 2016). The analysis of distractors for question N°31 shows that it is necessary to pay attention to incorrect answers, where we could detect that students chose only among options A and C, and option B was considered as incorrect. That is, we should reformulate option B so that it becomes a more attractive distractor.

There was no mock exam before Assessment 2. Even though the marking scheme was slightly different and the duration of the online test was longer compared to Assessment 1, we could observe a little lower performance for Assessment 2 with the average of 70 %. On average, grade results are similar to grade 1, although the distribution of grades is different. Although the students did not take the mock exam, they were already familiar with an assessment format. To account for complexity, questions N°5, 6, 8, 9, 24, 30 have to be considered and re-formulated according to the statistics and shown indices (Fig. 7).

Even though the mock exam has proved to be an effective tool to monitor the large class performance and was very well received by students (around 90 % of the class acknowledged its positive impact on the actual exam grades), the above approach has got its limits. Full coverage of all types of questions, including long open response and reports seems not possible, but this exploratory research though has offered useful insight into providing support the large class through the mock exam delivered on the virtual learning environment and how online technologies could effectively be used to engage with learners and help them to prepare for the actual exam.

5. Results

This section presents the results and answers the research questions introduced in Introduction.

RQ1: What are the positive and negative aspects of technology-enhanced learning from pre- to post-pandemic according to part-time adult students studying the MSc software development program?

The conclusions in this section are based on the statistics collected during the 2019/2020 academic year when on-campus teaching took place, and 2020/2021, 2021/022 academic years as the vast majority of student feedback and responses, covering technology-enhanced learning practices, were received at that time. The following Table 3 represents quantitative data of student attendance, engagement and satisfaction.

Adaptation of the Computing Foundation module to the new model of online delivery has been considered to be rather successful in the 2020/2021 academic year. We observed a high level of student engagement with the content on Canvas, they worked independently through videos, pre-reading resources, pre-recorded videos and completing quizzes in advance of attending live sessions (Pishchukhina, 2022). Online lectures even proved to be more engaging than lectures held on campus, because students were willing to use the chat rather than to speak in a lecture hall. Using chat also allowed more students to ask questions without embarrassment in front of their peers. The live online sessions in MS Teams had consistently high attendance in the 2020/2021 and 2021/2022 years with similar attendance for both modules between 72 % and 86 % of the class logging in every session up to week 12. We observed the peak of attendance in the year of the

Table 3
Positive students' experience.

Indicator	2019/2020 academic year	2020/2021 academic year	2021/2022 academic year	Data sourse
Level of student engagement	64 % Interactive activities in the classroom, discussion forums, emails	87 % Live chat boxes, discussion forums, announcement	78 % Live chat boxes, discussion forums, announcement	Data collected from the VLE Canvas statistics, instructor's notes and student emails (2019/2020); the VLE Canvas statistics, MS Teams reports (2020/2021, 2021/2022). The level of student engagement is calculated as the average value of all different types of activity. The level of student engagement in each activity is calculated as the proportion of number of students who took part in this activity out of the total number of students
Level of student engagement in formative assessment	86 % - mock exam between 64 % and 78 % - quizzes	93 % - mock exam between 81 % and 95 % - quizzes	92 % - mock exam between 75 % and 86 % - quizzes	Data collected from the VLE Canvas Quiz statistics. The level of student participation is calculated as the proportion of number of students who took part in the quiz/mock exam out of the total number of students. For 12 quizzes, the minimum and maximum levels of student participation are presented
Attendance of live classes / optional revision sessions	between 54 % and 62 % of the class attending 3 h teaching session per week to week 12 / 75 %	between 75 % and 86 % of the class logging in every "live" session up to week 12 / 87 %	between 72 % and 82 % of the class logging in every "live" session up to week 12 / 88 %	Data collected from on-campus attendance reports and logs to the VLE Canvas (practical session materials, 2019/2020), MS Teams attendance reports (2020/2021, 2021/2022)
Overall student satisfaction with the module /teaching (out of 5)	4.0 / 4.4	4.7 / 4.9	4.6 / 4.8	MEQ, TEQ
Satisfaction with the module content delivery	80 % On-campus lectures and labs	85 % Asynchronous mode of delivery that includes lecture pre-recorded videos	85 % Asynchronous mode of delivery that includes lecture pre-recorded videos	MEQ
Satisfaction with participation	82 % On-campus revision sessions and revision material and other content on VLE Canvas	98 % Revision material and other content on VLE Canvas	92 % Revision material and other content on VLE Canvas	MEQ
Satisfaction with assessment arrangements / marking	79% / 85% Practice challenges, formative quizzes, mock exam	83%/ 91% Practice challenges, formative quizzes, mock exam	88% / 92% Practice challenges, formative quizzes, mock exam	MEQ

pandemic, which can be easily explained by the lockdown conditions in the UK and learning / working from home, we have seen an increase in student online class attendance (Fig. A.4 in Appendix A). The slight decrease in attendance in 2021/2022 can be explained by the return of adult students to work, as well as their possible absence, which may be due to childcare, which has also resumed due to school and after-school activities. This is even higher than attendance at in-person lectures and tutorials for the module in the 2019/2020 academic year. Even the optional revision sessions held in week 6 and week 11 had 87–89 % attendance of part-time MSc students.

We see an increase in student engagement compared to face-to-face learning. This can also be explained by the fact that the active use of information technology in online teaching has made it easier to measure. Student engagement has both positive and negative aspects. On one side, instructors were facing the difficulty of keeping the student's attention during online classes. On the other hand, the use of innovative technologies such as online quizzes, chats, and discussion forums has made it possible to engage shy and non-native English students in active discussions on the topics being studied.

We also observed active student involvement in formative assessment. The combination of online quizzes and a mock exam was positively received by students both during face-to-face and online learning. The combination of formal automated feedback provided by the system and individual feedback provided by the lecturer was appreciated by students as they acknowledged a positive impact on enhancing the student experience and giving essential understanding about their progress (Pishchukhina and Allen, 2021).

The lower level of student satisfaction with the module and teaching in the 2019/2020 academic year can be explained by the fact that the module was introduced and taught for the first time in the 2019/2020 academic year rather than by the format of the module delivery or

Table 4
Negative students' experience (responses collected from mid-term surveys).

Criteria	2020/2021 academic year	2021/2022 academic year
Activity elements were missing by the student cohort	78 %	68 %
Lack of social interaction and opportunities to build learning communities a success	86 %	66 %
Lack of opportunity to collaborate with peers as the students had no prior experience at QUB in general and EEECS in particular	84 %	64 %

teaching techniques. After receiving students' feedback, some adjustments were made to the module materials and structure (e.g. revision material and extra practical classes), that has enhanced student experience and led to increased satisfaction in the following year.

Social activity elements were obviously missing by lecturers and the student cohort. Thinking of what did not work well, it is worth mentioning the lack of social interaction and opportunities to build learning communities between students in the class as well. Students commented in TEQ/MEQ and mid-term surveys, that the part of learning they missed was mostly relevant to the absence of "human communication" with classmates and sharing their learning experiences. This must have been particularly challenging for Year 1 part-time MSc students studying the software development course, as they had not had an opportunity to collaborate with peers before and had no prior experience at QUB in general and EEECS in particular, and would not have already been familiar with EEECS virtual labs and software or virtual learning environment Canvas.

Table 4 represents reflections on what did not work well while

Table 5
Analysis of student feedbacks.

Feedback	Action Taken	Impact	Data Source
Difficulty in understanding complex computing concepts and theories	Complex concepts were broken down into smaller parts and delivered as small lecture pieces immediately followed by practical challenges	Students improved their understanding and gained confidence in their ability to apply these concepts.	Open response questions from TEQ, MEQ feedback, and students' emails collected in 2019/2020 academic year
Students requested more in-depth explanation and practical exercises related to Boolean logic, logic gates, searching and sorting algorithms	Instructor added practical challenges, discussions, and interacting exercises during live classes	Students gained problem solving skills in computing areas related to the mentioned tasks	Open response questions from mid-term feedback and students' emails collected in 2020/2021 academic year
Insufficient resources detailing the Operating System topic, namely while setting and practicing in Linux operating system	The instructor provided a step-by-step video tutorial for setting up Linux operating system and detailed tutorials for Linux lab classes	Learners gained the hands-on experience with Linux operating system	Open response questions from TEQ, MEQ, students' emails collected in 2019/2020 academic year
Insufficient quality and availability of existing software testing techniques application	Supplemental online materials with the focus on software testing techniques application were provided to the students	Students were supported through additional resources	Open response questions from TEQ, MEQ and students' emails collected in 2020/2021 academic year

teaching the Computing Foundations module during the 2020/2021 and 2021/2022 academic years.

In addition to the data collected from TEQ and MEQ open response questions, as well as mid-term feedback form containing open response questions about student satisfaction with teaching online, we collected and analysed the content of student emails with regard to their perception of different curriculum components and support available to them.Table 5 summarises the critical feedback received from students and the corresponding actions taken by the instructor to improve the module in the next academic year. That allowed us to receive some detailed feedback on the module delivery to answer RQ1 and RQ2.

RQ2: What is the satisfaction of part-time software development students with the module delivered in the VLE while shifting to online learning?

Students have responded very positively to the shift to online delivery format. Student satisfaction increased significantly across topics related to course organization, interaction with the instructor, learning resources, and overall satisfaction with the course. Tables 6 and 7 represent the results of Module Evaluation and Teaching Evaluation surveys for the Computing Foundations module during the 2020/2021 and 2021/2022 academic years and show students reflections on the course content, assessment and feedback and the experience with the module.

The number of students participated in the surveys fluctuates between 34 % in the 2021/2022 academic year, and 38 % of the class in the 2020/2021 respectively. The lower number of student responses in the 2021/2022 academic year reflects the limits of the research correlated with massive returning of adult learners to their places of work, that resulted in reduced amount of feedback.

Overall student satisfaction with the module was 4.7/4.6 out of 5 according to the Module Evaluation Questionnaire, and student satisfaction with the online teaching was 4.9/4.8 out of 5 according to the Teaching Evaluation Questionnaire respectively in 2020/2021 and 2021/2022 academic years. According to the Module Evaluation Questionnaire, comprising responses from 46 students (2020/2021 academic year), 85 % of the students were satisfied with the module content and found it well-prepared and well organized (Table 6). The same indicator for the 2021/2022 academic year was 92 % (36 students).

The most positively viewed aspect of online learning is on-demand access to course materials. The presence of asynchronous material became an important component of the module structure because it gave flexibility to the MSc students to revise the lecture notes and practical challenges as many times as they needed, and learn the missed computing subject concepts when they could not attend a live lecture due to work, caring responsibilities or sickness. In the end-term feedback, students responded very positively to weekly organised resources – videos, lecture slides, quizzes and practice challenges – and clearly laid out materials. They also mentioned the fact that short pre-recorded videos and recorded live lectures were used to catch up with the theoretical material and practical topics when they could not attend live online classes conducted in MS Teams.

We also observed an improvement in feedback regarding the chosen delivery format showing that students appreciate their freedom to study courses at their own pace, especially those with additional learning needs who could review content multiple times; this was particularly appreciated by non-native English students.

Designed for self-directed learning purposes and to provide immediate feedback on student knowledge and skills, online formative quizzes were very widely used and well received by students. Student module evaluation feedback was positive and suggested that online formative quizzes have become an effective supportive tool for students to enhance their learning experience.

The majority of the class – 86 % (mid-term survey in 2020/2021 academic year) - expressed their positive and very enthusiastic responses towards online formative quizzes and requested an expansion of the set of practical challenges. Students mentioned that the quizzes helped them to get familiar with new concepts taught in the module as well as the operation of VLE Canvas.

There were a few student responses that were used for the instructor's own reflection, in terms of bug fixes and iterative development of the set of quizzes. Students mentioned non-accessible multiple-choice questions through Canvas mobile app and images not visible to them due to browser settings, so some workarounds were rapidly adopted: some of multiple-choice questions have been substituted by open-response with the problem statement formulated without using of images. In the instructor's opinion, one should be careful about and watch out for inconsistencies in quiz administration settings. Administration set up errors, such as student access error and correct answer setting error might occur and affect student responses.

The majority of students found the criteria used in marking clear (83 %/70 %), assessment arrangements and marking have been fair (91 %/72 %) and feedback received in line with School policy (94 %/83 %) respectively in 2020/2021 and 2021/2022 academic years, that is represented in Table 6. The difference can be explained by the fact that the majority of the part-time students returned to working from offices with extra responsibilities related to personal life arrangements, that has led to some reduced activity in taking formative assessments.

Student feedback on facilitation and engagement with the class was also overwhelmingly positive with 98 %/92 % of respondents satisfied with their participation and offered advice and support respectively in the 2020/2021 and 2021/2022 academic years, that is represented in Table 7. Due to the availability of online services, students had more options to interact with their instructors even outside the lecture sessions. This particularly helped the shy or hesitant students who did not

Table 6
Module evaluation questionnaire for the computing foundations module.

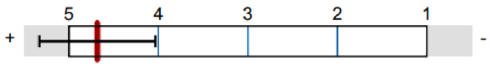
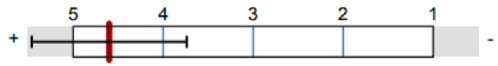
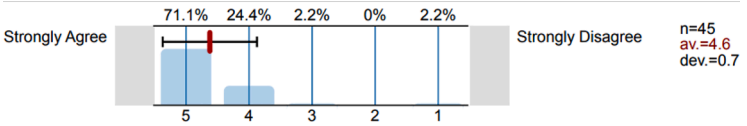
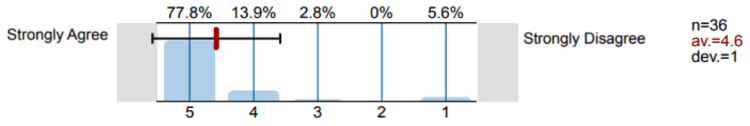
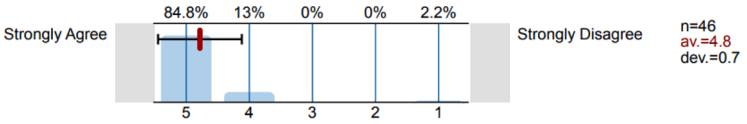
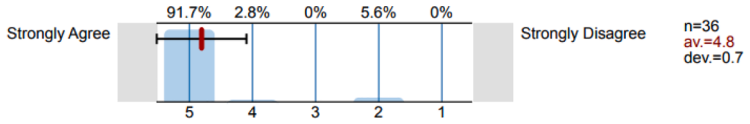
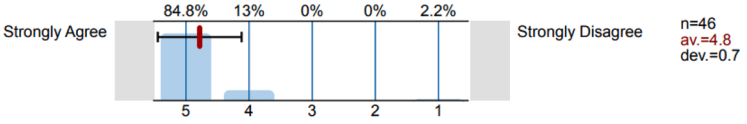
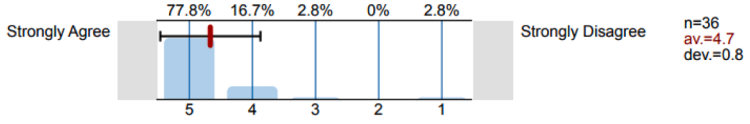
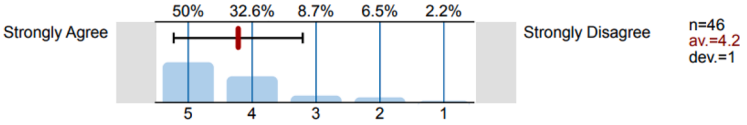
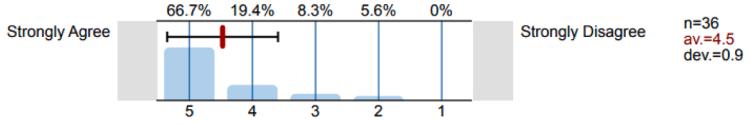
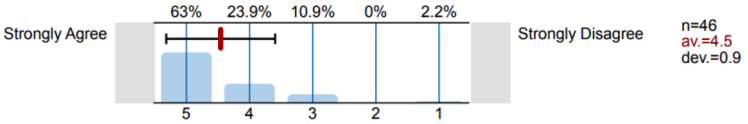
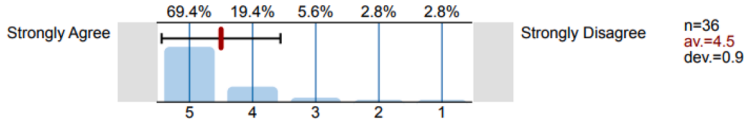
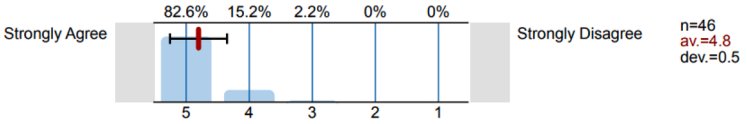
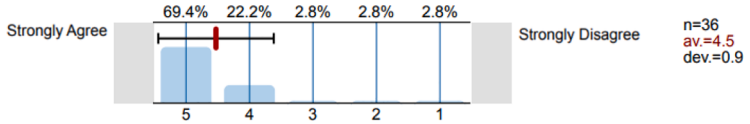
Overall indicators	2020/2021 academic year	2021/2022 academic year
Overall Module Score		
Overall Satisfaction Overall, I am satisfied with the quality of the module		
Module Structure and Learning Resources The module was well-prepared and well-organised		
The module learning resources (notes, web-based material, software, etc.) were accessible, clear and helpful		
The module was intellectually stimulating and challenging		
The module content met my expectations		
Assessment and Feedback The criteria used in marking have been made clear in advance		

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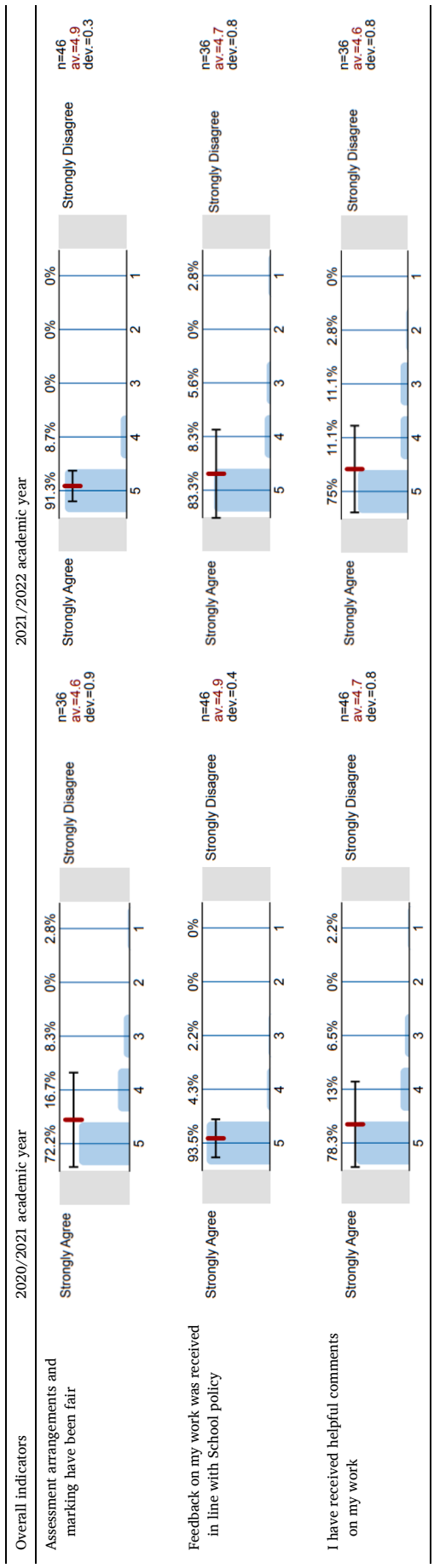
Table 6 (*continued*)



want to ask questions in front of everyone in the classroom.

RQ3: Is there a difference in students' performance while shifting to online learning?

To answer the research question RQ3 we state the null hypothesis of no difference in the level of students' performance, in 2019/2020 and 2020/2021, and 2019/2020 and 2021/2022 academic years. To test this hypothesis, we analyze the metric "Final grade". Descriptive statistics for the final grade (each out of 100) are presented in Table 8. The Kolmogorov–Smirnov test was performed to check the normality of the distributions. A very small p-value (<0.001) was obtained in each test, so we cannot assume that they are normally distributed and have to use a nonparametric test for comparing two independent samples.

Therefore, the Mann–Whitney U test and Kolmogorov-Smirnov test for independent two-sample samples were employed at a 0.05 significance level to ascertain any differences in the average final grades across the academic years. The results are shown in Table 9.

The p-value of 0.69 for Mann-Whitney U-test and 0.81 for Kolmogorov-Smirnov test (2019/2020 and 2020/2021 academic years) and 0.25 for Mann-Whitney U test and 0.75 for Kolmogorov-Smirnov test (2019/2020 and 2021/2022 academic years) respectively were greater than our p-value significance level of 0.05, therefore, we had to accept the null hypothesis. Therefore, there were no significant differences in academic performance between the face-to-face and online cohorts.

Additionally, the evaluation results of the final exams and pass rates in the academic years 2019/2020 (prior to the pandemic), and 2020/2021 (during the pandemic) and 2021/2022 (post-pandemic) have been compared to reflect the impact of the new delivery format on the academic performance of students (Fig. 8).

As we can see (Fig. 8), the averages and pass rates did not change significantly during the considered period, which can confirm the conclusion that the delivery format did not affect student performance.

6. Discussion

In this section, the results of the study are discussed concerning the three research questions (RQs) raised in the introduction.

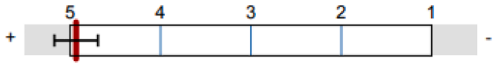
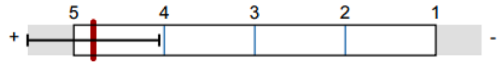
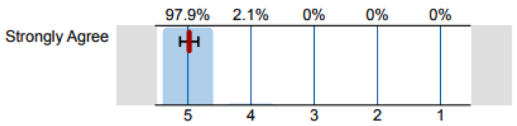
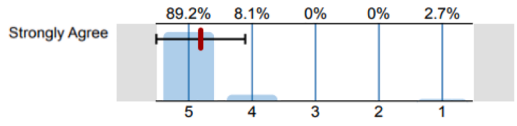
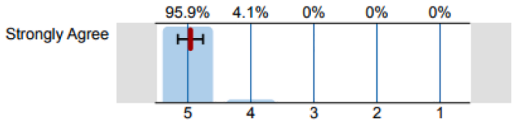
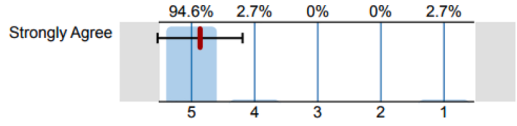
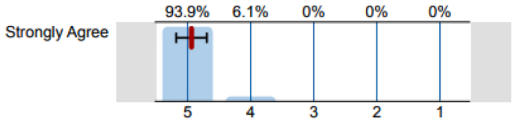
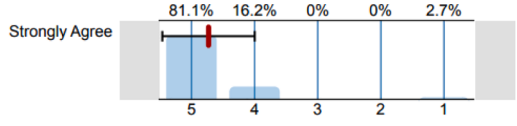
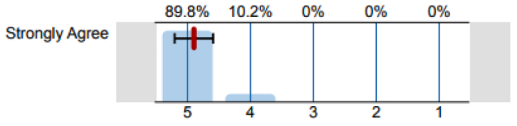
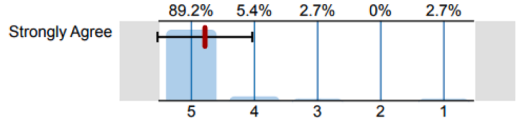
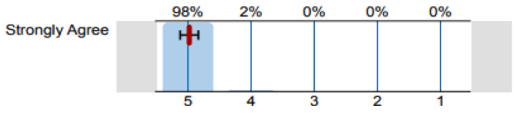
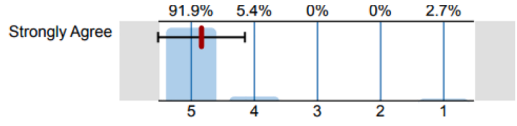
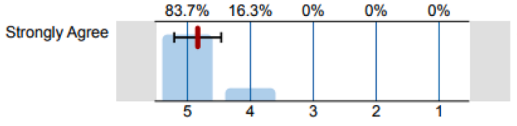
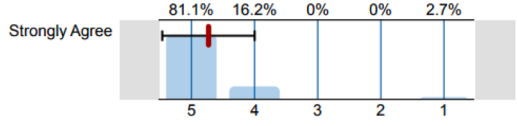
Positive and negative aspects of technology-enhanced learning from pre- to post-pandemic according to part-time adult students studying the MSc software development program (RQ1)

The pandemic has triggered shifts in the higher education system and has spurred the digitisation of educational processes. It has provided an opportunity for educators and universities to reflect on and reconsider existing practices, identifying possibilities for improvement and innovation. The pandemic has served as a catalyst in adult education, providing them with the opportunity to choose the delivery mode of educational programs. After the option to return to campus became available, many adult students opted for retaining the online or hybrid format for module delivery (Flynn et al., 2022; Gardner et al., 2022).

The main advantages of online delivery of the module, which were noted by students, are: saving time on trips to the university, the ability to study without leaving home, and the fact that lectures are provided in both synchronous and asynchronous formats, which correlates with the results conducted studies for part-time students (Fiorini et al., 2022; Duncan, 2020).

Students see the lack of social interaction as the main negative factor of teaching online. Some research has reported (Toti and Alipour, 2021) that despite the benefit of higher computer literacy among IT students, they found the transition to online challenging, especially with regard to tasks such as asking questions during video lectures and interacting with lecturers. There is full-scaled discussion in the literature on the issue of presence and connection while teaching and learning in a large class, with both staff and students experiencing a sense of isolation (Farrell et al., 2021). The data from our surveys indicates that reduced synchronous teaching and limited peer-to-peer and student-teacher interactions may become a problem, as a virtual class room despite its

Table 7
Teaching evaluation questionnaire for the computing foundations module: facilitation and engagement with students.

Overall indicators	2020/2021 academic year	2021/2022 academic year
Overall Teaching Score	 av.=4.9 dev.=0.2	 av.=4.8 dev.=0.7
Overall Satisfaction Overall, I am satisfied with the quality of the module	 n=48 av.=5 dev.=0.1	 n=37 av.=4.8 dev.=0.7
The Lecturer Was generally well prepared and well organised	 n=49 av.=5 dev.=0.2	 n=37 av.=4.9 dev.=0.7
Explained new terms, concepts and principles clearly	 n=49 av.=4.9 dev.=0.2	 n=37 av.=4.7 dev.=0.7
Motivated me to do my best work	 n=49 av.=4.9 dev.=0.3	 n=37 av.=4.8 dev.=0.8
Encouraged participation from students	 n=49 av.=5 dev.=0.1	 n=37 av.=4.8 dev.=0.7
Made the subject interesting	 n=49 av.=4.8 dev.=0.4	 n=37 av.=4.7 dev.=0.7

(*continued on next page*)

Table 7 (*continued*)

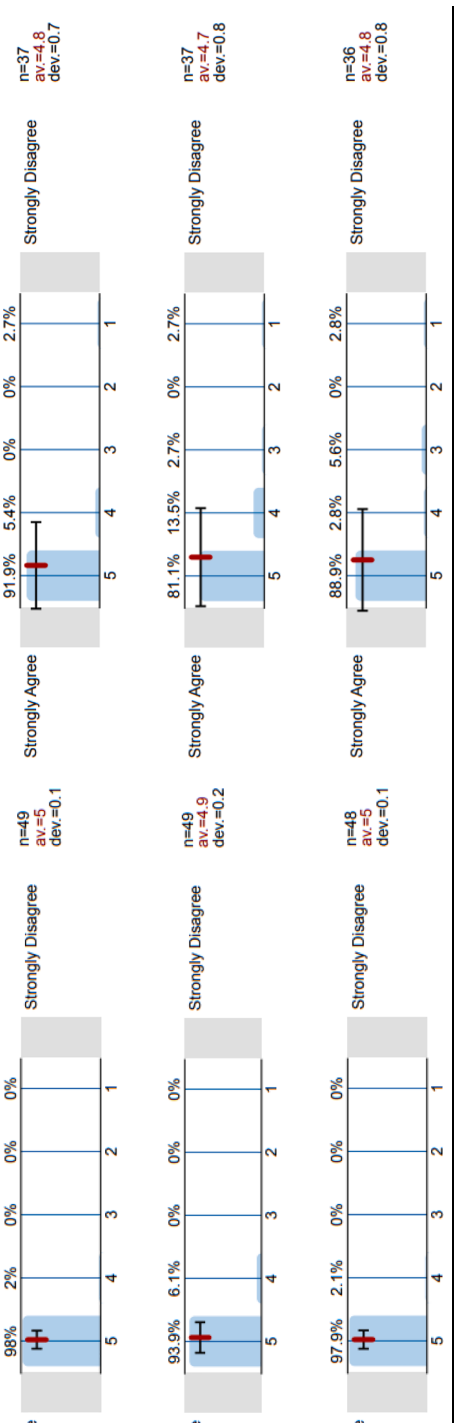
Overall indicators	2020/2021 academic year	2021/2022 academic year
Was enthusiastic about what they taugh		
Offered sufficient advice and support		
Was contactable when needed		

Table 8
Descriptive statistics for final grades.

Indicator	2019/2020 academic year	2020/2021 academic year	2021/2022 academic year
N observations	72	129	108
Mean	67.85	68.34	66.64
Median	70.00	70.00	69.00
Standard Deviation	18.84	14.81	15.59

Table 9
Nonparametric two sample test results at 0.05 significance level.

Hypothesis	Mann-Whitney U-test		Kolmogorov-Smirnov test		Research outcome
	Mann-Whitney U	p-value	D-stat.	p-value	
There is NO significant difference between the average final grades of 2019/2020 and 2020/2021 academic years	4111.00	0.69	0.06	0.81	Do Not Reject
There is NO significant difference between the average final grades of 2019/2020 and 2021/2022 academic years	2925.5	0.25	0.11	0.75	Do Not Reject

Fig. 8. Class average and Pass rate during 2019–2022 academic years.

proved viability is not that enjoyable as a "normal" class room that is shared with peers. At the same time, the results of our surveys in the 2020/2021 and 2021/2022 academic years show different views of learners on the importance of social interaction. In 2021/2022, this lack was not so acute (we see a decrease in student dissatisfaction by an average of 10–20 % depending on the indicator (Table 4)). This may be due to the fact that adult students compensated for the lack of communication in the classroom by work and in other social environments, focusing during training on learning goals.

Despite similar positive and negative aspects of technology-enhanced learning that can be applied to adult student education in general, our study has shown the more positive experience of online learning for mature students studying software engineering that can be explained by their positive attitudes towards technology and a desire to acquire and develop ICT competences, considering the chosen programme. Additionally, this can be attributed to the instructor's readiness and ability as a professional to actively engage with students and improve the course, using information technologies. This aligns with findings (Crick et al., 2021) regarding a higher level of readiness for technological changes among IT educators.

Satisfaction of part-time software development students with the module delivered in the VLE while shifting to online learning (RQ2)

Despite the spontaneous transition to the online environment due to the pandemic, the study shows that, in general, adult part-time students were satisfied with the result of converting the module to an online

format. The results obtained are consistent with studies conducted for this target audience post- pandemic (Fiorini et al., 2022; Toti and Alipour, 2021), and before the pandemic, when studying their satisfaction with online learning (Herrador-Alcaide et al., 2019; Padilla-Carmona et al., 2016).

Both positive and negative comments reflected the importance of the teacher's pedagogical approach. Moving teaching online may allow practitioners to be "flexible" and "creative" in their pedagogy, and to take advantage of information technology to improve teaching, but at the same time some key topics in computer science, such as programming and mathematical foundations, as well as more practical or collaborative topics such as robotics and group software projects may require other approaches (Crick et al., 2020), for example blended teaching.

We received positive feedback from students about the format of summative assessment in the form of online tests. The feedback, received after moving MSc Computing Foundations module online, indicates that the students appreciated the flexibility provided to them. Such feedback from our students correlates with the general trend that is observed in universities in the post-COVID period. University survey results also show that the forced abandonment of traditional exams has benefited the mental health of students, in which students noted that they became less worried about grades (Universities UK, 2022). These results have led to the initiative of planning to permanently phase out traditional exams and use online assessments more widely in many universities in the UK.

Since engagement is the key to measuring the quality and effectiveness of a course, we can conclude that this module and its delivery format are appropriate for this target audience. At the same time, learners now expect a higher standard of online course design as part of any teaching and learning experience and want options between in-person, online, or hybrid courses (Instructure, 2022).

In addition to the above, it should be noted that the transfer of the course online has facilitated the use of more modern teaching methods and concepts by the academics. Interaction with adult students in a large class online, in addition to hard skills, allows to develop digital skills to continue learning online, as well as the necessary soft skills of professional behavior in a virtual environment, which will be valuable and applicable for future work, since most companies in the field of information technology have retained a hybrid post-pandemic format. Improving the digital skills of both students and lecturers expands the opportunities for the use of more modern learning technologies in the future.

Performance differences between face-to-face and online students (RQ3)

Analysis of the final grades indicated that changing the module delivery format did not affect students' average grades (no significant statistical difference was found) and pass rates. These results suggest that flexible learning approaches, when provided with a well-structured module, active instructor interaction with students, and monitoring student engagement and performance, can produce good learning outcomes. This demonstrates that this delivery format is suitable for adult part-time students and online methodologies can maintain levels of achievement comparable to traditional learning, and sometimes improve grades (McGowan et al., 2022). Some research shows that there is no significant difference in learning online or face-to-face across the various levels of education (undergraduate students, MSc, Ph.D.) (Linnes et al., 2022; Toti and Alipour, 2021; Yu, 2021).

At the same time, in order to maximize the benefits of online learning in a large class of adult students, it is necessary to provide free access for everyone in the classroom to computer equipment and a stable Internet connection, and also pay special attention to the development of interesting online content of the module and support for this module in VLE, taking into account the requirements of users.

7. Limitations

The results obtained from this study on the effectiveness of teaching the Computer Foundations module to part-time students in two formats (offline and online), as well as the experience of redesigning this module for effective online technology-enhanced delivery, are extremely valuable for the module design in the future and implementation of technology-enhanced learning into the course. However, several limitations should be considered when interpreting the results:

1. The number of students who completed the TEQ, MEQ, and mid-term surveys is relatively small (Table 1) and all voluntarily enrolled in the surveys. This self-selection may introduce bias.
2. The survey was anonymous and voluntary, meaning the study relied heavily on self-reported data, which may be subject to bias. In some instances, the participants could withhold negative information or, in contrary, release their dissatisfaction that might have led to expressing their views in a less / more critical manner. Furthermore, students who were willing to volunteer to take part in an online survey were likely to be more confident and engaged with the learning processes that were the subject of discussion, so it should still be noted that the views of other students may differ from those represented in the paper.
3. Although this study was conducted for software professionals, it is necessary to take into account the specific nature of the Computer Foundations module, namely, its introductory nature. Teaching online modules that are more technical in nature and contain more components that are practical may face more challenges and require additional research.

8. Conclusions

We investigated the differences between the module delivery, student performance and learning experience during the 3 consecutive years: (1) the pre-pandemic 2019/2020 academic year with traditional on campus teaching; (2) the pandemic 2020/2021 academic year, when online learning emerged; (3) the post-pandemic 2021/2022 academic year when sustainable online learning took place. The redesign of the Computing Foundations module in order to be delivered fully online became a challenge, as it had to be done under unprecedented circumstances during the global pandemic. The Computing Foundations module transformation was generally successful in terms of meeting the needs of large cohorts. Student feedback indicates that they were satisfied with the module but that they would benefit more from a blended or hybrid approach, which is consistent with the findings evident in the literature (Farrell et al., 2021). The redesigned Computing Foundations module, that proved to be a successful module in the 2020/2021 academic year according to the MEQ/TEQ = 4.7/4.9 (out of 5, respectively), has been retained as an online module for the part-time cohort and being taught in the same format in the 2021/2022 and 2022/2023 academic years. While teaching online is certainly different (Hodges et al., 2020), many practices are transferable to the face-to-face environment, and aspects of the redesigned module will be kept for the 2022/2023 academic year. The opportunities for novel learning moments offered by the use of both synchronous and asynchronous models can be used to enhance teaching methods for large classes environment (Farrell et al., 2021). It is worth mentioning that maintaining a balance between synchronous and asynchronous engagement supports teacher's presence and improves perception of the course in general. Synchronous learning activities, in particular, provide opportunities for students to communicate with their large class instructor in real-time, e.g. to ask questions and debate module content during live lectures. However, asynchronous learning activities increase accessibility of remote, emergency teaching, that was evidenced in our survey by students. Utilizing the conceptual framing for effective online courses (Martin et al., 2019) as a frame of reference for pedagogical redesign was

important as neither lecturers nor students were unfamiliar with the experience of asynchronous teaching and learning. While the above study is concerned with the implementation of online learning to large cohort teaching, many of the findings could be applied to any class size.

Adaptation of the Computing Foundation module to the new model of online delivery is considered to be successful in the 2020–2021 academic year according to returned student feedback, and the module became a distance module delivered fully online in the 2021/2022 and 2022/2023 academic years. The transformation has helped to cope with a "new normal" in an increasingly hybrid higher education ecosystem as students' and educators' involvement into learning activities continued to be altered in the post-pandemic society.

The outcomes of the conducted research study may be useful for (1) researchers involved in the projects related to online teaching or teaching in large classes; (2) academics teaching both in online and hybrid format; (3) for developers of online courses; (4) for teaching assistant staff who supports the development of online courses structure and content delivered on VLE.

Future research will focus on the (1) teaching practices enhancing student learning experience both face-to-face and online through various forms of material presentation to satisfy all learner types, e.g., challenge and engage with students through online discussion forums and formative quizzes as a key to their deep understanding of computing subject; (2) techniques to deliver curricula flexibly to meet new learning patterns, e.g., the pattern of online and hybrid learning, and needs of postgraduate students related to their different abilities, background and potential; (3) greater use of active and interactive learning supported by innovative technology, e.g., the VLE Canvas so that students have the ability to use technologies effectively for learning and their success in mastering computing and programming subjects.

CRediT authorship contribution statement

Olga Pishchukhina: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing, Visualization, Resources. **Daria Gordieieva:** Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing, Visualization, Formal analysis. **Austen Rainer:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Daria Gordieieva reports financial support was provided by The British Academy.

Data availability

Data will be made available on request.

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Supplementary materials

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