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Preparing Students for a Digitised Future

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Abstract— Through this study, a vehicle to enhance existing education curricula was demonstrated, by exposing students to research-informed educational activities and to experience the key digital systems used in different industrial sectors. Digital skills are in high demand across the globe, with over a million digitally skilled people required by 2022 in the UK alone. With digital skills being vital to a country’s economy, there is a need to develop the higher education sector to prepare students for a digitised future - a key area of future graduate skills.

The overall aim of the project was to train students in cutting-edge digital technologies through two separate week-long boot camps, targeting undergraduate and postgraduate cohorts. To this end, an educational project primed by research-informed teaching was successfully organised at the University of Birmingham in collaboration with the industry, to directly enhance the student’s personal development in the digital field, the findings of which are reported in this paper. Researchers and practitioners presented practical applications of various digital technologies during the boot camps.

Index Terms— Research-Informed Teaching, Problem Based Learning, Digital Skills, Computing skills, Critical Thinking, Employment, Industry Involvement, Communication Skills, Problem-based Approach

I. INTRODUCTION

Automation and digitalisation in businesses as part of the 4th Industrial Age have brought about a global trend of replacing mid-skilled with a high-skilled workforce, including universities graduates [1, 2]. Börner, et al. [3] discussed the importance of human (or *soft*) skills, such as communication, that are not well addressed in higher education. The Berger and Frey [4] Report demonstrated that digital, creative and entrepreneurial skills and a combination of these are key for future employment. Berger and Frey [4] projected that 45% to 60% of the European labour market would be displaced in coming decades as the result of digitalisation, adding to the existing 14 million unemployed men and women in the EU as of February 2020 [5].

The requirements for digital skills and the demands

associated with these new skills have posed a new challenge to education systems, particularly within the higher education [6, 7].

Digital skills range from information and communication technologies (ICTs), e.g. abilities to use digital devices [8], to more advanced numeracy-based skills, e.g. Internet of Things (IoT), blockchain and Artificial Intelligence (AI). ICTs are recognised by the UN as an accelerator for achieving its seventeen Sustainable Development Goals (SDGs) [9]. Having said that, OECD [10] emphasised that ICT skills are not enough for succeeding in the digital economy, while other advanced and complementary skills are needed, including “*numeracy skills through to the right socio-emotional skills to work collaboratively and flexibly*”. The digital skills referred to in this article involve advanced and complementary skills, with more examples provided in Section III

According to the literature, currently, there is a skill gap in awareness of modern digital technologies and their applications among graduates. For instance, Khan [11], Hernandez-de-Menendez, et al. [12] identified a ‘proficiency gap’ in the adaptation of IoT by the industry and the level of graduates’ knowledge on the subject which may widen if no action is taken. A survey conducted by the Confederation of British Industry (CBI) showed that over 65% of the participated companies were struggling to recruit for digital roles, indicating the associated digital skills gap, and this was projected to cause £2bn loss per year to the UK industry [13].

Addressing this challenge requires an overhaul of the education systems [10]. A study of employment trends amongst Organisation for Economic Co-operation and Development (OECD) countries by Goos, et al. [14], reported a positive correlation between the spending in research within higher education institutions and the share of digital employment. The need for modernising training provision within higher education to prepare students as future employees with digital skills was highlighted by UNESCO [15] and recognised as essential to close the existing gap between global labour market necessities and teaching provision. European University

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Association (EUA), while highlighting the vital role of universities in digitally transforming societies and providing the required digitally trained graduates, also pointed out the need to recognise students' various needs and backgrounds [16].

However, a misalignment between science and technological development through research and educational training from higher education and industry to meet key job market requirements exists, as identified by Börner, et al. [3]. Their study was based on data from academic programmes and syllabuses, and job advertisements, published between 2010 and 2016. In light of these needs, many governments have started to explore skills development for the future. For example, the UK government estimates that over a million digitally skilled people are required by 2022, with driving up digital skills being a key plank of higher education's strategic framework and the UK's Industrial Strategy [17, 18]. To this end, the findings presented herein highlight the steps that universities need to take to prepare their students for a digitised future - a key area of future graduate skills.

Further to the digital skills the graduates are not well equipped with **soft** skills, e.g., team working. The Institute of Engineering & Technology (IET) reported that 73% of the participated companies have had difficulties with recruiting graduates with the right academic knowledge who lacked the required workplace skills for engineering jobs [19].

This paper incorporates the findings from a recently completed Higher Education Futures institute (HEFi) funded Digital Innovation Boot Camps undertaken at the University of Birmingham, aimed at training undergraduate and postgraduate students in digital skills. The research question was "How effective is a boot camp training event on digital skills to enhance participants' knowledge and vision on the subject".

These boot camps incorporated both research-led and industry-enabled access to new digital platforms, where students applied the skills gained during the boot camp to tackle a set of global challenges. To our knowledge, the boot camp in this format and its targeted objectives was a unique offering within the higher education spectrum and therefore the findings and lessons learned would contribute to informing future higher education strategy frameworks aimed at enhancing digital skills and education for students.

This paper briefly reviews the literature (Section II) before describing the adopted methodological approach to design and implement the boot camps (Section III). The success of boot camps in improving students' knowledge of digital technologies was measured and the results of this have been presented in Section IV. The wider implications for research and practice are subsequently discussed (Section V) and conclusions are drawn (Section VI).

II. LITERATURE REVIEW

Digital skills are vital for the future of employment, where many, if not all working environments will require employees to be able to both navigate and use constructively various digital platforms [20]. Not only will this require significant upskilling in the digital arena but an ability to constantly adapt and reconstruct the knowledge as various digital tools evolve and

change. Lewrick, et al. [21] analysis of 200 technology-based companies highlighted the importance of preparing students through teaching them the best methods for managing change and to enable them to have an appreciation of sustainable development. When preparing students for the future, it is, therefore, vital that theories related to both digital technologies and innovation or entrepreneurship are taught. However, the main challenge is to make these vital tech theories interesting, as discussed by Fiet [22] who proposed a student-approved approach through engaging them in learning activities and by giving them a direct role in any such learning delivery events.

In addition to digital skills, some other skills are often seen as lacking amongst graduates, with industry regularly bemoaning the lack of ability in a range of **soft** skills, such as the ability to work and manage teams [4, 23]. Moreover, Van Tonder [24] demonstrated that the higher education sector often fails to develop creative and entrepreneurial skills within its graduates. Greater use of digital platforms not only has the potential to provide the development of a broad range of digital skills through 'grand challenges' drawn from research and industrially based project ideas, but these platforms also provide the chance to enhance a full range of **soft** skills. This is particularly important in the dynamic field of digital technologies [25, 26].

Therefore, the ideal adopted pedagogy should inform students about the flexibility required in learning, as highlighted by Dutta, et al. [27]. Moreover, flexible learning has been highlighted as a means to achieve greater inclusiveness in higher education, where diversity in educational background and learning preferences can be addressed through digital platforms [28]. In particular, Akoh [29], Staddon [30] showed that greater inclusiveness can be better achieved by using digital platforms for teaching. It is important here to use a flexible approach to learning, by engaging and involving the student in teaching, through a so-called 'pedagogic voice', which has proved to have a significant role to play in the student learning [31-34]. A pedagogic voice allows students to engage directly in their learning through a personalised experience [35].

The literature describes key pedagogic approaches that are most suitable for exposing students to the missing soft and digital skills. It has been shown [36] that the use of intensive focussed sessions that take place over a short period can be a very effective means to develop a full range of soft, and potentially digital, skills. Barber, et al. [37] showed that problem-based learning, using, for example, selected global challenges can be an appropriate tool for teaching rapidly changing concepts such as digital technologies. Further, van Laar, et al. [38] identified the key components of digital skill-based teaching via a systematic literature review, as follows:

- Collaboration
- Creativity
- Critical thinking
- Communication
- Information management
- Technical
- Problem-solving
- Creativity

The problem-based approach, which is adopted for our task in hand, is shaped around the 'problem scenarios' where there is no 'correct' or expected answer. In this flexible pedagogy, students have to decide what information and skills are useful

for them to solve the problem, supporting a move towards hands-on learning in the education [39]. Moreover, West, et al. [40] identified three teaching methodologies to encourage the transformation of creative thoughts into innovative solutions, as follows:

1. Innovation training; designed around human's or 'users' need, i.e. understanding human consumption behaviour [41, 42]
2. Students working within a multidisciplinary team [43, 44]
3. Project-based learning [45, 46]

Teaching digital and innovation technologies, and skills have huge potential for engaging research, through the so-called research-informed teaching (RIT) [47]. In the RIT approach students “*acquire, indirectly through the pervasive research culture as well as directly through the example of leading researchers and the challenge of assignments, the intellectual curiosity and rigorous approach that can be widely applied*” [48]. RIT has been emphasised as a way forward amongst leading institutes around the world [49-51]. It has been identified as one of the core elements of the future curriculum in which teaching will be more valued [52]. RIT can also be seen as taking students to be ‘Producers’ [53] or ‘Co-producers’ [54]. Further, RIT can help students to achieve independent and autonomous learning skills, but current academic cultures can be seen as a challenge for RIT, as sometimes teaching is a less valued activity and the time spent on preparation is not relatively appreciated [55]. This can be seen as an opportunity for RIT to positively link teaching and research, and for the former to employ key subject-specific learnings from the latter.

Aikat, et al. [56] proposed a new ‘data-centred’ pedagogy for dealing with the new digitalised era, the so-called ‘fourth paradigm’, which incorporates a data-intensive, interdisciplinary training with an emphasis on data and big data training through a collaboration between the industry and academia. Whilst the focus of Aikat, et al. [56] work was big data, the concept of a data-centric approach that utilises digital skills provides useful insights here.

Digital technologies have been effectively utilised in higher education including in the form of digital pedagogy. However, Lewin and Lundie [25] discussed a threat from digitalisation of education, where online platforms and Massive Open Online Course (MOOC) may entirely replace the traditional classrooms. However, the need for interacting with others and the significance of learning by doing approach would appear to mitigate these threats, as hands-on approaches provide opportunities to develop many soft skills that MOOCs cannot adequately promote [57]. Many authors have identified the boot camp framework as a successful delivery methodology, to overcome such difficulties. Thus, the authors proposed a boot camp format for achieving multiple key elements within the data-centred pedagogic approach.

Pearce, et al. [58] adopted a multi-disciplinary approach in implementing a boot camp on sustainability, which was developed using the ‘pedagogical best practices’ formed around a problem-based learning pedagogy. A problem-based pedagogy was also successfully implemented by Peabody and

Noyes [59], through a reflective boot camp in which, ‘brick-building’ and ‘metaphoric storytelling’ were utilised as a means of communication to solve problems. Patelli, et al. [60] reported a problem-solving approach in running a boot-camp on digital boot-camp related to software training.

A study conducted by Clarysse, et al. [61], based on interviews with various higher education stakeholders in Europe, found that technology management education is moving towards ‘entrepreneurial boot camps’ in which working across disciplines is encouraged. A challenge of relying on outside expertise for running boot camps was highlighted by Clarysse, et al. [61], who emphasised the importance of engineering and business schools sharing their expertise to overcome these challenges.

The success of boot camps was reported in other disciplines, for instance, Wischusen and Wischusen [62] reported the success of a boot camp in biology by comparing the exam results of two student groups, one of which participated in the boot camp. The utilisation of a two-day boot camp for undergraduate students in technology and engineering were reported by West, et al. [40] who used tests and surveys to assess its success. Such an approach was reported to be successful and adopting a multidisciplinary approach was key. A three-day engineering innovation and entrepreneurship boot camp held for two years were reported by Bodnar, et al. [63] who stated the need for developing an entrepreneurial mindset through similar teaching methodologies presented earlier by West, et al. [40].

Thus, the use of a short weeklong research-informed boot camp is ideal to develop digital skills set in a grand challenge format whereby other soft skills can be enhanced. Through these findings, it was possible to adopt a research-informed and problem-based pedagogical approach in designing week-long digital boot camps, one each for undergraduate and postgraduate students, run at the University of Birmingham, the details of which are described in the following sections.

III. METHOD

This section describes the boot camps’ design, implementation details and the method used to evaluate their success.

One-Group Pretest-Posttest Design, which is used to evaluate the impact of a treatment or intervention on a sample [64], guided the study. This research design was used by Altanopoulou, et al. [65] to evaluate the effectiveness of a wiki-based learning activity for a group of undergraduate students. Kholida [66] also used the same research design to assess the effectiveness of YouTube videos in teaching listening skills in higher education and to assess students’ willingness in using them.

A mixed-method, i.e., combined quantitative and qualitative methods, was used. Research outlook was developed based on a quantitative approach, while participants’, i.e., students, academic and industrial partners, viewpoints on the development and delivery of boot camps and their feedback after the delivery of boot camps were gathered through a qualitative approach, described in the following subsection.

A. Equations Design and Implementation of Boot Camps

In total 33 students took part in two separate week-long boot camps. The first consisted of 14 undergraduates from cohorts representing years 1, 2 and 3 from Electrical, Mechanical and Civil Engineering programmes. The second boot camp consisted of 19 postgraduate students, from four different MSc Engineering Management programmes. The two boot camps were designed by integrating a research-informed approach and engagement with industry utilising a reflective framework. The use of a research-informed approach was identified by Armour [52] as one of the core pillars of the future curriculum. To this end, a research-informed approach was selected to showcase current cutting-edge applications of digital technologies within the research environment, whilst introducing associated theories and models to students. The framework developed by Fung [51] was adopted to develop the research-informed boot camp activity and to bring the different pedagogical approaches together. The suitability of the Fung [51] framework has been highlighted by various studies as having several advantages, see Khandagale and Shinde [67], Yerworth, et al. [68], Irwin, et al. [69], for example. Fung's [51] framework aims to help, "*Students make connections across subjects and out to the world*" and incorporated the following elements in a "*connected curriculum*" as part of learning through research and an inquiry approach:

1. Connecting students with researchers and with the hosting institute
2. Building research activities into each programme
3. Assisting students to connect the subject with the industry's practices
4. Assisting students to connect academia and industry
5. Improving students' presentation skills
6. Connecting students with each other and the alumni

The boot camp programme covered all these six elements as described below.

The industry was involved throughout both the boot camps to ensure that students were exposed to the current applications of digital technologies in the industry [see 70]. This also provided the students with an opportunity to engage with potential employers and to improve their employability skills.

Furthermore, a problem-based and experimental learning environment were adopted, based on the findings of Barber, et al. [37], together with a hands-on approach to moving away from overwhelming students with information. The adopted approach in our study also gave students the chance to apply their learning and deepen their knowledge on digital technologies, based on their preference.

A reflective approach, using the frameworks developed by Atkins and Murphy [71] and Boud, et al. [72] was selected in designing the boot camp, as this approach has been highly successful in these studies. A key component of their success was achieved through a pre-engagement workshop with the students (i.e., the potential participants), to identify key focus areas/vehicles for the boot camp. Structured discussion [73, 74] was used during the workshop as a tool to engage with students which was also used after the boot camps to capture their viewpoints.

Both week-long boot camps were held during the summer of 2019, a camp each for undergraduate and postgraduate students, from across the School of Engineering and the Business School (via their Department of Management). Morning sessions were dedicated to training, led by both academics and industrial partners (Elements 1-4 within Fung [51] framework). Research groups from the Universities of Birmingham, Leeds, and University College London (UCL) were engaged to demonstrate research developments in the field that use digital technologies. Industrial partners also provided one-to-one training and mentoring sessions. Students were also given time to work within pre-allocated groups, to ensure various disciplines were mixed, allowing groups to solve selected global challenges drawing from across broader discipline skillsets using digital technologies to develop the proposed solution. This aligns with Element 6 within Fung [51] framework, noting that an alumnus was involved in developing and financing part of the programme. Each challenge was given to provide students with the opportunity to work in a team to conduct original research, and to apply the digital skills learned in earlier sessions via practical activities.

Reflecting upon students' opinions and preferences, captured during the pre-engagement workshop, the following digital technologies were selected and covered within the boot camps' programme:

- Blockchain
- Artificial Intelligence (AI)
- Virtual Reality (VR) and Augmented Reality (AR)
- 3D Printing
- Robotics and Automation
- Internet of Things (IoT)

Students were also trained on presentation and team working skills, including Design Thinking and were asked to present their solutions at the end of the boot camps to an expert panel (Element 5 in Fung [51] framework). From this, the panel selected the three best solutions. The soft and transferable skills covered during the boot camps were including:

- Devising initial concepts
- Design Thinking
- Social Media Awareness and Self Branding
- Technological Challenge & Industry 4.0
- Pitching Ideas
- Crowdfunding Innovation
- Data Analytics and Business case

B. Boot Camps evaluation

The success of the boot camps was evaluated by assessing the students' knowledge both before and after the boot camps had taken place. This was achieved through questionnaires, as research instrument to collect data [75, 76], that measured students' awareness and eagerness to pursue training on various digital innovations. All the participants in the boot camps willingly completed the questionnaires, and hence no sample size determination was required. Based on the One-Group Pretest-Posttest Design, questionnaires, in physical format, were administered prior- and post-boot camps. Two sets of questions were included in the questionnaires conducted during the pre-engagement workshop which were also administered immediately after the boot camps. These two sets of questions covered students' awareness of digital technologies and their

perception on whether the considered technologies would revolutionise students' field of study. Students were asked 20 questions, in total, around the digital technologies introduced during the boot camps. Moreover, the students were also asked about their interest in pursuing a future career in academia/industry and the boot camp's impact on graduate employability.

Effectiveness of questionnaires for self-reporting students' academic learning has been questioned in the literature [77]. For instance, in a study by Conway and Ross [78] students reported improvement of skills, through a questionnaire, after attending a programme which contradicted their academic performance. This was linked to students' psychology in differentiating their past and current condition with bias. To address this issue, Richardson [77] has suggested setting post event questions as such that 'the psychological context' in which the learning originally happened would be re-established. This suggestion has informed the design of post-boot camp questionnaire.

A research instrument, i.e., the questionnaire in this study, should be reliable in providing the same result if undertaken by the same participants under the similar condition [77]. Therefore, internal consistency of the utilised questionnaire was tested by Cronbach's coefficient alpha [79] which yielded an alpha value of 0.93. The result showed high consistency and hence reliability of the questionnaire. A high Cronbach's coefficient alpha value could be attributed to redundant questions [80] which was not the case for this study as each question covered a different technology.

The statistical significance between different variables is usually investigated using T-test, Chi-square test, F-test and Z-test [81]. While the T-test is used to determine if there are significant differences between the means of two samples, F-test examines the equality between two sample variances [81]. Z-test is employed when the variances are known, and the sample size is large [82]. The Chi-square test is an independence test applied to discrete data to compare the observed and expected frequencies of the result and to show the magnitude of any observed differences [83].

Chi-square test has been used to analyse questionnaires and interviews data. For instance, Rahman [84] investigated the application of ICTs in teaching agricultural topics in higher education, by using Chi-square test to analyse responses of a conducted questionnaire. Similarly, Obiwulu, et al. [85] used Chi-square test to analyse questionnaire responses from students and employees on creativity in higher education. The test was also used by Whitla, et al. [86] to analyse questionnaire responses gathered on educational benefits of diversity in two medical schools at Universities of Harvard and California. McClelland [88] also used the test for the evaluation of digital education in higher education based on surveys and questionnaire results.

To this end, the Chi-square test [89, 90] was employed within this study to analyse the collected questionnaire data. While the interpretation of Chi-square test results is reported challenging for more than 20 independent or dependent categories of variables [91], the number of variables in this study ($n = 2$, i.e.,

pre and post boot camps responses) made the test an ideal method. The hypothesis was that the two boot camps improved students' digital skills which was tested through applying the Chi-square test on the questionnaire results and examining students' awareness of digital skills prior- and post-boot camps. As part of this test, a calculated Pearson's Statistic value (χ^2) is compared with a critical value. The latter is determined so that the likelihood of error for the first kind does not exceed a selected level of significance (α), normally between zero to 0.5 [92]. When the χ^2 value is less than the critical value it can be concluded that the observed distribution is almost the same as the expected distribution, which means that the boot camps were not effective in improving a particular digital skill. Similar to the McClelland [88] study a level of significance of 5% ($\alpha = 0.05$) was used for conducting the Chi-square test.

IV. RESULTS

The survey's results showed in Figure 1 illustrated that the boot camps significantly improved students' awareness of digital innovations and their applications within their respective field of study. On average, improved students' knowledge of the digital skills covered by 30%, where IoT (including the Block chain) achieving the highest raise of attention, by over 40%. This was probably due to the interactive training session that was used, whereby students were able to download an app and interact throughout the session. Other topics such as robotics and 3D printing require more time to address/train, and so proved more challenging. Both robotics and 3D printing were showcased using two research projects following a research-informed learning approach. However, the less interactive structure, resulted in less awareness of the improvements students gained.

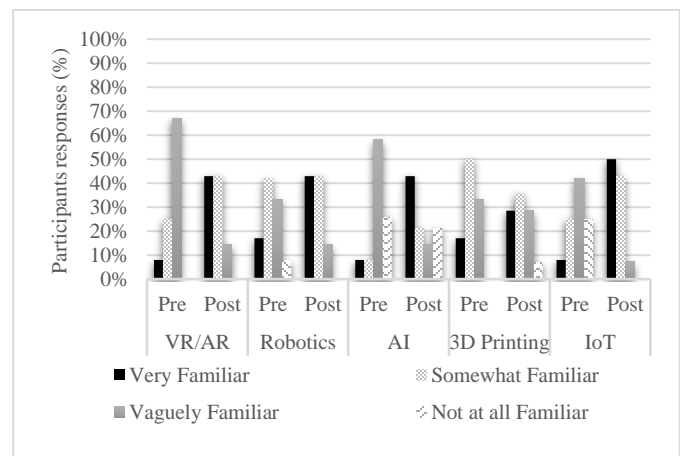


Figure 1: Impact of boot camps on familiarising the participants (33 students) with applications of digital technologies in their field of study. Question: Further to attending the Boot Camp, how familiar are you with the applications of VR/AR, Robotics, AI, 3D Printing and IoT in your field? The answer choices were 1) Very Familiar 2) Somewhat Familiar 3) Vaguely Familiar 4) Not at all Familiar

The results of the Chi-square test, with three degrees of freedom, also showed a significant increase in students' awareness of VR ($\chi^2 = 28.9$), AI ($\chi^2 = 29.1$), and IoT ($\chi^2 = 36.7$), while for 3D printing ($\chi^2 = 1.7$), and robotics ($\chi^2 = 8.1$) the impact

was not significant, compared to the critical χ^2 value of 7.82.

To gauge other aspects, the questionnaire, focussed on how digital technologies would revolutionise students' field of study (see Figure 2). The questions aimed to evaluate the students' vision of the future. The result showed that students strongly agreed that Robotics (54%) and Artificial Intelligence (AI) (50%) were the most promising technology for the future. The Chi-square test results, with four degrees of freedom, showed that students' perceptions about most of the technologies remained unchanged after attending the boot camp. Noting that students' responses to the significance of questioned technologies in revolutionising the field were quite high before attending the boot camps. The Chi-square results for VR ($\chi^2 = 2.4$), robotics ($\chi^2 = 1.4$), AI ($\chi^2 = 2.9$), and IoT ($\chi^2 = 8.1$), were less than the critical χ^2 value of 9.5, while for the 3D printing ($\chi^2 = 10.2$) both the boot camps changed the students' perception.

Students were further asked whether they were motivated to further explore the technologies covered during the boot camp, to which all the participants expressed interest in IoT, VR and AR (see Figure 3). Overall, the results suggest that there is a need to change the current higher education curriculum to incorporate digital technologies and to provide learning opportunities in the aforementioned areas.

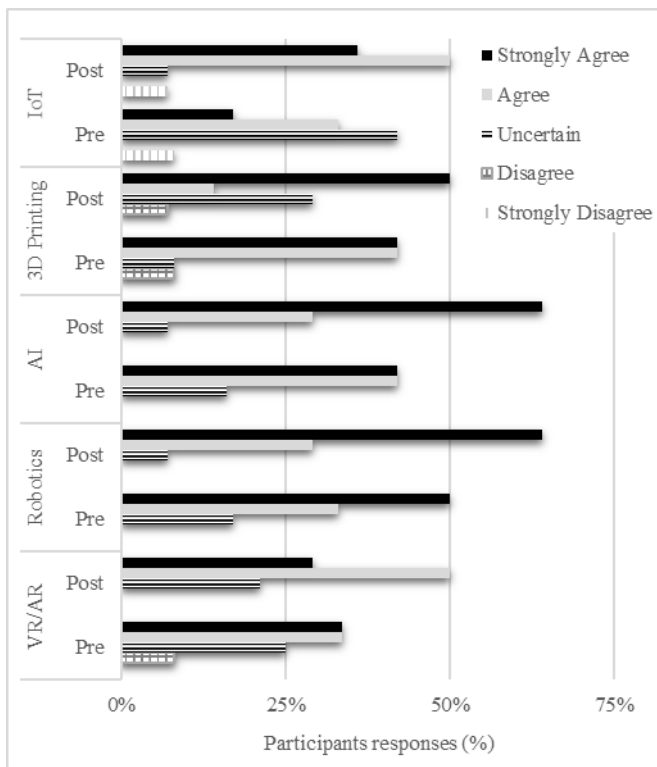


Figure 2: Students' responses (N=33) on whether digital technologies could revolutionise their field of study. Question: Further to attending the Boot Camp, do you think VR/AR, Robotics, AI, 3D Printing and IoT are revolutionising your field of study? The answer choices were 1) Strongly Disagree 2) Disagree 3) Uncertain 4) Agree 5) Strongly Agree

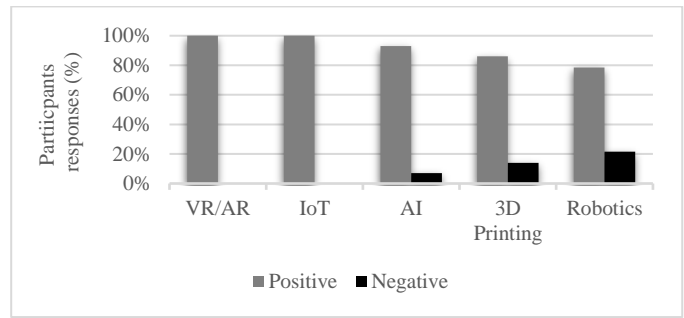


Figure 3: Students' inspiration to explore digital technologies after attending the boot camps (33 students). Question: Further attending the Boot Camp, are you inspired to explore more about VR/AR, IoT, AI, 3D printing and Robotics? The answer choices were 1) Positive 2) Negative

Just under 80% of students, expressed that attending the boot camp had significantly improved their employability, while the same percentage expressed that it helped them to improve their digital skills overall (Figure 4).

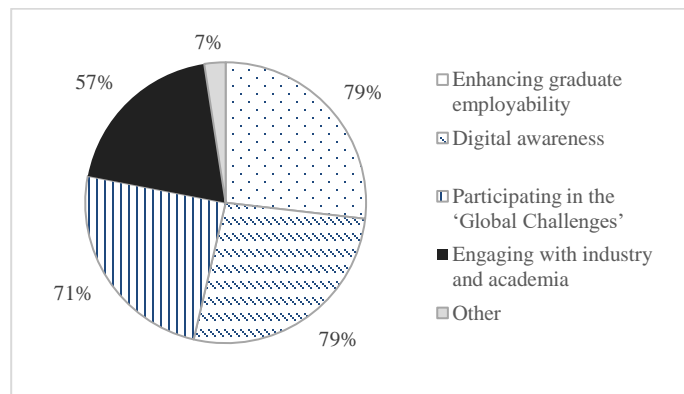


Figure 4: Achievements from attending the boot camp (33 students), Question: What among the following have you achieved by attending the Boot Camp? The answer choices were 1) Enhancing graduate employability, 2) Digital awareness, 3) Participating in the 'Global Challenges', 4) Engaging with industry and academia, 5) Other

Digital skills are an important element for the future job market and employability, as highlighted within this paper. The results shown in Figures 2-4 suggests that the participants were aware of this situation, and they felt that the boot camps helped them to improve their digital skills and future employability. It would be particularly interesting in a follow-up study to look into the future benefits to these attendees, exploring with them whether they used or recognised the training provided by the boot camps during both recruitment processes, and/or while in any future employment.

Further to this, students highlighted that Presentation skills were one of the key achievements of attending the boot camp (Figure 5). This indicates the potential success and suitability of problem-based learning pedagogy provided through a boot camp to enhance students' transferable skills, in line with Element 5 of the Fung [51] framework. Normally within higher education programmes delivery, there are opportunities for students to practice some of these transferable skills, such as presentation, while there are fewer opportunities for problem-based activities where students learn other skills such as

independent learning and research skills. Problem-based learning enhances students' decision-making abilities and so help them develop the ability to decide which skills or knowledge would be beneficial for them to tackle a problem [93].

Students also provided statements describing their experiences, which showed extremely positive feelings about what they had learnt. For example, one student stated that: *"The Boot-camp was an enthralling experience for me as it gave me a taste of different technologies shape the rapidly developing world around us."*

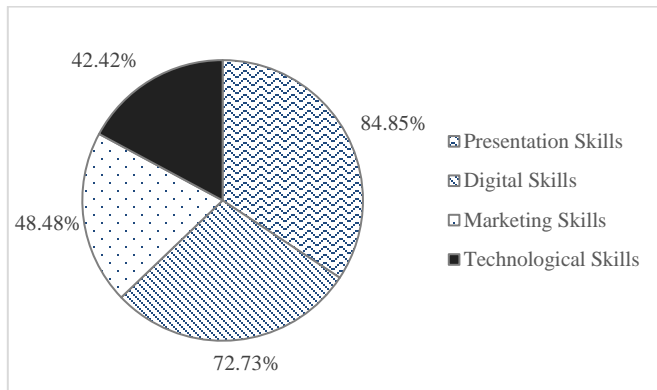


Figure 5: Skills gained from the boot camp (33 students), Question: What skills do you think the Boot Camp has prepared you for your future career in academia/industry? The answer choices were: 1) Presentation Skills, 2) Digital Skills, 3) Marketing Skills, 4) Technological Skills

The other aspect that was not possible to capture by the surveys was the joy and enthusiasm among all the participants. Despite the boot camps being held during the summer following the final exam period, the participants were eager to engage in all classes and training. This was evident from the comments made by the judging panels (made up of academics and industrialist) who were very impressed by what students had presented. A couple of the ideas produced will be adopted by the industrialist on the judging panel. Students were able to show the ability to successfully apply the training they received during the boot camps by providing highly innovative solutions to tackle global challenges. For instance, one group was able to learn basic app development and apply machine-learning to a real-world computer vision problem, all within the boot camp timescale of one week. Importantly, around 80% of the cohort expressed that it was important to enhance the current curricula by offering a similar boot camp in the future.

The workshop approach adopted here, proved to be a very effective way to draw out active student engagement in the boot camp, and through this allowing a period for students to reflect on their needs and expectations. The participants expressed positive reactions to the approach, as their feedback is normally obtained after finishing an activity/course, which results in poor returns. This reflective approach also helped the organisers to manage students' expectations, as the boot camps were introduced to the students during the pre-programme workshops where students were given the opportunity to discuss their viewpoints. Moreover, the data gathered through a questionnaire undertaken during the pre-engagement workshop

helped the organisers to identify the required digital skills that needed to be developed. This ensured that these skills were covered in a targeted way within the boot camp programme to ensure greater student learning. The feedback provided by the students at the end of the two boot camps showed that adopting the approach that actively involved students in the programme design was well appreciated and proved to be highly successful in ensuring full and effective engagement.

The statistical significance analysis for the study showed the boot camps were generally effective in improving students' awareness of digital technologies, i.e., in four technologies, namely VR, AI, IoT, and robotics, while for 3D printing the impact was not significant. The boot camps were less significant in changing students' perception on whether the considered technologies would revolutionise students' field of study, i.e., only for 3D printing technology the boot camps changed the students' perception.

V. DISCUSSION: IMPLICATIONS FOR RESEARCH AND PRACTICE

Both the boot camps acted as a pilot to test the success and impact of training students on innovation and digital skills. The results of the pre-and post-boot camps surveys showed that the boot camps were very successful in achieving their aims. However, these results only reflect students' perceptions of their increased knowledge in key areas. The results confirm the findings of the studies by Patelli, et al. [60] and Wischusen and Wischusen [62], described in Section II, on the effectiveness of a boot camp format for teaching digital technologies topic. Having said that, Patelli, et al. [60] case were related to an apprenticeship programme that ran for two years and the evaluation was done based on average student marks, while Wischusen and Wischusen [62] was related to a 5-day intensive biology programme. While in this study the evaluation was done through engagement with the students and other stakeholders (i.e., academics and industrial partners). Similarly, the result of West, et al. [40] study reported the importance of engaging with participants in similar boot camp style activities to canvas their feedback and to evaluate the activity. Bodnar, et al. [63] proposed an interesting follow on evaluating the impact on participants' *"broader professional development and promoted characteristics"* by creating a LinkedIn group and monitoring boot camp participant progress in their future career. Such an approach could be added to the proposed boot camp format with the potential of involving previous participants in future events, e.g., as mentors.

As discussed above (Section I) there is a clear need for introducing digital technology-based innovations into the higher education curricula. This need arises due to the dynamic changes facing the modern labour market, brought about by digital technologies through the 4th Industrial Age. These changes put pressure on higher education institutes to equip their students with innovative and critical thinking skills needed for their future careers. Further, placing digital skills into a global challenge setting provided students with the additional ability to analyse problems and utilise the required skills to learn independently in a dynamically changing working environment. Through this, they are provided with an

opportunity to improve key graduate employability skills. The format utilised for the boot camps, in which both industry and research were incorporated in delivering training sessions, proved a particularly useful method for achieving the requirements of such training. To this end, both the boot camps showcased a key enhancement to current curricula that embrace digital technologies (both industrially led and research-driven) and through this the profile of graduates.

Adopting digital innovation training in education curricula will position higher education institutes as a futuristic vehicle that equips future generations with up-to-date skills and therefore encourage new generations of students through higher education to enhance their future career potential.

The adopted reflective approach, through the pre-engagement workshop, proved to be a very successful method in capturing students' learning needs. This provided an early step towards achieving a flexible learning environment where more personalised learning opportunities can be facilitated. By adopting such a reflective pedagogy, a dynamic approach with critical analysis in higher education can be achieved, enabling rapid reflection upon any changes in both the job market and associated skills need.

The paper showcased a successful involvement of management and engineering disciplines. Other disciplines benefit from digital technologies; therefore, future research could explore these opportunities, allowing discipline-specific digital learning cultural dimensions to be explored in more depth. Ultimately, in an ideal scenario, the authors believe that similar boot camps should be presented to students across the Higher Education sector, and this could be tailored to suit students from a disadvantaged background where access to the digital tool may have been limited. Overall, the digital boot camp concept has demonstrated the potential to help embed a key plank of futureproofing to the development of a student's skills set.

A. Limitations and future work

There were some limitations associated with this study which are highlighted in this section. The study did not consider the difference between undergraduate students' experience recruited in first boot camp and the postgraduate students in second boot camp. Future work could identify and consider any difference when designing a similar boot camp and in the associated research instrument to ensure the difference would be considered in organising the event and analysing the associated data. Another limitation of the study was associated with the questionnaire's questions as no option for a neutral or negative response was considered. Future work could follow a more robust design of the questionnaire to address this issue.

Future study could also investigate the impact of a similar boot camp on students' employability in more details through a qualitative, quantitative, or mixed approach. Quantitative parameters, e.g., salary, and number of unsuccessful job applications before securing a place, could be considered to compare students with and without such extra curriculum digital training. While a qualitative approach could be used through collecting data from both graduates and employers on

their experience during recruitment process and once in the employment. Future work could also recruit a larger cohort to better sample students with various backgrounds.

VI. CONCLUSIONS

Two boot camps covering digital innovation were organised for undergraduate and postgraduate students the outcomes of which are reported in this paper. The boot camps trained students in key skills associated with digital innovation. Through this, students were introduced to various digital applications of innovative technologies set against current research and industrial practices. The technologies included in these boot camps were: Blockchain, VR and AR, AI and Machine Learning, 3D Printing, Robotics and Automation and IoT. Research groups from the University of Birmingham and other universities were engaged to demonstrate the application of research-driven digital platforms. Further, industrial stakeholders provided case studies exposing students to existing applications of digital innovation in relevant fields.

Students were provided with an opportunity to put their learning into practice and reflect on this through the development of solutions to the given global challenge. Students were also engaged in designing the boot camps via a pre-engagement workshop. The work presented herein from the two boot camps demonstrated success in:

- Enhancing professional development opportunities for all students
- Improving graduate employability potential of the participants by training them in digital and entrepreneurial skills
- Bringing a key enhancement to current curricula to embrace the digital technologies and through this the profile of graduates
- Positioning higher education as a futuristic institution that equips the future generation with up-to-date skills

The adopted problem-based learning, experimental and reflective learning methods proved particularly effective in encouraging student involvement in teaching complex topics. A particular highlight for the project team was how students made a significant improvement in their skills in machine learning and data analytics through an industry-sponsored challenge, demonstrating how in a relatively short period a digital boot camp can have a dramatic impact on students.

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