Research-Informed Teaching for Assessing BIM Courses during COVID-19 and Beyond

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Abstract

Purpose
In the COVID-19 era, where blended learning is gaining popularity, research-informed teaching could be one of the alternatives or options to assess students' progress in Higher Education institutions. In the past, educators have assessed students' research skills gained from research-informed teaching through coursework components or assignments. However, whether the assignments can be converted into peer-reviewed output acceptable in a reputable journal or conference has hardly been investigated. This study explores how research-informed teaching has been rolled out in undergraduate/postgraduate BIM related modules/programmes in the School of the Built Environment, Oxford Brookes University and which has culminated in high quality published outputs.

Design/Methodology/Approach
The method used is purely qualitative in-depth interviews, where students who have published were tracked and invited to share their experiences. In total, 9 former students, of the 12 invited participated in the interviews. Inductive content analysis, a suitable qualitative data analysis technique was used in analysing the feedback from the interviews.

Findings
The main finding is that research-informed teaching can be done in a technical and complex BIM discipline and students' coursework components or assignments can further be converted into published outputs.

Research Limitations/Implications: The main limitation of this study was that the sample was small. That notwithstanding, it has provided valuable insights into the understanding of student's ability to undertake research while studying and experiences of how educators can deliver research-informed teaching to students in Higher Education institutions.

Originality/Value
The study adds to existing body of literature about undergraduate and postgraduate research-informed teaching and goes further to provide strong evidence through published outputs thereby confirming that students at both levels can indeed conduct and publish peer-reviewed research articles while undertaking their studies.

Keywords: BIM, COVID-19, Malpractices, Research-Informed Teaching, Virtual learning

1. Background

In early 2020, the world was shocked by the outbreak of COVID-19 that affected and currently affecting all sectors of life. Education was not spared and is one of the sectors heavily impacted by the outbreak of COVID-19. Over a short period, teachers and students were obliged by government measures to rapidly change their practices (Cleland et al., 2020). Students switched partially and, in some cases, completely to online or distance learning mode. Switching to distance learning, online or otherwise requires new protocols and/or changes to ensure high quality of programmes, effectiveness and efficiency from teachers and students. The changes, although not exhaustive are daily tasks, responsibilities, accountabilities, learning outcomes, lecture notes, assessment and evaluations, and monitoring of students' learning. Other changes include supporting online discussion, recording lectures, adding voiceover commentary to PowerPoint slides, using web conferencing tools, etc. (Almpanis and Joseph-Richard, 2022). Although, distance learning or its variants is not recent and the changes being recommended (e.g., Almpanis and Joseph-Richard, 2022) may not be entirely new, it is the scale and the short time for which educational institutions had changed or need to change that is unprecedented and challenging. Some of the main challenges delivering programmes is how to make sure students still acquire an in-depth understanding of educational content, how they are assessed fairly with strategies that eliminate collusion and malpractices amongst learners. In other words, in the era of COVID-19 and blended learning, can research-informed teaching be one of the approaches for assessing and evaluating students? In the past, it was assumed senior management of universities recruited research-active staff with the assumption that research-informed teaching will naturally flow once in front of students (Mathieson, 2019). In spite of the presence of research-active staff in front of students, most performance measures including the National Student Survey revealed student dissatisfaction with teaching that was not actively engaging them in their learning (Mathieson, 2019).

Teaching Building Information Modelling (BIM) is one of the practices that has been impacted by the COVID-19-pandemic. Although still emerging, BIM is now top on the agenda of many construction companies, with many already using or planning to roll it out in the near future. According to ISO 19650, BIM is defined as the "use of a shared digital representation

of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions". BIM is a cross-cutting discipline that builds on many concepts: Process, Law, People, Technology, Process, Standards, Policy and Security. Each of these concepts is a huge area that in itself challenging and requires in-depth understanding for efficient and effective application in practice. For example, from a technological perspective, Abanda et al. (2015) examined the different software that can be used in supporting BIM processes and argued how challenging it is to make informed decisions about their selection and use in projects. There are other technological aspects such as smart devices (iPAD), hardware (PC), artificial intelligent-based technologies (Robots, Drones, 3D Printers, etc) used in capturing construction information which can be used in BIM processes.

Being an emerging field and building on many concepts (e.g., Technology, People, Law, Standards, Processes, Policy, Security, etc.) BIM requires more in-depth research in order to gain an understanding of its applications in practice. Research-informed teaching provides that opportunity to expand and develop in-depth knowledge about BIM. Also, like any typical project, BIM is a complex discipline cutting across so many fields with many different applications. This further reinforces the need of research-informed teaching for students to develop an in-depth understanding of the domain of BIM. Given the multiplicity of BIM and its fast-evolving related technologies (e.g., Robots, Drones, 3D laser scanners, etc.), research-informed teaching is amongst the best approaches to keep track of the evolution. As argued by Bubou et al. (2017), keeping pace with technological dynamism; high attrition; and most importantly, quality teaching/learning require multifaceted approaches including research-informed teaching. Through research-informed teaching, many new BIM technologies and their applications in practice can be discovered. Embedding research-informed teaching into BIM has been strongly recommended by Wang *et al.* (2020b) as it allows for better understanding of data integration which of course can be supported by the aforementioned technologies.

From a pedagogic perspective, research-informed teaching can be one of the solutions to challenges associated with online or virtual learning assessments. A recent study in the context of COVID-19 pandemic, suggested switching from closed-book to open-book

examinations, (allowing students to consult textbooks and notes during timed/locked down assessments) or converting exams to project work that is completed remotely as solutions to academic malpractices in online or virtual assessments of students' coursework (Cleland et al., 2020). Connolly et al. (2020) argued that teachers need to adopt research-led practice in order to enhance learning, teaching and assessment online during COVID-19 pandemic. A major study that examined the impact and implications on initial teacher education (ITE) of the crisis brought about by the Covid-19 lockdown of schools and universities from the perspectives of four universities in England recommended that research-informed teaching should be adopted at undergraduate or postgraduate levels due to changing circumstances (la Velle et al., 2020). Similarly, given the changing circumstances during the COVID-19 pandemic, educators should explore evaluation exercises using one or a combination of the research-teaching nexus (i.e., research-led, research-oriented, research-based, and research-informed) to validate a best-fit design approach for their courses and programs (Babatunde and Mashigo, 2021). The concept and the need to adopt research-informed teaching is not new. In fact, in 2006, the Higher Education Academy launched the "Teaching Informed and Enriched by Research" initiative, where Higher education institutions could submit applications for funding to the Higher Education Funding Council for England for three years, until 2008/9 (Graham-Matheson, 2010). Thus, research-informed teaching has been adopted in many fields especially the medical (Higgins et al., 2021), and recently the construction or built environment disciplines (Wang et al., 2020a; Bentley et al. 2012). However, the application of research-informed teaching in a highly technical discipline like BIM is scarce. Furthermore, the skills gained from research-informed teaching have hardly been evaluated out of classroom settings. Thus, the extent to which students' research coursework components or assignments can be converted into published outputs have hardly been evaluated. Other than classroom-based evaluated works, can some of the students' work be accepted by reputable high-quality journals or conferences? In our School of the Built Environment at Oxford Brookes University, research-informed teaching has been adopted in some BIM related modules over the years. Through this, undergraduate and postgraduate students have been able to publish in reputable journals and conferences. For clarity purposes, postgraduate or graduate students as used here means students on taught MSc course, not on PhD programmes or research MSc. Our experience over the years, means

transitioning to assessing students using research-informed teaching in the COVID-19 era is seamless and easy and can be adopted in post-COVID-19 or during similar pandemic. In this study, our experiences of delivering research-informed teaching in undergraduate/postgraduate BIM programmes and how students' coursework or assignments have been converted to outputs and published in reputable journals and conferences will be discussed. This is significant in the sense that educators do not need extra time to write separate articles in already heavy workload environments (Mathieson, 2019) as they can mentor students to generate high quality output that can be of benefit of both them. Furthermore, the burden to invigilate coursework is eliminated as in research-informed teaching students can use their books and other resources as they wish. To facilitate understanding and ensure the research is focused, the following research questions will serve as the basis of investigation.

RQ1: What are the research-informed teaching techniques used in BIM programs?
RQ2: What is the quality of the student outputs achieved through research-informed teaching currently on or graduated from BIM programs?
RQ3: What are the benefits of undertaking research-informed teaching in BIM programs?
RQ4: What are the challenges undertaking research-informed teaching in BIM programs?
RQ5: What are the skills gained from undertaking research-informed teaching in BIM programs?
RQ6: What are the impacts of research-informed teaching on a graduate working in academia or industry?

2. Literature Review

2.1 Research-Informed Teaching: What is it?

Research-informed teaching is an elusive and highly contested concept. The elusiveness of the term can perhaps be attributed to its multidimensional/multidisciplinary nature which entails its ability to cut across many domains. Many scholars have called it different names. Enquiry-based learning, research-teaching, research-led teaching, teaching-led research, research-led education, teaching-as-research or research-based practices in teaching are common in the literature (Kaasila et al., 2021; Valter and Akerlind, 2010; Stevens, 2004; Kahn and O'Rourke,

2005; Brown et al., 2022). Others have even confused research-informed teaching with problem-based learning (Kahn and O'Rourke, 2005; Jenkins, 2007b), although Healey (2005a) considered problem-based learning to be a more specialised form of research-informed teaching. According to Healey (2005a) and Griffiths (2004), research-informed teaching is an umbrella term to describe a cocktail of approaches to learning that are principally driven by a process of enquiry. The cocktail of approaches has been encapsulated in Healey's model for linking research and education which consists of 4 components: research-led teaching, research-oriented teaching, research-tutored teaching, research-based teaching (Healey, 2005b). According to the model, students are more like audience in research-led and research-oriented while in research-tutored and research-based, students are participants (Healey, 2005b).

The literature does suggest the application of the aforementioned models in built environment disciplines (Wang et al., 2020a; Bentley et al., 2012; Pan et al., 2012) with none in BIM courses or programmes. Consequently, a search of some universities' websites was conducted to understand how they have rolled out research-informed teaching in practice. The outcomes of the investigation can be categorised into methods of research-informed teaching and disciplines of application. The methods commonly used by universities include using lecturers' own research in teaching (e.g., Liverpool Hope University, 2022; Birmingham University, 2022), teaching students to conduct research by themselves through research methods and problem-based learning is common amongst universities (e.g., Liverpool Hope University, 2022; London South Bank University, 2022), encouraging students to present at their annual research conference and writing for their in-house journal (Birmingham City University, 2022; University of Plymouth, 2022). Some examples of in-house journals are The Plymouth Student Scientist, The Plymouth Student Educator and The Plymouth Law & Criminal Justice Review all focused on undergraduate research hosted by the University of Plymouth. There was no evidence of educators encouraging undergraduate to publish in top peer-reviewed journals not hosted by their institutions. The different disciplines where research-informed teaching have been applied include Social Sciences (Birmingham University, 2022; University of Leicester, 2022; Loughborough University, 2022), School Bullying (Birmingham City University, 2022), Criminal Justice (Loughborough University,

2022), Photography, Social Work, Forensic Science (London South Bank University, 2022), Urban Planning (Newcastle University, 2022), entrepreneurship (Canadian University of Dubai, 2022). There was no evidence of any university practicing research-informed teaching in the BIM discipline.

Similar to Valter and Akerlind (2010), Stevens (2004), Kahn and O'Rourke (2005) and Brown et al. (2022), the term research-informed teaching was used interchangeably with others such enquiry-based learning, research-led teaching, etc. For example, research-intensive teaching and research-led teaching were used by Birmingham University (Birmingham University, 2022) and University of Plymouth (University of Plymouth, 2022) respectively. In order to imply a different meaning, the research-informed teaching related terms will be as used as stated in the different literature. Despite this multiplicity of terms, their common goal is to foster undergraduate research (UR)/postgraduate research is one of the avenues through which research-informed teaching can be realised.

2.2 What is undergraduate/postgraduate research?

Like research-informed teaching, 'Undergraduate research' is a highly slippery term. There are so many competing definitions (Jenkins, 2007b). The term is hard to pin down and as such it is interpreted differently by different people (Stevens, 2004). In quoting Healey (2005a), Jenkins (2007b) provides the University of Gloucestershire's definition of 'undergraduate research' as being the undergraduate "student engagement from induction to graduation, individually and in groups, in research and inquiry into disciplinary, professional and community-based problems and issues, including involvement in knowledge exchange activities". In the literature, mostly undergraduate research is often used with very limited reference to postgraduate (graduate as used in the US, equivalent to MSc level) research. In this study, wherever UR is used, the same can be said of postgraduate or graduate research.

In the US, undergraduate research is more associated with students having to produce original or cutting-edge knowledge that can be published in external journals. This is especially the expectation within the 'hard' sciences which enjoy relatively good financial support from establishments like the Howard Hughes Institute and the National Science

Foundation. While discovery of 'new knowledge' may be critical in certain realms, it is not always a prerequisite in UR as the definition by Jenkins (2007b) suggests that undergraduate research entails students learning through courses designed to be as close as possible to the research processes in their respective disciplines. What is produced in this model is thus not necessarily 'new knowledge' but something new to the student (Jenkins, 2007b). Chang (2005) also subscribes to this model when he observes that the requirement for (undergraduate) students to produce 'new knowledge' is the very reason that hinders progress in undergraduate research:

> *"Research at the undergraduate level (or any level) is often hindered by the idea that originality means coming with something that nobody anywhere has ever said before in the whole history of scholarship. This absurd idea has actually contributed to the desiccation of scholarship by driving researchers into esoteric details that are easy to publish although they may lack interest or importance….In the context of a class, the rule of thumb is that if students are discovering things that are unknown to the teacher, then they are doing original work" (pp 390).*

These different views as to what constitute research-informed teaching is better captured by Nicholson (2017) as revealed here: "…, there is some disagreement amongst academics about what actually counts as research-informed teaching and therefore how it should be developed and delivered". However, given the focus of this study is on already published outputs by undergraduate and postgraduate it is not in our interest to delve into this academic tussle as doing so will add no value to this study.

Despite the plethora of definitions, there is one generally accepted dimension that is fundamental to research-informed teaching in general and undergraduate research in particular. That is engaging (undergraduate) students into research whilst pursuing their coursework. For this reason and for the purpose of this paper, we adopt the more appropriate definition by Stevens (2004) which states that undergraduate research (note that Shaun Stevens uses research-led learning and not UR) is a learning/teaching approach that engages

students in research practice as part of the pedagogy or content of their respective disciplines. This definition is also applicable to postgraduate or graduate students.

The concept of research-led learning and teaching is not relatively new. The concept was coined mainly as a result of realizing the growing threat of research/teaching disaggregation (Stevens, 2004). Prior to the inception of the concept, research was seen as a domain for teachers/professors alone. The role of students was just to watch and do nothing. Worse still, the domain of research was in many countries separated from institutions of learning. Instead, it was the external research-only institutes that were entrusted with research, while the role of universities was only to teach. This was the view the UK government embraced in 2003 when they produced the white paper *The Future of Higher Education* which viewed universities and other institutions of learning as 'teaching only' institutions (Jenkins, 2007a). But this is now changing (Coppola, undated). There is a growing public outcry to introduce UR in institutions of learning. One of the prominent pioneers of UR, Professor Alan Jenkins of the Oxford Brookes University in England stated that "talk of education for a knowledge economy is hollow if students take no part in scholarly inquiry" (Jenkins, 2007a). Alan Jenkins also observes that undergraduate research is partly necessitated by the growing realization that student leaders in many institutions are angered by the limited contact many undergraduate students have with academics who, instead, are preoccupied with Research Excellence Framework (formerly called Research Assessment Exercise)-focused work.

Indeed, there has been an unprecedented growth in advocacy for UR. Many universities have set up centers specifically to spearhead this cause. In the UK, for example, a Reinvention Centre for Undergraduate Research has been set up at Oxford Brookes and Warwick Universities. The United States of America, through the works of the Boyer Commission, is also championing the cause for engaging students into undergraduate research. Following the recommendations of the Commission, many universities in the US are now UR-compliant. However, the US model of engaging undergraduate students into research differs from that of the UK. In the former, the main models are summer programs (students undertake research activities during summer vacation); and assistantships during an academic year. In the UK,

on the other hand, final year students are expected to undertake research and write a dissertation as part of the requirements for the award of the degree (Jenkins, 2007b).

The foregoing exposition shows that UR has grown in prominence. But advocacy may not necessarily be as challenging as implementation. So, how can undergraduate/postgraduate students be engaged into research?

2.3 Methods of engaging undergraduates into research

Despite the debates on what constitutes undergraduate research, many universities including those in the United States and the United Kingdom are already engaging undergraduates and graduates/postgraduates into research. This has been done using various methods in motivating students. This review examines some of these methods, which include: problem-based learning (Simm, 2005; Jenkins, 2006; Allen, et al 2003; Lee, 2001; Center for Innovation in Teaching & Learning, 2022), problem-solving learning (Wilson et al, 2005; Smith et al, 2005; Aslan 2021), student volunteering programs (Edwards et al, 2007a), Interactive web portal (Edwards et al, 2007b), internship (Healey, 2005a), experiential learning model(Gawel and Greengrove 2005; Simm, 2005; Morris, 2020), "Cook-book" laboratory approach (Clough (2002), cited in Apedoe et al. (2006); Abdussyukur et al., 2021), Research projects (Healey, 2005a), assignments that involve elements of research (Healey, 2005; Gawel and Greengrove, 2005; Edwards et *al*., 2007b), Mini-Research Symposium/Seminars/Workshop/Conference (Gawel and Greengrove 2005; Edwards et *al*., 2007b), Introduction to motivational or core curriculum courses (Helfand et *al*., 2013), Undergraduate publication (McKelvie and Standing, 2018). Only engagement methods relevant to this study will be examined in the ensuing paragraphs.

Research projects: These are end of course projects given to students to undertake an inquiry and present a dissertation module, or project-based module (Healey, 2005a). Often at times students are supervised by qualified or senior member of staff. Students on a BSc undergraduate nursing program have been observed to engage during dissertation supervision (Scholefield and Cox, 2016).

Assignments that involve elements of research: This mode through assignments engage students in some elements of research such as literature reviews, bidding for grants, drafting bids for projects outlines, and analysing project data (Healey, 2005a; Gawel and Greengrove, 2005; Edwards *et al.,* 2007b). The feed-back from students could be through research seminars, mini-workshops or mini-research symposiums.

Mini-Research Symposium/Seminars/Workshop/Conference: This method usually proceeds from any of the enquiry-based learning methods, where by students (individually or in groups) synthesized their results or findings in a final mini-research symposium, conference or seminar (Gawel and Greengrove 2005; Edwards *et al*., 2007b)**.** A study by Little (2020) revealed that participation in an undergraduate research conference increased their level engagement including extracurricular activities.

Undergraduate publication: Undergraduate students can be encouraged to engage into research through publication of their works. (McKelvie and Standing, 2018). These works could be articles in a particular area of interest, or even a high rated end of year dissertation.

Research-informed teaching is not designed as a way to enhance content understanding alone, skills such as the ability to find, analyse, communicate ideas using various media are also tested. Other skills such as the ability to reason critically and creatively are also enhanced through research-informed teaching. The greatest challenge is to test the students' achievement (assessment and evaluation) with respect to the aforementioned skills using the methods of enquiry discussed in the preceding paragraphs. In other words, how can students' coursework or assignment undertaken through research-informed teaching be assessed and evaluated? The following sections present various research-informed teaching assessment and evaluation methods.

2.4 Assessment and evaluation

Assessment is the process of documenting skills, knowledge, concepts gathered by an individual acquired in the course of learning. In other words, it is the process of gathering what students know, understand, and can do during learning in order to make informed

decisions about the next steps in the educational process. Two major ways of assessment exist: *summative assessment*, a process whereby students are assessed at the end of study and *formative assessment*, a process whereby the students are assessed throughout the learning process.

On the other hand, evaluation is a systematic way to determine if a student has actually mastered a concept. In research-informed teaching the procedure of assessment and evaluation is even more complicated as majority of the learning occurs out of the classroom or traditional studying environment. To this end, so many evaluation methods have been designed for measuring the impact or effect of research-informed teaching method upon students. Some of the evaluation methods have been examined in The Learning Technology Dissemination Initiative (2007), Wheater *et al.* (2005), Draper *et al.* (1996) and Biggs *et al.* (2001). There are: checklists, concept maps, confidence logs, cost-effectiveness, designing experiments, ethnography, focus groups, interviews, nominal group technique, questionnaires, resource questionnaires, split video, supplemental observation, system log data, trials, formative peer-assessment, etc. However, the application of each of these methods depends on the subject, what is to be tested, who is to test, the time frame of the test, etc. In this proposed study, the concepts of assessment and evaluation are relevant because the outputs obtained through research-informed teaching would have been assessed and evaluated by educators before being submitted to journals for reviewers to do the same.

2.5 Benefits of undergraduate/postgraduate research

The benefits of research-informed teaching in general and undergraduate research are manifold. These can be categorized according to the beneficiary participating agencies.

2.5.1 Benefits to students

Engaging undergraduate students in research has empirically proven to be beneficial to the participating students themselves. In their research, Seymour *et al.* (2006) reported that the benefits that accrue to students include enhancing opportunities of being considered for admission at postgraduate level; the students also gain in research skills, confidence and career clarification. Students also develop the habit of thinking and working like scientists. In

this particular University of Colorado, 1122 students and 2 243 faculty members were asked to evaluate the performance of UR. The results are shown in Figure 1a & 1b.

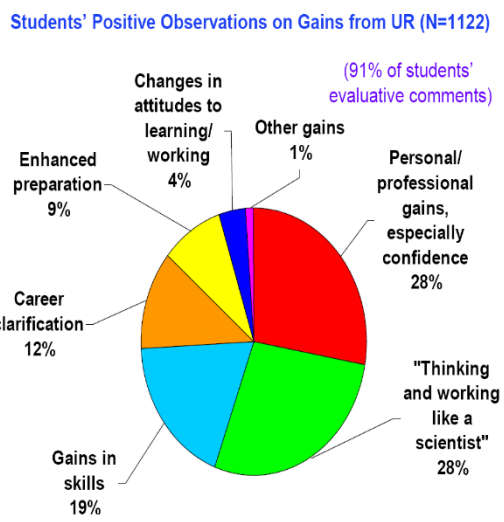

Figure 1a: Student's own perception about gains from UR, (Seymour et al, 2006)

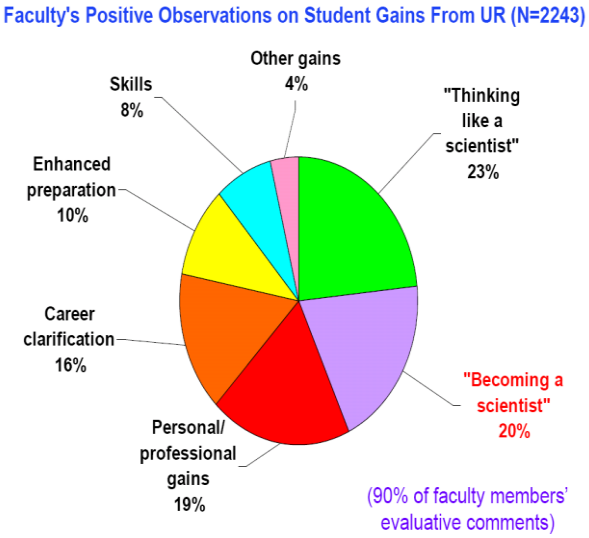

Figure 1b: Faculty own perception about gains from UR (Seymour et al, 2006)

Although there are variations in terms of how students and the faculty evaluate the students' gains from UR, it is evident from Figure 1a that undergraduate students actually do benefit from undertaking research.

Kahn and O'Rourke (2005) also pointed out that the students that engage in research become more familiar with the multifarious resources at their disposal, e.g., e-journals and research databases. Undergraduate research promotes social interaction and (academic) debate among the students. Thus, exchange of ideas is enhanced. This may not be easily achieved through the more rigid model of taught programs. Besides, contemporary economies place premiums on abilities to create knowledge; develop leadership skills to manage complex, inter-disciplinary, real-life enquiries in employment. These elements are all embedded within the

research-informed teaching model (Kahn and O'Rourke, 2005 Rasteiro, 2007; Reinvention Center, 2004; Edwards *et al.*, 2007a; Gawel and Greengrove, 2005). Informed career choices, engagement, mentorship and membership in scientific or relevant research communities are but just some of the other benefits that accrue to students (Coppola, undated; Little, 2020; Mastronardi et al., 2021). Mastronardi et al. (2021) stated that research and communication skills, increased interest in graduate studies, and improvement in student persistence are gains that can be accrued by undergraduates who participate in research. Other benefits include students' exposure to real-life problems, motivation to undertake research in future academic endeavours, and close interaction with the industry. Samad *et al.* (2021) further argued the importance of virtual undergraduate research opportunities and highlighted how they addressed the needs that cannot be achieved through face-to-face assessments. The authors suggest that virtual undergraduate research should be adopted even after the containment of the COVID-19 pandemic.

2.5.2 Benefits to academic institutions

Other than benefiting the students and organizations that may at the same time be funders of undergraduate research programs, UR also benefits the faculty from within which UR is executed. The pleasure of working side by side with students as research colleagues is one of such benefits. Furthermore, intellectual and professional growth of the faculty is enhanced. A recent study revealed that faculty members' research publication productivity substantially increases with their academic rank and the education level they teach (Tadesse and Khalid, 2022). Seeing students develop intellectually, in maturity, and skills, and in helping them find their place in the real world can also be satisfying to faculties. Besides, it gratifies to be associated with the production of 'fully baked' graduates (Seymour *et al.*, 2006). Coppola (undated) also observes that UR can contribute towards the overall faculty research productivity, which can be used universities in their Research Excellence Framework (REF), Teaching Excellence Framework (TEF) and Knowledge Exchange Framework (KEF) submissions (Johnson, 2022; Jackson, 2018; Mathieson, 2019). Mentoring UR can also lead to added experience for research staff within the faculty as more research activities are introduced by UR. Furthermore, the faculties keep abreast with developments in practice.

Interaction with the industry is also enhanced, thereby increasing possibilities of securing external funding through research collaboration with the industry.

Despite the above virtues, realizing fully fledged undergraduate research programs has continued to be a challenge. There exist many barriers that hinder progress of such well-intended programs. The next section examines the barriers to UR.

2.6 Barriers to undergraduate research

Despite the benevolence associated with undergraduate research, there have been a number of barriers that thwart successful implementation of the concept. This notwithstanding, evidence suggests that there is still some poverty of research/literature into barriers of undergraduate research. Many writers and researchers alike focus on *why* and *how* UR can be designed and implemented. Some prominent research on the barriers of UR has been carried out by Seymour *et al*., (2006), and Guedri (2001). Some of the barriers are: lack of student awareness, unequal student access, poor curricular timing, lack of publicity, and uneven access/incentives for faculty) (Wayment and Dickson, 2008). With regards to developing countries, e.g., Cambodia, some of the barriers are limited access to books or journals, time constraints, poor knowledge of research methods, and insufficient institutional support (Heng et al., 2022).

2.7 An appraisal of research-informed learning

Most research-informed teaching have seldom focused on BIM with far too many focusing on traditional discipline such as project management, quantity surveying, civil engineering, etc. (Wang *et al*., 2020a). Bentley *et al.* (2012) conducted a study about the application of research-informed curriculum design (RICD) for the development and implementation of an MSc Program in Project Management. The study led to better understanding of current practice from project managers' perspectives and informed the curriculum design of the program. A study by Pan *et al.* (2012) examined the drivers, barriers and practices in relation to research-informed teaching in sustainable construction. The study revealed that despite sector, institutional and disciplinary drivers in favour of research-informed teaching, significant barriers existed to the implementation of such an approach among both lecturers and students. A study by Coldwell *et al.* (2017) conducted an assessment of progress towards a

system within which the teaching profession improves practice through the rigorous use of robust evidence. The authors used "evidence" to mean research evidence. Lu (2020) focuses on the development of the data analytics specialism of the BSc Digital and Technology Solutions degree apprenticeship at the University of Winchester Business School informed by current research and practice. Bubou *et al.* (2017) uses evidence-based teaching (EBT) strategies, and research-informed evidence to guide educational decisions regarding teaching and learning.

What emerges from existing research are threefold. Firstly, most research-informed studies hardly focused on BIM. This may be due to the fact that BIM is still considered by many as being emerging. Secondly, most studies are still investigating about how research-informed teaching can be rolled out. This is evidenced by Heng et al. (2022) who argued that academics in developing countries do not understand research and research-teaching nexus. Earlier studies had argued that the state of whether "research-informed teaching" should be embedded into curricula has long passed (Griffioen, 2020). The author (i.e., Griffioen) argued that the burning question now is "how and how far to integrate" research-informed teaching into curricula. Thirdly, although research-informed teaching is about exposing students to research content and activity, most research have hardly investigated what students can do and their impacts upon participating in such an educational strategy. In other words, in most research-informed teaching students are considered as audience with very few playing the role of participants. The questions yet to be answered are many with some of them being: can undergraduate/postgraduate students write a research article upon exposure to research methods? Can the article be of high quality and be acceptable by a high impact journal or reputable conference? What are the experiences of students who have gone through this process of writing an article and publishing it in a reputable journal or conference? The work presented here is informed by the view that students should not only be observers (audience), but also be participants as stated in Healey (2005). Therefore, this study will focus on research-informed teaching where students are active participants and have been involved in writing at least a peer-reviewed article. Before embarking on the study, it is imperative to examine how research-informed teaching has been rolled out in the School of the Built Environment at Oxford Brookes University.

3. Research – Informed Teaching in the School of the Built Environment, Oxford Brookes University

In the School of the Built Environment at Oxford Brookes University, a suite of built environment-related programmes has been on offer for a number of years. These are BSc Construction Project Management, BSc Quantity Surveying and Commercial Management, MSc Construction Project Management, MSc Quantity Surveying and Commercial Management, MSc Project Management in the Built Environment and MSc BIM & Management. Other than MSc BIM & Management, which is a specialist BIM program, all other programmes have embedded BIM modules in them.

The first is Managing Technology for Sustainable Environments with module code PMAN7004. This module is taken by students enrolled on MSc Quantity Surveying and Commercial Management, MSc Project Management in the Built Environment. The second module Advanced Construction Technology & BIM with code PMAN7006. The third is Construction Communication and Information Technology 2 with code CONM5006. This is taken by students on BSc Construction Project Management and BSc Quantity Surveying and Commercial Management. The fourth module is PMAN7007: BIM in Practice taken by students in MSc BIM & Management.

In the aforementioned modules, there are various elements of research. In CONM5006, an element of one of the coursework components aims to investigate the adoption of AI-based technologies in onsite construction project delivery- taking into consideration workers' vulnerabilities – and in implementing recommended actions that enhance the prevention COVID-19. In PMAN7006/PMAN7004, an element one of the coursework components aims to investigate the perception of construction professionals about the adoption of emerging technologies in onsite construction project delivery- taking into consideration workers' vulnerabilities – and in implementing recommended actions that enhance the prevention COVID-19. In PMAN7007, an element of one of coursework components aims to investigate and develop a digital adoption plan to support a major contractor in embracing BIM and related technologies. It is important to note that this research coursework changes every year

depending on prevailing industry circumstances. Other than these theoretical aspects, other research elements consist of investigation the potential of BIM technologies for managing risk in construction, assessing the sustainability performance of projects, for designing out waste, etc. In the ensuing section, the different methods used in delivering research-informed teaching will be examined. To facilitate understanding, the methods are summarised in Figure 3.

4. Research Methodology

To facilitate understanding, the research methodology was broken into steps depicted in Figure 2.

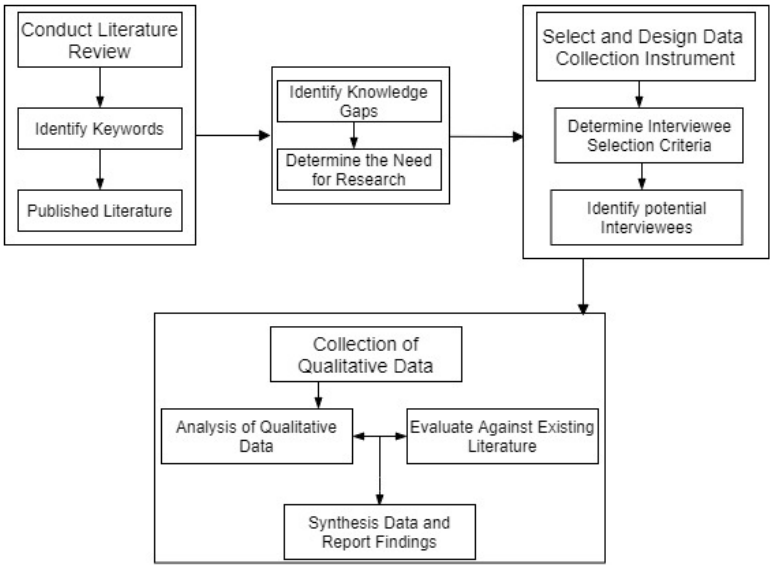

Figure 2: Steps of research methodology

To provide the context of this study and identify knowledge gaps, a literature review has been conducted. An overview of the concept of research-informed teaching was presented. This was followed by an appraisal of its application in built environment discipline, which led to the identification of knowledge gaps and the basis for designing this study. In the 2nd step, an in-depth interview was chosen as the data collection instrument. It was deemed appropriate as a suitable data collection instrument for this study as it allows for gaining an in-depth

understanding of individuals' or previous students' views based on their experiences, skills and knowledge of having published.

Therefore, purposeful sampling was used to identify students with experience in research. The criterion for selection of interview participants was that they must former students and must have published at least one peer-reviewed conference or journal article. Twelve former students were identified and contacted via Linked and personal phone numbers. Upon talking to the about the proposed research and reasons for the interview 9 agreed to participate (See their profile in Table 1). As argued in Bernard (2002) and Spradley (1979), prospective interviewees should be available, willing and able to communicate their experiences and opinions in an articulate, expressive, and reflective manner. The 9 participants complied with the requirement by Bernard (2002) and Spradley (1979). The profile of the participants has been summarised and presented in Table 1. Although, there is no generally agreed minimum number of interview participants in qualitative research, when compared with other studies, 9 participants are enough. Namey (2017) have argued that 6-12 is enough sample to attend a reasonable level of saturation in a qualitative study. Saturation is defined as the point when incoming data produce little or no new information and is the well-accepted standard by which sample sizes for qualitative inquiry are determined (Guest *et al.*, 2020).

Table 1: Profile of interviewees [Source: Author's]

Students	**Current role**	**Comments**
Interviewee A	BIM Consultant	4D BIM specialist in a BIM Consulting firm
Interviewee B	BIM Coordinator	Working for a major UK company
Interviewee C	PhD Student*	Studying in Curtain University in Perth, Australia
Interviewee D	PhD Student*	Studying in Universiti Teknologi Malaysia.
Interviewee E	Lecturer in a University in Nigeria	Teaching Construction Project Management at undergraduate and postgraduate levels
Interviewee F	Lecturer in a University in Italy	Teaching BIM at postgraduate level
Interviewee G	Senior Climate and Low Carbon Development Analyst (Cameroon-Canada)	Working as a Climate Change Scientist for a business firm based in Canada
Interviewee H	Digital Construction Technologist	A freelance digital construction technology consultant
Interviewee I	Information Manager	Working in a major contracting firm in the UK

*Although these individuals were/are PhD or Doctoral candidate when they were being interviewed, their interviews were actually based on their experiences as participants in research-informed teaching while still MSc students under the author of this paper.

The main points of the interview protocol by Jacob and Furgerson (2021) were adopted. As part of the consent requirements, interviewees were asked to kindly agree to participate in the interview or not and that they could withdraw at any time should they wish. They were also required to agree to the recording of the interview and also consent to their input being used for research purposes only. The other points include commencement of questions from the easiest to the most difficult, use of prompts, and sticking to interview duration used during the interviews.

Inductive content analysis was used to analyse the data. The method allows researchers use to develop theory and identify themes by studying documents, recordings and other printed and verbal material (Kyngäs, 2020). According to Mayring (2021), inductive content analysis is applied to qualitative data where categories or themes have yet to be determined, but must be created for more precise methods of analysis to work effectively. The method is appropriate to this study as it allows for themes to be identified from interviews that will lead to a better understanding of the application of research-informed teaching in BIM programs. In performing the inductive conducting analysis in this study, three main steps were adopted. Firstly, the researcher transcribed and read and re-read the 7 interview manuscripts group to get familiarised with the data. Secondly, the researcher search for themes with broader patterns. Thirdly, the patterns that emerged from the collected data led to their classification into 3 main categories: benefits, challenges, research skills gained, and how the skills gained inform their day-to-day job. These categories served as the basis of the analysis of the findings of this study.

Given the qualitative nature of this study it is imperative to establish its trustworthiness. Based on the literature, there is a lack of consensus on the most appropriate term(s) used in the assessment of the trustworthiness of qualitative research. The terms rigor, validity, reliability, trustworthiness, etc. have been used and in some cases interchangeably (Cho and Lee, 2014; Elo *et al.*, 2014; Lincoln and Guba, 1985; Amin *et al.*, 2020). Consequently, the criteria developed by Lincoln and Guba (1985), the most widely used in research will adopted for this study. The authors (i.e., Lincoln and Guba (1985)) used the term “trustworthiness” to support the argument that the findings from the qualitative study are “worth paying attention

to". Therefore, the 4 criteria for assessing trustworthiness as defined by Lincoln and Guba (1985) will be used. The criteria are credibility, dependability, confirmability and transferability.

Credibility requires the researcher to return the analysed data from the content analysis to the interviewees to confirm that they captured their views accurately. In this study, the analysed interview content was returned to the different participants who reviewed it and confirmed it reflected their views. They were also provided with the conclusion drawn from the interview reports before it was included in this study.

Dependability refers to evidence or findings that is consistent and stable (Polit and Beck, 2003). The methods used to establish dependability include: an audit trail, code-recode strategy, triangulation, stepwise replication, peer examination/peer debriefing (Chilisa and Preece, 2005; Schwandt et al., 2007; Polit and Beck, 2003).

Confirmability refers to the degree to which study findings are derived from characteristics of participants and the study context and not from researcher biases (Polit and Beck, 2003). In other words, it refers to the extent to which the findings are neutral or the degree to which the findings of the study can be confirmed or corroborated by other researchers. The confirmability of qualitative study can be achieved using an audit trial or inquiry audit, reflexive journal and triangulation (Bowen, 2009; Koch, 2006; Lincoln & Guba, 1985). For the purposes of this study, an "audit will be used for both dependability and confirmability. An audit trail offers visible evidence-from process and product-that the researcher did not simply find what he or she set out to find (Bowen, 2009). The data and relevant supporting documents of this study was handed over to two senior researchers with 5 and 10 years' experience in research and teaching in higher education. The two were from two post-1992 universities in the UK other than the researchers and had no previous ideas of this study. They also did not know each other. The two reviewers scrutinised the analysed data and supporting transcribed sheets for a period of 5 days. Their feedback was compared and found to be similar with no significant differences, proving the dependability and confirmability of the study findings.

Transferability refers to the extent to which qualitative findings can be transferred to other settings which can also serve as another aspect of a study's trustworthiness (Polit and Beck, 2003). This can be achieved through a thorough description of the research setting and of observed transactions and processes, also known as "thick description" (Polit and Beck, 2003). Although any research findings should be evaluated against existing literature (Silverman, 2008), which can enhance transferability, the burden is left to readers to decide if the setting of the study is sufficiently similar for its results to be transferable to their own context (Kuper and Levinson, 2008). Therefore, the author of this study provided a thick description (Polit and Beck, 2003) of various aspects of the research that can help readers to establish how to transfer the findings to their own settings (Kuper and Levinson, 2008). In the 2nd paragraph of Section 4, the researcher provided a clear description of the research context, sampling, characteristics of interviewees and data collection and analysis methods. This approach enhances the transferability of results. Also, the demographics of the interview participants reveal different areas of practice (researchers and lecturers, BIM technologist, Digital Construction technologists) and countries (Italy, Nigeria, Canada, UK, Malaysia). These heterogenous demographics can enhance the transferability of the results to readers of similar professions and regions. Lastly, although the methods proposed (Figure 4) were implemented on BIM courses, they are however generic and can be implemented on any course.

5. Findings and Discussions

The main findings of this have been grouped in 3 categories as shown in Figure 3.

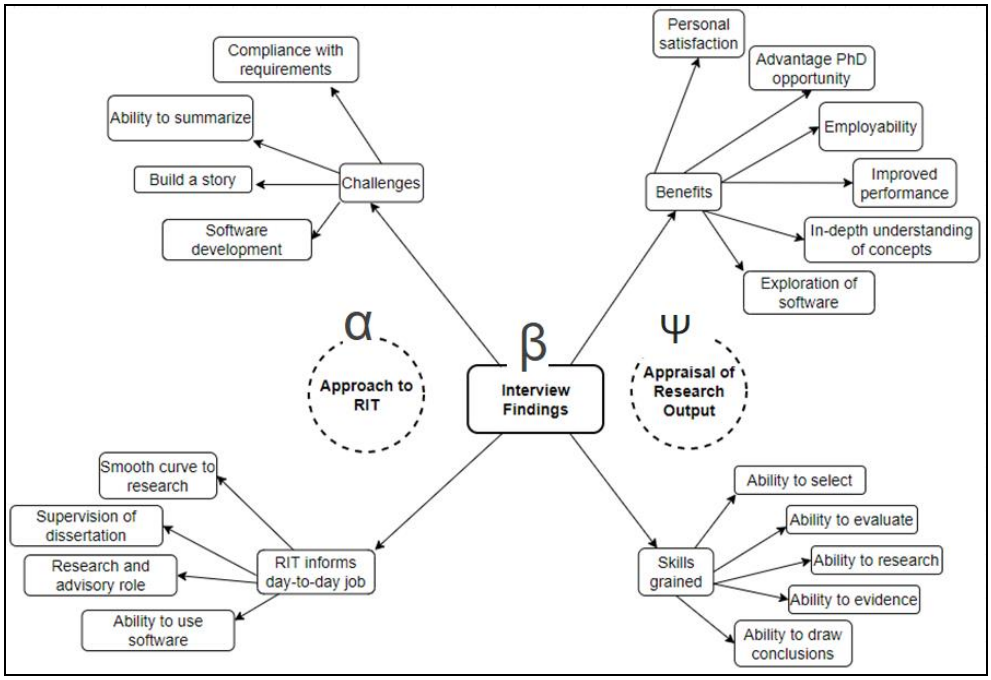

Figure 3: Research Findings [Source: Author's]

The first "approach to research-informed teaching (RIT)" is discussed in section 5.1. The finding is a response to the research question RQ1, about the research-informed teaching techniques used in BIM courses.

The second "appraisal of research outputs" is discussed in section 5.2. The finding is a response to research question RQ2, about the quality of the student outputs achieved through research-informed teaching in BIM?

Lastly, the findings from interviews are discussed in section 5.3. The findings are responses to research questions RQ3, RQ4, RQ5 and RQ6. RQ3, RQ4 and RQ5 are about the benefits, challenges and skills gained from undertaking research-informed teaching in BIM modules. The finding about the impacts of research-informed teaching on a graduate working in academia or industry is a response to research question RQ6.

To easily reveal the contribution of any study, Silverman (2008) argued that research findings should be evaluated against or knitted with existing literature. Given the emerging nature of BIM and that this study is the first of its kind in the BIM domain, it was hard obtaining

literature to corroborate the findings from this work. However, given some of the findings relates to transferrable skills most were corroborated with literature from different disciplines including social work (Lee et al., 2022), accounting (Mali and Lim, 2022), marketing (Little et al., 2008) and computing (Barker, 2009). In sections 5.3.2, 5.3.3 and 5.3.4., where there was limitation related to evaluating the empirical findings against existing literature a paragraph was introduced to justify why.

5.1. Approaches of research-informed teaching (RIT)

The various approaches used in rolling out RIT on BIM courses in the School of the Built Environment in Oxford Brookes University is depicted in Figure 4.

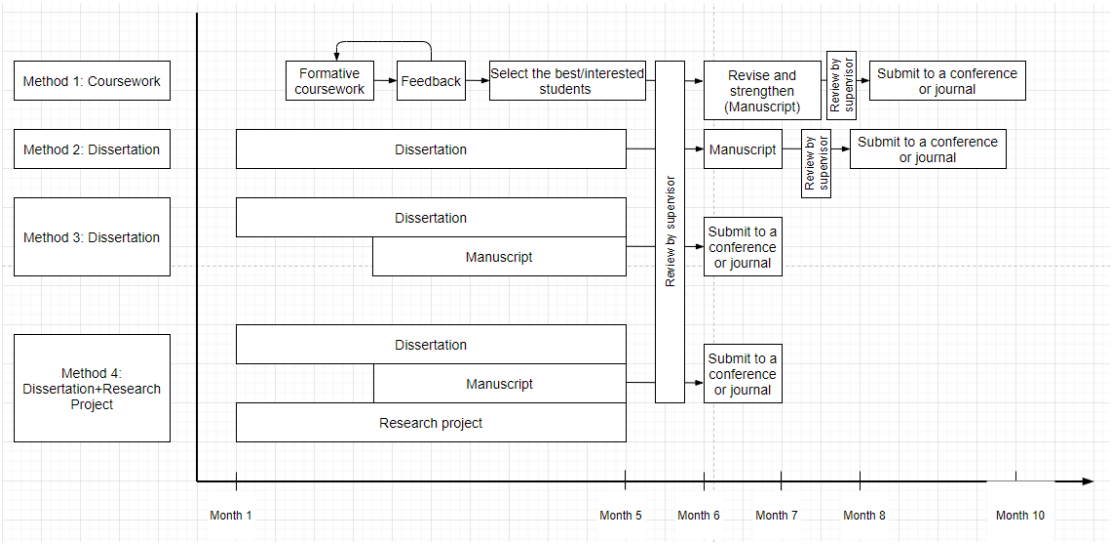

Figure 4: Approaches of RIT on BIM courses [Source: Author's]

In method 1, students are given a coursework early on in the semester. Based on the feedback and quality of the submissions, some students are invited, and supported to convert their coursework into an article and submitted to a conference or journal. Examples of output converted using this method are Amin and Abanda (2017) and Abanda and Whitlock (2017), both postgraduate students.

In method 2, students complete their dissertation and then an aspect of their research is converted into a research article. This is done after the dissertation must have been submitted. Examples of outputs published using this method are Abanda and Byers (2016) and Buhammood *et al.* (2020), undergraduate and postgraduate students respectively.

In method 3, a student is supported to conduct their end of program research while writing an article at the same time. The article is reviewed and submitted to a journal once reviewed and seen fit for publication. Examples of outputs published using this method are Whitlock *et al.* (2018), Adamska *et al.* (2019), all are postgraduate students.

In method 4, an output is generated from a research project. Also, the dissertation of the student constitutes an aspect or all of the project. At the time of writing of this article, there is a postgraduate student working with the author of this article and another colleague on a project on positive energy buildings. The student is currently writing a research paper from the project and her dissertation addresses one of the research project's objectives. In the end, the student will produce a research article, project report and dissertation. This approach whereby part or all of students' end of dissertation is converted into a research output is becoming popular especially in the medical field (e.g., Munung *et al.*, 2014). The methods proposed in this section attempt to address the major issue hindering the uptake of research-informed teaching, that of "how" to undertake it as argued by Heng et al. (2022) and Griffioen (2020).

5.2 An appraisal of the various research outputs

The author of this paper began implementing research-informed teaching in 2015. This has led to 23 outputs since 2015 despite heavy workload, compounded by the outbreak of COVID-19 in early 2020. Out of this 23, 13 are journal articles while the rest are peer-reviewed conference articles. The articles cover various aspects of BIM and related digital technologies including: digital construction technologies (Abdel-Tawab and Abanda, 2021), 4D BIM for logistics management (Whitlock *et al.,* 2021; Whitlock *et al.*, 2018), 4D BIM for risk management (Abanda *et al.,* 2020; Musa *et al.,* 2015; Musa *et al.*, 2016), energy simulation (Abanda and Byers, 2016), BIM business cases (Amin and Abanda, 2017; Abanda and

Whitlock 2017), Integrating BIM and game engine for construction knowledge enhancement (Buhammood *et al.*, 2020), 3D printing of buildings (Pica and Abanda, 2019; Almukhtar et al., 2021; Saeed et al., 2021), blockchain applications in construction practice (Adamska *et al.*, 2019), fundamental principles of BIM (Prabhu and Abanda, 2020a;b). In addition to the afore-mentioned BIM related research, the author has supervised an undergraduate student in the school to publish a conference article about the role of women in the construction industry (Naqadi and Abanda, 2015) and a post-graduate student to publish on how to reconstruct a post-war city (Saeed et al., 2022).

Other than supervising students in Oxford Brookes University, the author has mentored students to publish from other universities. These are Massey University, New Zealand (Enongene *et al.,* 2019; Enongene *et al.*, 2017; Enongene *et al.*, 2016; Enongene *et al.*, 2020), Ecole Nationale Supérieure Polytechnique de Yaoundé Cameroon (Charly *et al.*, 2010), Ahmadu Bello University, Zaria, Nigeria (Abdullahi *et al.*, 2019). Some of the articles are Q1 categories in Scimago. For example, Abanda and Byers (2016) Q1 in all categories in Scimago. The other articles are in journals that are indexed in Scopus (e.g., Pica and Abanda, 2019; Adamska et al., 2019; Saeed et al., 2021; Saeed et al., 2022, Whitlock et al., 2018). The number of outputs and their quality show that academics can conduct research-informed teaching as required by the then Higher Education Academy (Graham-Matheson, 2010) now Advance Higher Education and can use the outputs for the TEF, REF and KEF which has also become another metric of performance in universities (Johnson, 2022; Jackson, 2018; Mathieson, 2019).

5.3 Interview findings

5.3.1 Benefits of undertaking research and publishing an article

Personal satisfaction: All the participants highlighted personal satisfaction as one of the benefits of conducting research and getting it published. “It is personally fulfilling to know that what I wrote will be read by different people in several parts of the world, and that they can use it in their research or generally gain new information from it”. “While concerning personal satisfaction, it is a great experience being cited by other researchers and getting more than 2000 reads”. “It is nice to know that there is research in my field that is attributed

to my name, and a sense of fulfilment that the work I have completed will potentially contribute to further research in that area and subsequently create potential for progress in the way construction site logistics is managed". Although not focused on students, similar studies have revealed educators' personal satisfaction in supervising undergraduate and graduate research (Baker et al., 2007; Dolan and Johnson, 2009).

Advantage in searching for a PhD opportunity: Four of the interviewees stated that publishing at undergraduate or postgraduate is an advantage in PhD applications. Of the 4, 3 confirmed it helped them in their applications as they were asked during PhD interviews to discuss about their published papers. Interviewee C stated "I was asked, who is your published related to your PhD proposal"? This corroborates evidence by Seymour *et al.* (2006) which states that, research-informed teaching can enhance students' capacity to continue into Master's if undergraduate or PhD if postgraduate. This is further corroborated by Mastronardi et al. (2021) who argued that undergraduate research-informed teaching can promote career pathways into engineering by increasing enrolment and retention rates. Two of the 3 students (Interviewees C and D) that confirmed their research outputs helped them in their interviews are now Doctoral students in Curtain University in Perth, Australia and Universiti Teknologi Malaysia. Although this study did not seek to find out whether by participating in research-informed teaching influenced their choice to undertake a PhD, a study by Barker (2009) revealed that the involvement of undergraduates in the culture of research had a correlation with the intention to undertake a PhD.

Enhancement of employability: All the 9 interviewees stated that the published articles enhanced their employability. Two working in practice stated that employers were interested in them because they believed students who have published can write excellent reports. Interviewee A said that during the job interview, one of the panel members considered him to be a suitable candidate to head the Research & Development department. Similarly, Interviewee B stated during the job interview, one of the panel members recommended to be the companies Twitter and LinkedIn handler. This was because, the panel member believed I have skills to be concise and able to write very short pieces of articles in the area of practice of the company. This aligns with Kaewunruen (2017) who argued that research-informed

teaching enhances employability. The interviewee H, a freelancer said, “Today, in my business, I am able to synthesis and write very good reports for my clients. This would not have been possible without the research skills gained writing a research piece of coursework during my Master’s”. Although not working for a firm, Interviewee G still found the research skills gained through research-informed coursework very useful for their business. Carpenter at al. (2022) argued that insights from research-informed teaching can help inform and refine future undergraduate research experience programs to improve their efficacy as vehicles to benefit graduate employability.

Improve performance at work: All of the interviewees stated that some of the skills acquired in conducting research and publishing an article or articles have helped them in their jobs. One of them stated that he implemented skills gained from writing the following articles: Abanda *et al.* (2020), Musa *et al.* (2015) and Musa *et al.* (2016) in his first job. The skills and knowledge include risk management, using BIM to model and management risk and be able to run Monte Carlo simulation. Interviewee E stated “I learnt how to model risk in Vico and was able to run a simulation to determine the risk levels of the different construction activities”.

In-depth understanding of the certain aspects: Six of the interviewees stated that by conducting research, they were able to conduct an in-depth study of certain aspects that would not and cannot be possible in normal class conditions. A quote from one of them (Interviewee G) reads: “… it gave me the possibility to deeply investigate some specific aspects near the boundaries of actual knowledge and access to valuable information”. Also, 8 of the 9 interviewees (Interviewees A, B, C, D, E, F, G, H) stated that they gained detailed knowledge of designing and developing different BIM applications when conducting research. As one of them (Interviewee B) stated: “While in the Master Studio and seeing the quality of work in my tutor’s and another student’s previous research articles, I was motivated to do better. As such I took time to study in detail how to design and conduct different applications, to the level judged to that of an expert”. The freelance digital technologist expert (Interviewee H), stated “I am a sole proprietor and have no line manager to guide me. I solely depend on my ability to dig deep into the various literature and media sources for knowledge-skills gained when I

undertook a research piece of work during my MSc degree". This finding corroborates that of Little et al. (2008) where they found that research-informed teaching enhanced students' capacity to understand complex process-based phenomena in the marketing discipline.

Exploration of different software: All the interviewees stated that by conducting research, they were able to explore many different software and tested their suitability in given applications instead of just picking and depending on what the lecturer has said in class. This is well-articulated by Interviewee D, "I installed and uninstalled so many different software while investigating the best for conducting energy simulation. This could not have been possible during normal teaching. I learnt a lot during the process". This finding corroborates that of Power et al. (2018) in which it was found that one of the main skills gained by engineering students on internship and doing research in a company is learning new software tools (programming, computer-aided design and computer-aided engineering).

5.3.2 Challenges encountered in writing research article

Despite an abundance of literature about challenges undertaking research-informed teaching exist (Wayment and Dickson, 2008; Heng et al., 2022) most focused on classroom research-informed teaching coursework that often do not lead to published outputs in reputable journals. As a result, there is paucity of research about challenges focused in writing high impact articles as output from research-informed teaching. This gap is addressed in this paper with focus on the challenges experienced by undergraduate and postgraduate in writing articles that were published examined in the ensuing paragraphs.

Ability to summarise: The first challenge mentioned by all 9 interviewees was how to summarize so much information in a few pages. As Interviewee C stated, "there are so many published articles in the domain of BIM, and so one is overwhelmed with too much amount of information and the need of being concise and going straight to the point make the summarize activity critical".

Build a story: The second challenge mentioned by 7 of the 9 interviewees is that of telling a story that makes sense from many disparate literature. The interviewees struggled with

writing fluently and coherently while navigating between the various concepts from an overwhelming amount of literature which at times have contradictory viewpoints. One of the feedback from Interviewee E reads: "…defining a coherent big picture of the actual boundary-knowledge is daunting".

Compliance with requirements: The third challenge highlighted by 4 of the interviewees is compliance with the number of words of the abstract and writing smart conclusions. The interviewees said all the journals place a limit on the number of words for the abstract and they struggled to summarise that much in very few words. They also stated that writing a concise summary was a huge challenge. Feedback from Interviewee E reads: "to be able to provide suggestions and outline smart conclusions in such context is probably the most exciting challenge".

Software development: The fourth challenge was that of developing software skills to the level required to design or build an application worthy up to the level that it can be published in a reputable journal. One of the feedback from Interviewee A reads: "I was faced with the challenge of undertaking a simulation experiment (for the publications) across a number of software systems which I previously had no knowledge about, and had very limited time to learn and work with these software tools". Another feedback from Interviewee B reads, "we were taught Navisworks for 4D BIM, but I had to learn Synchro on my own and be able to perform a detail comparison with Navisworks and finally use it in producing 4D BIM in Synchro".

5.3.3 Research skills gained

Most published literature in research-informed teaching often mention of gain in research skills (e.g., Chakraborty et al. (2021)) in generic terms without or with limited specificity about which. This study addresses this gap and provides specific research skills gained. Through conducting and publishing the afore-mentioned articles, the students gained at least 6 main research skills.

Ability to select: The first skill to gain when writing a research article is the ability to select a topic for discussion. This is highly relevant in BIM as there are many angles from which to

approach BIM research. In the introduction section of this paper, the multi-disciplinary nature of the domain of BIM, its areas of applications and relationships with other emerging technologies were highlighted. One other area where students gain skills in "selecting" things is in choosing technologies to use in a particular application. The BIM market is over-flooded with so many BIM technologies. Students need to possess skills to be able to make informed choices before selecting the different software. In Abanda and Byers (2016), the student had to select Green Building Studio over so many other energy simulation software.

Ability to evaluate: Once a topic has been selected, it is important to demonstrate an understanding of its significance. This entails establishing criteria that allow the researcher to evaluate the topic. In the case, of Abanda and Byers (2016), the significance of the topic of building energy efficiency can be at the amount of energy saved if buildings are properly oriented during construction. In BIM discipline, it is important to have the ability to design a set of criteria for selecting software. In Musa *et al.* (2015), a set of criteria that can be used in evaluating the different scheduling software. This aligns with the findings from Lee et al. (2022) where they found that students who participated in research-informed teaching gain skills of being able to evaluate other research topics.

Ability to research: In every study, the ability to research is imperative. Through research, most recent theories, knowledge and gap are identified. In the BIM courses, in addition to theories, e.g., theory of participation, theory of integration, etc., research skills in identifying existing and relevant software for use in practice is imperative. Although not in the BIM field, a research-informed teaching implemented in Social Work discipline found that students gained skills in the research process that allowed them to analyze other research and be able to implement in practice if needed (Lee et al., 2022).

Ability to evidence: In research, there is often a huge amount of literature, with different scholarly interpretations and methods in different scientific databases. Learners should be able to appreciate and identify the most relevant literature for use as evidence to support an argument. Due to its emerging nature so many articles have been published about various BIM applications. Providing evidence to support a fact in BIM is quite important. Life cycle

data is different from non-life cycle or phase data; thus, my BIM students have acquired such skills to support accurate and correct evidence.

Ability to draw conclusions: In research, describing and reporting research findings is not enough. It is important to draw conclusions from research findings. The BIM discipline is no exception, and giving the evolving nature of the field, such conclusions often feed into the directions of future research.

5.3.4 How my research is informing my day-to-day job (Impacts on their day-to-day job)

Most research about research-informed teaching often focus on the experience of the student while they are still on the study program. To the best of our knowledge and literature search, there is no evidence about studies investigating experiences of alumni with focus on how the skills gained from research-informed teaching is informing their day-to-day job.

Smooth curve to research: Of the 9 interviewees, 2 currently undertaking PhDs said, it was just a matter of continuity of the skills already gained when they published articles while still undertaking their Master's. They stated that they already knew how to access reputable databases such as Web of Science, Science Direct, and Dimensions, etc. and very efficient in Harvard reference style. This corroborates findings from Kahn and O'Rourke (2005) where they pointed out students gain skills in browsing multifarious resources such as e-journals and research databases. Their critical and analytical skills have been used in their studies. A small-scale project investigated undergraduate students' participation in an undergraduate research conference reported that it had impacted their academic and professional practices, one year after their involvement in the conference (Little, 2020).

Supervision of dissertations: Two of the PhD students (Interviewees C and D) who happen to be lecturers in their universities stated that, the skills gained have helped them to be able to supervise undergraduate research dissertation. One of the feedback reads: "Overall,

it has helped me in providing the needed guidance to students I teach and supervise in any research project".

Research and advisory role: One of the interviewees (Interviewee F) working as a R&D manager in a company in Italy stated that the skills gained from writing an article when he did his Master's is being used every day in his job. The interviewee stated "I use my research skills every day to conduct research and advise my company of the latest development in digital construction technology, a very fast evolving field". "I also use it to write professional/trade articles". Although not specifically to the BIM domain, findings from Lee et al. (2022) revealed that research-informed teaching helped student alumni do better in their social work job aligning with the experience of Interviewee F.

Ability to use software: Two of the interviewees (A and B) working in practice stated that they their transition into practice was seamless. This was because in their jobs, they could use software that they had explored in detail which they included in their research articles. Interviewee BIM stated, "my line manager was impressed with my level of knowledge of Synchro and Revit and wondered if I had attended a 5 days intensive course after my degree". Having discussed the findings in the preceding section, their implications and lessons learnt from this research will be discussed in the ensuing section.

6. Lessons learnt and implications

Other than Charly *et al.* (2010), the author of this article has implemented research-informed teaching that has led to 23 published articles (13 journals and 10 conferences), most of them in BIM between 2015 and 2021. Building on the experience gained over the years, it will be great to share with other educators how this success of guiding students published was achieved.

6.1 Lessons from "α (Figure 3): Approach to RIT"

6.1.1 Design research-informed-teaching coursework components or assignments: Other than the dissertation and end of year or program project that students are expected to conduct research, a coursework component can be designed to have elements of research. In our case in the BIM programmes, the CIT Scientific report in CONM5006 and

PMAN7006 is research-based. These coursework components give students the opportunity to conduct research, which ultimately helps them when they come to the dissertation stage. A major implication is students developing confidence in academic writing and ability in searching and utilising scholarly resources, reported to be major challenges faced by graduate students during dissertation writing (Holmes *et al.*, 2018).

6.1.2 Identification of students at proposal viva/proposal stage/early engagement: In our undergraduate dissertation module, there is a viva component where students are expected to defend their proposal idea orally. In some years, this viva has been replaced with a more detailed proposal. At MSc level, students are expected to submit a research proposal. The viva and proposal at undergraduate and postgraduate are usually worth about 5-10% of the whole dissertation mark. At this stage, students with great research potential can be identified for potential engagement with research later. Engaging students in research is extremely important especially at Master's level given its duration is only 1 year in the UK. In our case, early identification and engagement of students with the potential in research led to the publication high impacts articles at undergraduate (Abanda and Byers, 2016) and postgraduate (Abanda et al., 2020; Buhammood et al., 2020) within the duration of their programs. A major implication from this lesson is that, educators will be more willing to identify and engage students in research at an early stage in the semester knowing well that it is possible for such students to deliver high impact articles while at the same time completing the other coursework components or assignments.

6.1.3 Motivation: Educators should actively motivate learners to engage in research. Regular appreciation of students' efforts can also be a strong motivational factor to stay engaged. One way to motivate students is to use previous students published work in module's reading list and draw from them to inform teaching. Students are curious and more likely to read works of previous students. By being exposed to research of previous students, current students become motivated and develop self-esteem is increased. For example, one aspect of the work by Abanda and Byers (2016) was the implementation of a case study whereby Green Building Studio was used to investigate the impact of building orientation on energy consumption. By sharing the article with students, they were more motivated in

learning Green Building Studio and above all motivated in writing a research article. The implication of this lesson is that if educators share students' achievements with current ones, there is a potential of the latter gaining confidence and embracing research.

6.1.4 Closed supervision: Like most UK universities, the duration of our Master's programs is 1 year. This means it is incredibly difficult for a student to write a research piece of work as well as dissertation together with other coursework commitments. Therefore, educators should pay a closer attention to students engaged in research and be able to provide extra support if need be. One of such areas is for educators to inspect and make sure the data collection instrument is robust and reflect the research objectives. The practical implication of inspecting and making sure a robust data collection instruction has been designed is that when use, the correct data will be collected and potentially lead to a high-quality research output if smartly exploited.

6.2 Lessons from "Ψ (Figure 3): Appraisal of Research Output"

6.2.1 An opportunity for educators to publish high impact articles

Staff in Universities often complain of the pressure to publish to be retained in Research Excellent Framework (REF), compounded by heavy workloads, and the lack of raw data to inform their research. In addition to REF other similar initiatives including Teaching Excellence Frameworks (TEF) and Knowledge Exchange Frameworks (KEF) have been proposed which further builds up the pressure on educators (Johnson, 2022; Jackson, 2018; Mathieson, 2019). REF, TEF and KEF are performance metrics with research at the heart whereby research-informed teaching can play a significant role as it cuts across teaching, research and knowledge exchange. This study has shown that staff can supervise or mentor students to write an article and submit for publication that can also be used in REF or some other purposes such as promotion. This will require less of staff time as the student will collect the data and the staff will supervise as part of his/her usual role, not an additional burden. With many universities encouraging students to publish in in-house journals (e.g., University of Plymouth, 2022), this study shows that educators can now step up their game and supervise students in coursework and dissertations to a level whereby they can submit their research work to other peer-reviewed journals.

6.2.2 Alignment of research and teaching interest

Out of the 23 research articles produced by students discussed in this study, 18 were focused on digital construction technologies and BIM, 4 were on renewable energy technologies (Enongene *et al*., 2019; Enongene *et al*., 2017; Enongene *et al.,* 2016; Enongene *et al*., 2020), 1 on women in construction (Naqadi and Abanda, 2015). It is important to note that the research interest of the author of this article are BIM, Digital Construction Technologies and Renewable Energy. However, the author is only teaching BIM and digital technology related modules which are aligned with his research interest. This is an easier approach as argued by researchers in the Canadian University of Dubai (Canadian University of Dubai, 2022) and should be adopted by educators. The approach adopted by the Canadian University of Dubai is that educators should published articles in the disciplines they teach in (Canadian University of Dubai, 2022). For example, when an educator teaches Physics and publishes articles in mechanical engineering, the latter does not inform the former, as such students cannot learn from the educator's published works. This sentiment has been repeated over the years. In Bloom (1990), it was recommended that researchers should write what they teach and publish it. This approach was re-echoed and considered to be a "great time-saver" by Vicens and Bourne (2009). Recently, in Mathieson (2019) and McKnight (2022), tightly integrating research with what is taught is strongly recommended.

6.2.3 Remote assessment of students

This study revealed the success achieved by undergraduate and postgraduate students in undertaking research with minimal face-to-face or remote supervision. A main implication is that some coursework or assignments can be designed in the form of research in order to avoid the constraint of face-to-face invigilation especially in the COVID-19 era.

6.3 Lessons from "β (Figure 3): Interview Findings"

The interview findings were categorised into benefits, skills gained, how RIT interviewees day-to-day job and challenges faced by students in undertaking RIT.

With regards to benefits, the research uncovered that personal satisfaction, more advantage in PhD application, employability, improved performance, in-depth understanding of concepts and exploration of software. The main implications are related to PhD applications and increase chances of employability. The feedback provided from participants revealed those who had published found their PhD or employers interviewees were interested in their previous research skills which gave them an advantage over those without. The implication of this is that students with research skills are likely to be successful in PhD and job applications, where research skills are required.

The aforementioned strategies are not exhaustive. In order to maximise the full benefits of UR many other issues need to be addressed. Depending on the subjects, planning, implementation, organisational and operational issues need to be considered before students are sent out for any research led learning. Some important issues to consider are, the type of students to recruit, research group formation, design consideration, scheduling and cost, health and safety, travel logistics, location of the activity, ethical issues, cultural issues and other training. For instance, Oceanographic students planning to go to the sea for research must consider, the time, cost and logistics, while for a construction of civil engineering, health and safety issues will be predominant.

7 CONCLUSIONS

As the global debates go on, and advocacy for research-informed teaching gain prominence, it is self-evident that the superiority of research-informed teaching over traditional learning methods will become more obvious. Furthermore, the benefits of research-informed teaching to universities and students cannot be overemphasised and leave every modern learning establishment with no choice other than introducing research-informed teaching into its curriculum. This view will become even stronger as more evidence about the benefits of research-informed teaching are revealed in the different disciplines. An experimental study that compared students that participated in research-informed teaching to another group that did not, showed that the academic performance of the former improved than that of the latter (Mali and Lim, 2022).

In the COVID-19 era and beyond, in case of any other unfortunate pandemic, research-informed teaching can serve as one of the approaches to assess learners especially in blended learning modes. This is because, through research-informed teaching, educators no longer worry too much about examination malpractices and the burden of invigilation. Upholding academic rigour and integrity was a challenge during COVID-19 especially in the early days of the outbreak (Kier, 2020; Gamage et al., 2020). Furthermore, it emerged from this study that research-informed teaching can be practiced in technical disciplines such as BIM and students are able to produce research outputs that can be published in reputable journals and conferences. The effort that culminated in the aforementioned outcome can be summarised in 4 main steps. Firstly, a thorough literature review (section 2) was conducted on research-informed teaching, undergraduate/postgraduate research, methods of engaging undergraduate students into research, assessment and evaluation, benefits and barriers of/to undergraduate research. This led to the establishment of the fact that research-informed teaching has seldom been undertaken on BIM programs. It also emerged from the review that despite many studies about research-informed teaching at undergraduate and postgraduate levels, very few have been transformed scientific publications. Secondly, it was imperative to provide a context by presenting how research-informed teaching is being delivered on BIM programs in the School of the Built Environment at Oxford Brookes University (see section 3). Thirdly, against the aforementioned backdrop in section 2, this study was designed and the method used included interviewing former students that have published articles in conferences and journals (see section 4). Fourthly, the findings of the study were presented in section 5. To facilitate understanding, the main themes from the findings were presented in a diagrammatic form in Figure 3. Fifthly, the main lessons learnt and recommendations from the study were discussed in section 6.

Summarily, it was revealed that students on BIM programs transformed their theses/dissertations and research coursework components or assignments to scientific publications. Therefore, as a recommendation, there is an urgent need to sensitize students on the importance and possibility of publishing their research findings in scientific peer-reviewed journals or conferences. This has been echoed in Wang *et al.* (2020b) where they recommend

an urgent need of research-informed teaching to be embedded in BIM programs. There is also a great necessity to build capacity in scientific writing among undergraduate and graduate students.

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