# Framework for the adoption of digital work flows in construction education.

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# FRAMEWORK FOR THE ADOPTION OF DIGITAL WORK FLOWS IN CONSTRUCTION EDUCATION

Building Information Modelling (BIM) application centres on the delivery of projects that encompasses theory, technical knowledge, regulations and practice. BIM is typically adopted in highly complex projects either in scale or typology which is difficult to replicate in education. Construction Education has struggled to fully embrace this new digital workflow paradigm in its teaching of students, however, because of these complexities. This paper will discuss how construction education across a variety of vocational courses has a long-standing constructivist, project-based pedagogy and this is quite effective in developing, for example, critical thinking and digitisation in education. However, there is much to be learnt and to change in the studio pedagogy approach and how effective it can be in adopting broader digitisation changes in industry into education. The future of education in the built environment may be through a practice-orientated, collaborative approach and this paper discusses the extent of change needed to effectively adopt digitisation in education using Architecture, Architectural Technology and Quantity Surveying students as exemplars.

Keywords: [BIM, Construction Education, Digitisation and Digital Workflow, Pedagogy].

## INTRODUCTION

Collaboration and communication between professionals in construction, and the problems associated with it, is nothing new. O'Brien (1994) is an early, but one of numerous, academic papers to discuss the advent of digitisation and it's influence (and obstacles) to its integration and adoption. Olowa, Witt, and Lill (2020) note that the issue still exists today. Better understanding of the digital frameworks that are now in use within the built environment and construction industries in practice is needed to ease the adjustment of digitisation in education that reflects practice. This paper explores the current understanding in education of digital workflows, how effective the current approach is and how the pedagogy and learning of the digitalisation of technologies can influence design thinking. Fundamentally the research undertaken is aimed to understand the importance of integrating BIM more efficiently into the design and education process, particularly in order to communicate peer to peer, across disciplines and between staff and students. A study of students was conducted investigating the current use of digitisation and how it maps against practice workflow (e.g. RIBA Plan of Work). The outcome intended from this research is to develop a framework and the formulation of digital workflows that can aid the contextual learning of digital technologies in universities and higher education levels. It is well recognised that the development of a framework and understanding of the digital work flow can aid collaboration between disciplines as well, therefore the research has

investigated the same digital work flows across a range of early learning disciplines (Jung & Joo, 2011; Kassem, 2014; Oh, 2015; Sinclair, 2019).

## BACKGROUND

All built environment courses benefit from the use of digitalised software, which has expanded in its usage throughout the built environment and construction sectors. Through the interpretation or simplification of specific Building Information Modelling (BIM) application components, BIM protocols provide extensive stages and processes that might result in significant improvements in the design process (Sinclair, 2019).

Digitalised technology in architecture is becoming increasingly recognised as a crucial area of software engineering over the last ten years. In that time, significant advancements have been made in creating the methodological framework and technological workflow needed to treat architectural design as a separate engineering discipline (Garlan 2000). The foundation and development of the BIM process was the concept of integrating the collection and management of various data generated throughout the building life cycle (Ma, 2018).

A growing array of software applications is available to designers, engineers, and contractors in the construction sector. To promote programme interoperability, architecture, and engineering companies establish internal databases through complex workflows designed to navigate around software restrictions (Kensack, 2021). A few software packages, such as Revit, provide software access by means of scripting languages and application programme interfaces (APIs), which enable the creation of new tools. Moving forward, AI will have a heavy influence on this and collaboration as well (Regona, 2022).

Thus, over the past two decades, BIM implementation has started to revolutionise the construction industry helping make projects more efficient and cost-effective (arguably). The construction sector can incorporate new digital technologies into their operations as they become readily available to the industry and develop the disciplines and skills to lead this (Sinclair, 2019). This implies that there will be a strong need for education to respond to this skill and graduates who can recognise and use the numerous digital programmes that cross over and integrate, as well as who are proficient with using them individually.

Building Information Modelling for construction education (BfCE) is a new approach taken by universities to tackle the emerging digitalisation of the construction industry in construction education (Olowa, Witt, and Lill 2020). This implementation is to drive change in education; improve collaboration, and; to provide opportunities for the contextual learning and teaching of BIM to meet the approaching industry needs and rising standards.

By using digital tools to develop a sequential framework, one may easily establish a flowing workflow that can reduce work time and convey a feeling of concatenating in the design process. This relates to the pedagogy of digitisation, which will help educators and help students comprehend how this can affect the design process and adopt collaboration in the teaching process.

# PEDAGOGY OF CONSTRUCTION EDUCATION

Architectural education, and construction education more widely to a limited extent, has a long-standing constructivist, project-based pedagogy that is quite effective in developing, for example, critical thinking (Lea, 2015; Webster, 2004; Kuhn, 2001). There is, however, a perception that this form of education creates elitism, or favours certain 'types of people' (Stevens, 2013; Jessel, 2018) or constructivism does not work, particularly in its adoption at undergraduate (or lower) education levels (i.e. with the need to develop technical knowledge first before adopting this approach) (Kirshner, etal, 2006). Webster (2004) also links the motivational aspects of student learning to the type of tutor, illustrating how the need to select the correct tutor, with the relevant experience to the appropriate module, is key. However, there is much to be learnt from the Architectural Studio pedagogy and it can be successfully employed across a wide range of vocational courses (Kuhn, 2001). The future of education in the built environment may be through the route of 'earning and learning' claims Marrs, (2018) albeit this approach will inhibit broader learning without appropriate pedagogy in the profession.

According to Tedjosaputro (2020) however, the quickly evolving field of digital design for buildings has changed how designers and architects approach their jobs and therefore how they should be taught. An essential element of construction education for designers is the design studio as noted above, which allows students to integrate the skills they have learnt in 'technical' modules into an experimental setting. Studio pedagogies also allows the understanding in construction disciplines (particularly design professions) to use a practice reflective setting that simulates for students how to consider projects from concept to completion with real scenarios. According to Tedjosaputro (2020), the studio pedagogy approach offers a platform for knowledge elaboration and is enhanced through collaboration.

The approach in this research is the assumption that studio based, practice orientated projects in construction education may bridge the understanding of digitisation in education and allow for greater collaborative 'potential'. Pedagogically, COVID (2020-22) has had a significant influence in the development of this research as without the studio setting, staff support and access to key digital tools - students began to produce inferior and simplified schemes and project outcomes. This research undertaken from 2022-24 aims to strengthen future obstacles and enhance pedagogy in the construction sector through greater collaborative practices - which is fundamentally how students learn in studio pedagogies.

### Digitisation and Education

Building Information Modelling for construction education (BfCE) has become an important aspect of the industry with the need for knowledgeable and skilled graduates in BIM (Dithebe et al. 2022). To advance students' ability and competency level, construction education must incorporate a range of BIM software. Learning these programs practically through trial and error contextually within projects, a practice-led learning environment is more suited to gain the level of understanding needed in the industry.

Comprehending how digital technologies can impact design thinking is among the issues concerning educational establishments. Designers work with a broad spectrum

of digital technologies; for students who are unfamiliar with these systems, technical standards, structures, and other details, learning how to draw digitally can be overwhelming and require specialised knowledge (Dithebe et al. 2022). The present study aims to explore a sequentially digitised framework that may facilitate digital technology learning and facilitate contextual learning in higher education. (Gouri, Sonia, Nanjundaswamy, and Baskaran, 2021). Technology use is an integral component of digital pedagogy and is only beneficial when used in combination with appropriate pedagogy (Tedjosaputro, 2020). The pedagogy of digitisation involves analysing and utilizing digital technologies in teaching and learning. Digital pedagogy is crucial now as the industry moves towards digitalisation in all fields (Sonia Gouri, Nanjundaswamy, and Baskaran 2021).

The design process requires students to consider the project comprehensively, from its conceptual stage to the ultimate technical realization. The design process itself supports the learning of digitalisation in construction (Abdirad and Dossick 2016). Digital tools provide designers access to skills that are difficult to accomplish in equivalent amounts of time with traditional analogue tools like pen and paper or physical models. These include large-scale digital investigations and simulation and manipulation in real-time at different scales (Tedjosaputro, 2020).

To understand the different approaches to technology integration within teaching, we need to consider the complex relationship between pedagogy, context, technology, and content (Harris, Mishra, and Koehler 2009). Employing a framework to effectively integrate technology into the classroom while acknowledging that each component and the instructors' expertise are required to teach content-based curricula using educational technologies (Harris, Mishra, and Koehler 2009).

The interaction of digitalisation, pedagogy, and building information modelling (BIM) in the built environment and construction industries is therefore significant. BIM and workflow in industry is changing rapidly and can be 'free-flowing' meaning a framework in education needs to be adaptive. As a result, effective teaching methods, software utilisation, and collaborative approaches are crucial for improving efficiency and innovation in education.

## METHODOLOGY

*Research Strategy*

This study aims to provide a deeper understanding of the wide range of digital tools that are accessible for use in the design process, from technical output to concept design, as well as the improvements in workflow and productivity in the field and how the educational setting is responding. This needs to be considered while examining the educational system and how it will function in consideration of increasingly complex technological advancements. To improve information consistency and efficiency, this study intends to suggest methods to utilise digital software used in BIM collaborative design. It will be necessary to analyse the computer-aided design and the advantages of using collaborative software for this. To do this, case studies of techniques and relevant digital tools have been examined. The tools have then been practically applied for its effectiveness, usability, and potential to further enhance the design process for workers and students.

*The digital workflow*

This study aims to achieve an analysis of the diverse types of software in the UK construction industry by analysing data and a case study along with knowledge from current students and guided by professionals. A series of questionnaires, interviews and workshops were undertaken that included students, lecturers, and professionals in the industry to gain an understanding of the different software used throughout the design process, from a variety of sectors within the construction industry. The students this focused on were Architecture, Architectural Technology and Quantity Surveying professions. A limited number of Building Surveying students were also included but would be difficult to provide any definitive information based on the low numbers on the course.

An investigation and extensive examination of how software was taught and used (in projects undertaken throughout 2022-24), how they are used in and throughout the design process, and how they can be linked and integrated with each other will be conducted. The workshops undertaken were therefore observational as the students worked on projects in a studio environment at various phases of the development of the project. This provided an understanding of the digital workflow the students adopted set against the educational framework of what is taught.

## THEORETICAL FRAMEWORK

*Educational Observations*

A comparative analysis model was undertaken between professions from the observational workshops with students and staff working on projects in a studio setting. The comparative analysis is used in this sense as a mapping exercise to determine where links and thus collaboration may be undertaken i.e. which platform or digital tools students (and staff) can use to collaborate with. The aim is to create building blocks towards collaborative practice, to enhance a constructivist approach to learning across professions that teach in different learning environments where digitisation may be the bridge to better collaboration (Otting and Zwaal, 2007).

This was followed by interviews of the participants in small study groups where it was determined what tools were used currently (and what was desirable to learn). Outcomes from this initial phase, illustrated in the following figure, where the digital tools used by the students are highlighted against the instances of their use.

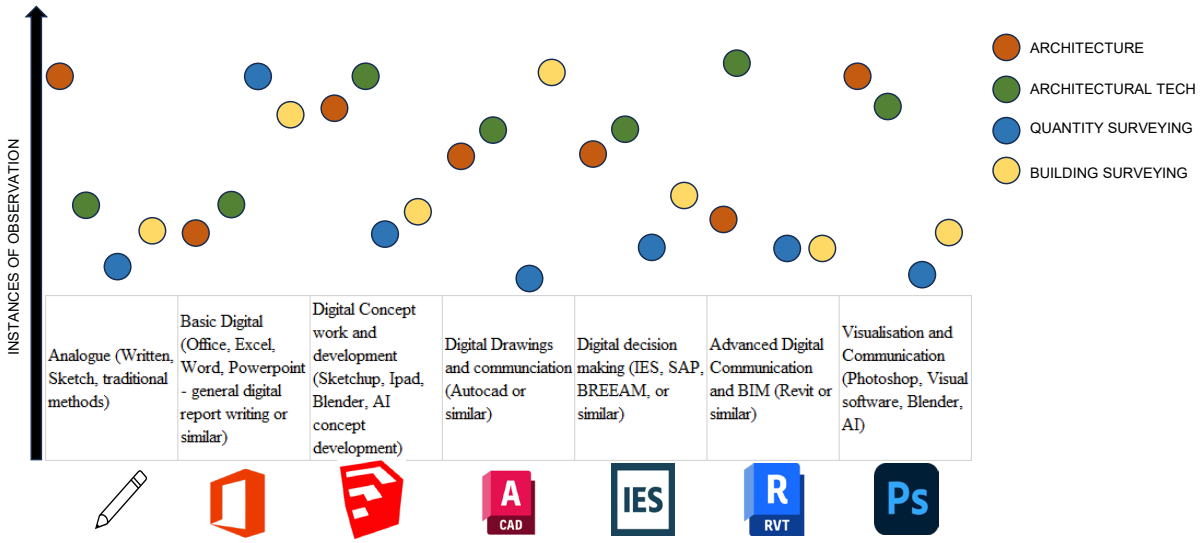


*Figure 1 : Results from observational workshops against professions, tools and their weighting (reflected in the instances of occurrence (numerical into proportional representation) (Author, 2023)*

Following this initial investigation the summary observations were as follows :

a) there was a preference (by students) to use as limited a number of digital applications as possible to produce the work as quickly as possible (directly attributable to what they were taught in the curriculum). There was little effort to expand learning from what was taught in the curriculum except in some isolated cases.

b) digital tools are often taught in silos in modular teaching curriculums. These digital tools are often not interoperable (i.e. between digital drawing software (see figure 1) and digital decision-making software). This has caused confusion as to their adoption and their place in the digital workflow and what their purpose was (in the scope of a project, not a module) (by students, and in some instances staff). When included in a collaborative exercise and in a project to evidence their use results have been unsatisfactory (in terms of student experience).

c) there was little opportunity (currently) for collaborative activity digitally given the choice of applications used for the projects undertaken (despite comparison with the curriculum where each profession was taught the same digital tools, against the same hours with the same accessibility to the tools). Figure 1 adequately details this across a range of digital tools groupings.

d) the only collaborative tool, which advertises itself as collaborative, that is used currently is Autodesk REVIT (with only one group dominantly using this tool). The desire in a collaborative education setting is to have all students collaborating to the same level.

The study results have given a significant outcome in that students have limited scope and understanding on the software they use and have little understanding of a digital workflow beyond what is asked of them in their project.

*Practice Observations*

Practice observations were undertaken with alumni from the course, currently working in practice for at least 3+ years (and preferably were chartered in their professions).

The method was through interviews rather than observations of practice - yet this is the authors summary observations from the exercise. Professionals showed insight into how they use the software within the industry that may be distilled into three categories (broadly). Firstly, it was found that companies prioritise cost more over software, such as using software bundles like Autodesk that give multiple software that can be used across the design process as a cheaper investment as shown in the figure below. Secondly, using digitalised software that can be used multiple times across the plan of work and that can easily integrate within other software as plugins. Interoperability is key here. Finally, similar to student observations professions work in silos, and digital literacy across professions is limited.

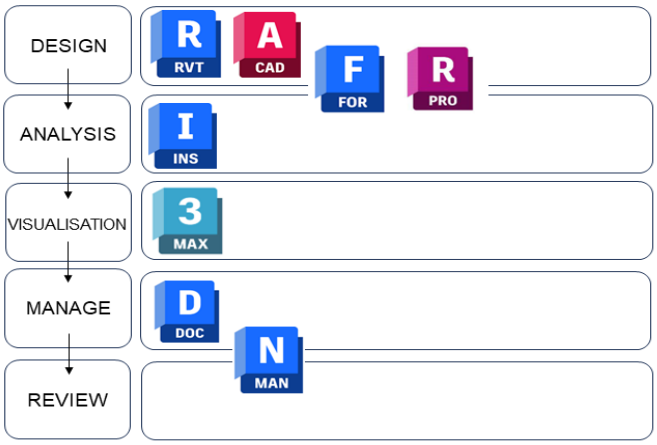


*Figure 2: Autodesk Collection Framework (Author, 2023)*

Figure 2 demonstrates the Autodesk architectural, engineering, and construction (AEC) collection for designers across a framework to show how a simple bundle of tools, can be efficient enough to create a seamless workflow without the need for any unnecessary software that the industry and companies do not require or have the time frame or budget for. This enhances interoperability. From this we can surmise that the bundle of digitisation tools can be taught that prioritise interoperability seamlessly (Autodesk is not unique in providing a suite of tools like this).

Upon reviewing existing studies, it became apparent that BIM protocols are frequently formulated at an industry-wide scale, necessitating significant modifications for effective implementation at the project level. Comparing the results the level of technology and software use is different within the learning and education sector compared to the professional industry. The software taught in education is limited compared to an extensive list of programs that can be used within the industry and their interoperability, there is a diverse range of digital tools that can be used throughout the design process. Construction education is therefore lacking in the ability to keep up with the ever-changing and demanding presence of software that is becoming necessary within the construction and built environment industry, particularly around collaboration and interoperability.

After completing this investigation the framework and digital workflows were created as seen in Figures 3 and 4. The frameworks were constructed and designed to focus on the process and how it can be easier to work alongside the design stages, integrating the software together to create a more seamless and efficient workflow. A workflow that is smooth and logical without any disjunction.

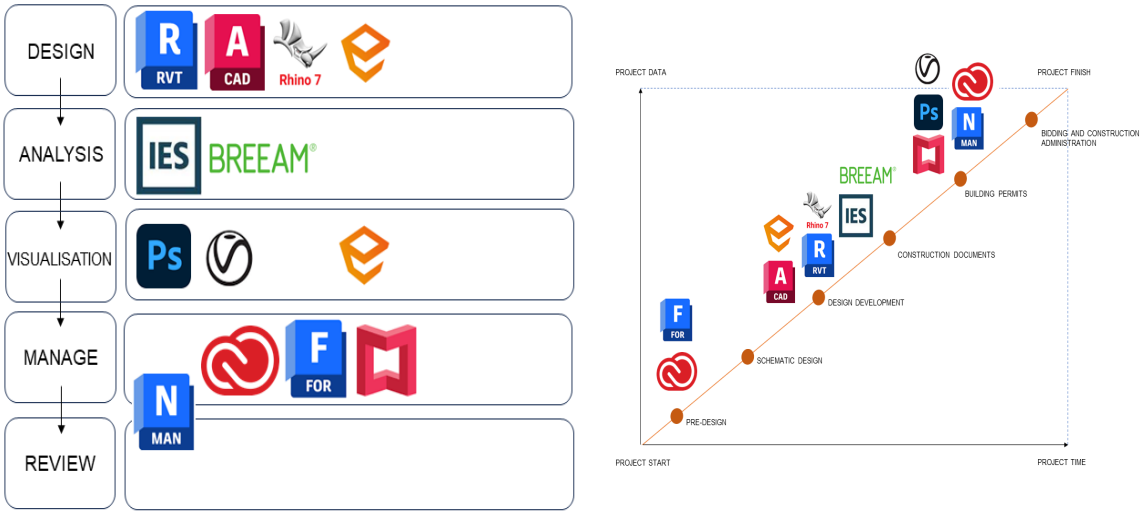


*Figure 3: Digitalised Framework + Placed alongside project workflow (priority software is place to the left in the workflow diagram) (Author, 2023)*

The digital framework and workflow show the steps and benchmarks within the design process with software laid across the stages to achieve a suitable framework that can be used as a contextual learning tool and as a base tool in construction education. The proposed framework and workflow have been developed to use a limited number of programs (maps against students usage observations) as well as utilising software companies that provide multiple software applications (that provides interoperability), this has been done to allow the software to be used by all. Given the observations of students and practice, upskilling is required across professions in order to achieve desired learning as well as (of course) collaborative practice. Therefore there will be barriers to this initiatives adoption.

Providing a workflow across a project timeline showing the benchmarks and steps can allow the contextual learning of digital technologies in universities allowing for easier teaching and guidance from the conceptual design to technical output and throughout the main benchmarks within a project.

Comparing the above workflow to the many software tools in the industry, it increases the efficiency of design and productivity within the design timeframe (for students). The framework is focused on the design process and how it can be easier to work alongside the design stages, integrating the software together to create a more seamless and efficient workflow. BIM frameworks aim to enhance the understanding from the student level and implementation of technology at the beginning with education within the industry. This means that students can enter the professional workplace able to understand the process of workflow and can easily adapt into the industry. Ongoing research will move forward with the advent of parametric architecture and these digital tools alongside evidence-based tools such as environmental assessment tools (Sinclair, 2019; Kensek, 2021; Regona, 2022). AI will be a part of this ongoing discussion.

## CONCLUSIONS

This paper analysed the various digital tools that can be employed in the design process, as well as how each digital tool can be used as a component of a digital

workflow from conceptual design to technical output in a construction education setting. As the industry moves towards digitalization in all fields, the first objective of the study examined the impact of digital pedagogy in higher education on workflow and its potential to enhance students' comprehension of software. This highlighted the importance of knowledge building around the use in technology in digital design. Yet the analysis found that the efficient use of digital tools in education is not currently being used. The learning of digital technologies could be made easier for contextual learning in higher education through a sequential digitalised framework.

BIM frameworks aim to enhance the understanding and implementation of technology within the industry and aid collaboration. Digital tool model creation, manipulation, and storage can be made easier with the use of BIM technologies. Currently BIM software and understanding is not equal across disciplines and therefore collaboration is not equal or comparable.

The use of the methodological strategies found that a digital framework/ workflow was needed to ease the learning process and the fluidity of digital software use in the construction and built environment industry. The study subsequently will develop and expand that integration of digitisation and technology as to whether it can increase the communication and performance between software, students and staff.

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