Abstract. With academic curricula for architectural education increasingly packed with new and expanding fields of inquiry, questions emerge on how to incorporate the ever-growing number of subjects that tackle the use of computational tools for design and delivery. This paper analyses approaches to blended learning under a semi-flipped classroom model where learning content gets divided into complementary in-class and online components. The author describes the epistemological challenges in curating the blended-learning mix and discusses ways to optimise learning outcomes while minimising the effort for custom content-development of training material. Two subjects taught at the author’s home institution (one in Computational Design and the other for BIM education) serve as case studies to test the flipped classroom approach and to derive feedback from students about their preferred method of delivery.

Keywords. BIM; Flipped-Classroom; Computational Design; Education; Online learning.

1. Introduction
Approaches to teaching design and documentation software address a broad spectrum of topics, ranging from a focus on technical issues, to process-related concerns, all the way to policy and collaboration. Common to all of these approaches are questions related to the best possible delivery mechanism of CAAD software training in a class setting where educators often deal with large student numbers and varying capabilities of students to learn new tools in a face-to-face teaching environment. Academic curricula in tertiary architectural education become increasingly crowded and educators are looking for alternatives training methods to maximise the usefulness of face-to-face interaction with students. With training for software applications becoming an ever more integral part of the architectural education, online training resources (both paid and freely available) present themselves an ever more promising alternative to teaching CAAD tools in the classroom. The quality and quantity of online resources available is of such nature, that the viability and usefulness of teaching ‘software’ face-to-face in architectural education ought to be questioned. If dozens of high-quality tutorials for software training are available online, what is the merit of teaching tools in the classroom? Accepting that every student learns at his/her own pace, why would
educators still train students in the use of computational design and BIM tools? Other questions remain - such as: Is the quality of online tutorials sufficient to rely on them entirely, or can/should they be complemented by in-class teaching? If so, what is the most appropriate mix between face-to-face training and online training? The research presented here aims to respond to the above questions and point towards the opportunities and challenges within semi-flipped classrooms.

2. Background

The spectrum of computational tools supporting architectural design and delivery processes is ever increasing. They cover a broad territory of applications from supporting highly experimental approaches (Achten 2009) to facilitating mundane tasks that typically encompass a high degree of repetitive work. The proliferation of computational methods for the design and delivery of projects in practice has gone hand in hand with changes in teaching and learning in academia. Architectural Design becomes ever more knowledge-intensive, driven by technological advances and an increasing appetite to test and validate a project’s performance.

The use of digital tools forms an integral part of the epistemological development of architecture students. Education providers therefore need to ensure their course-structure caters for classes that address the use of digital tools on various levels. On a procedural level, it is about ways of supporting their design thinking via computational means and matching their desired design process with referring tool-ecologies. On a practical level it is about gaining the right software skills to become more efficient in the production of documentation and other representational output on their projects.

Numerous commentators scrutinised the integration of digital tools as part of the architectural education by noting the opportunities (among other) for exploring computer-mediated social interaction (Earl 2000), maximising the engagement of students in class (Cheng 2001), or by highlighting the benefits and challenges of using digital tools within the design-studio context (Al-Qawasmi 2004). At the start of the new millennium, the discourse concentrated the introduction generative systems and parametric techniques into the design process of students. In the early 2000s, the proliferation of parametric design approaches progressed with the increasing availability of parametric design tools such as Bentley’s Generative Components and later McNeel’s Grasshopper plugin for Rhinoceros. Some critical voices emerged: Chase (2003) warned academics about the “mindless definition and application of rules without a clear understanding of how they operate” while (Burry 2005) stressed the need for transdisciplinary cross-fertilisation between academic teaching, research, and practice. Kensek (2012) later raises the same issue when referring to the opportunities of BIM to foster interdisciplinary collaboration.

Whilst available literature focused heavily on the use of rule-based design for early design exploration, the advent of BIM and its adoption-levels in the industry led to questions about the best way to integrate related training in academic curricula. Some commentators saw BIM as a major disruptor to traditional design
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studio education, prompting Ambrose (2009) to urge academia to “completely revisit the curricula and imagine a system that acknowledges the obsolescence of the how and what of that which is taught in today’s schools of architecture”. This position was seconded by Deamer and Bernstein (2011) who see BIM as a threat to well-established hierarchies and divisions between academic disciplines, pointing out the insufficiencies in contemporary curriculum-structures to facilitate proper BIM education beyond its notion as a tool.

Over the second decade of this century, the dust has settled (at least to a degree) when it comes to the veracity of changes perceived to affect the inclusion of BIM in education. Training for and application of BIM has become second nature to most educational institutions (Holzer 2015), but the way it gets taught has been changing. Walaiporn (2015) assesses that: “Students enter an architectural school with an aspiration to design something, not to learn tools” as she calls for teaching strategies that move away from software training to more applied and contextual approaches to learning tools. One key step within architectural education is therefore to consider new modes of teaching that allow for discussion of concepts and reasoning behind the tools in use, whilst straying away from a focus on mundane capabilities and commands.

2.1. ENTERING THE E-LEARNING PARADIGM

From an educator’s perspective, the developments in CAAD bring along certain challenges. Given the increasing application of digital design/delivery tools, how does one select and configure the right courses for students to engage in? How can the associated training be consolidated within a curriculum that appears to be ever-expanding? Should software courses substitute existing training, be taught in conjunction with it, or be taught in parallel to existing subjects? In case of the latter, how can one justify the added time-commitment associated to online content development? Do traditional ways of teaching still correspond to the contemporary knowledge acquisition of students who tend to interact in online communities and social networks?

One other aspect of learning that has increasingly affected knowledge acquisition of students over the past few years is the transformation of its delivery-mechanism. The change in media from text-book based to online-tutorials and videos provides new opportunities for the delivery of software training. Traditionally such training was typically in person within in-class tutorials and using printed handbooks. The proliferation of the world-wide-web towards the end of the millennium facilitated an influx of online training material. This material became available online PDF tutorials (both free and paid), and increasingly also as video tutorials. The main advantage of electronic media for training purposes is the potentially unlimited access and the opportunity to go through the learning material at their own time as often as they want (offering students flexibility on when, where, and at what pace to learn). Increased network speed for content-streaming has allowed online class presentations and video tutorials to become a via support mechanism to enhance the teaching experience within academia. Researchers have since explored the nature of combining in-class tutorials with online training resources. Research about teaching methods, and
in particular the inclusion of web-based e-learning options addresses some of the questions mentioned before. Ham (2010) highlights the potential of online social network settings in the context of design-studio teaching, Wang et al (2012) declare eLearning a mediator in the relationship between student-student and student-teacher interaction. Schnabel and Ham (2014) go further by questioning the often sequential way of learning experienced by students and they point out opportunities of using social networks to increase communication and knowledge transfer in 21st century architectural education.

2.2. THE FLIPPED CLASSROOM TO THE RESCUE?

Fryling at all (2016) discuss these blended learning options based on the so called flipped and semi-flipped classroom models where content is distributed to students by the tutor so they engage with it outside of scheduled class times. Looking at various options, they argue that “the semi-flipped model is an effective compromise for an instructor who cannot devote the time needed to replace all lectures with videos”. Similarly Thay et al (2017) point out the benefits of the semi-flipped classroom for students and tutors alike as students are given ample time to go through the online material at their own pace to then prepare for the face-to-face conversations and targeted feedback sessions in class. Jenkins et al (2017) assess that the focus on getting the mix between online and in-class activities right is only one aspect to be considered when programming blended learning options. They point out the need to consider blending options based on pedagogical requirements that allow for “flexible interpretations of flipping in different contexts”, moving fluidly across “content-focused to process focused and teacher-led to student-led”.

The argument for flipping classrooms carries with it some major obstacles: Assembling a well-structured set of video-tutorials is highly time-consuming and requires specialist skills. Due to the frequent upgrades associated to design software, any referring training tutorials have a short life-span and need to be refreshed continuously. A drawback of online learning content for digital design and delivery tools is that it is often un-structured and randomly put together by individuals with no particular curriculum or course structure in mind. In some instances, the selection of online material is purely based on the software-provider’s commercial interests, in others it may be limited by the moderation/editing capabilities of the individual who compiled the information in the first place. In order to address the above shortcomings, commercial organisations have started to develop targeted course-content in order to make it available online via a subscription model. Testing different blended-learning options under a semi-flipped classroom model is a way forward to evaluate and fine-tune methods of course delivery for software training in architectural education.

3. Case study

For the purpose of the research presented in this paper, the author has monitored the performance of Masters-level students across two elective courses over the
duration of one 13-week semester at his home institution. One course titled: “Digital Design Applications” has the aim to introduce students to a range of computational design tools in support of their exploratory design processes. The second course titled “ICT in Building” centers around the transformative character of Information and Communication Technology (ICT) on the construction industry, and the production of 4D Construction Sequencing in BIM on a pilot project.

In both instances, classes were taught using blended learning in a flipped classroom setting; in particular following the model suggested by Al-Ratrout and Zureikat (2014) who assess that the addition of preparatory classes in a course-program to advance students’ computational skills can enhance their design performance. The author had previously taught both classes and was able to advance and fine-tune the teaching methodology in both cases over several years based on student feedback, and empirical observations.

3.1. “DIGITAL DESIGN APPLICATIONS” - BLENDED LEARNING MIX

The key learning outcome of this course is to provide students an in-depth understanding of algorithmic digital form explorations using intensive computational scripting coupled with fabrication of detailed material models. Each class starts by an introductory lecture that introduce students to a specific aspect of the course (Parametric Design Rationalisation and Fabrication Analysis, Simulation & Optimisation / BIM / Designing with Data and Machine Learning / Scripting & Physical Computing). The in-class lecture is then followed by in-class tutorials on that specific topic, in most cases facilitated via Rhino-Grasshopper.

Due the steep learning curve required by students to engage with Grasshopper on this level of sophistication, each student is required to prepare for class via pre-configured online tutorials that cover the basics of Rhino/Grasshopper and beyond. These tutorials are taken from the online platform ArchiStar Academy that the home institution of the author subscribes to. The platform was developed by a third party parametric design expert who has prior experience in academic teaching and practice-work alike. ArchiStar Academy has the advantage to let tutors set up ’virtual classrooms’ where specific tutorials can be pre-selected for each class and students then receive automated invites to go through those specific tutorials on the system. Further, the online platform allows tutors to monitor who
has actually completed the tutorial and to send custom messages to students about the tutorial if required. Next to the use of ArchiStar Academy(TM) the Digital Design Application course also runs their own wiki page where course material is presented, alternative tutorials are listed, and students have the opportunity to engage in a social Web2.0 context.

3.2. LEARNING BIM VIA "ICT IN BUILDING" - BLENDED LEARNING MIX

The ICT in Building course offers Masters of Construction Management an overview of various applications of Information and Communication Technology utilised across the building sector. The majority of the course is dedicated to discussing the theoretic framework behind ICT use and a general introduction to associated tools. Each class contained of introductory lectures about the history of ICT in building, supply-chain interaction, software solutions, tool ecologies, and ICT use by clients, consultants, Head Contractors, Trade Contractors, and Facility Managers. These theory classes are complemented by discussion-rounds and industry guest speakers in order that allow students to get a comprehensive picture of ICT use throughout the building industry and to increase their understanding of the 4D BIM exercise undertaken in part two of the semester. Based on student-feedback in prior iterations of the course, a specific practical component was added to tackle the task of using a 4D BIM approach to link a construction program to a 3D model-coordination and data management environment in Autodesk Navisworks(TM); this applied software training was requested by students as a way to get hands-on with the tools. It was run in the second half of semester once students were already familiar with the basic concepts of ICT and BIM in particular.

For the purpose of the BIM training, the technical tutor introduced the task at the beginning of semester and handed out a set of Navisworks template files for students to interrogate over the coming six to seven weeks. Students were then requested to go through basic Navisworks training using the online Lynda platform. Specific Training classes were pre-selected by the tutor and links were made available to students on the custom course wiki-page that was set up from first week of semester. From week 8 onward, the in-class tutorials commenced. The tutor introduced a new aspect of 4D BIM planning in-class each week, building up towards the production of an animation (video) based on a revised construction program to be develop by each student. Lynda offered a ready-made solution for covering the basic training requirements in Navisworks to allow the tutor to focus entirely on teaching the specific functions required for linking a construction program to dedicated 3D elements via selection sets to facilitate the 4D time-lining process in Navisworks.

4. Observations and Discussion

The findings presented in this section are based on active observations during both the Computational Design course, as well as the BIM-focused ICT course. The key source of information results from a 9 question survey each student filled in at the end of semester. There, students expressed their views on the quality of the
online, as well as in-class training, and they comment on the balance between the two. They voice their ideas on how to improve the flipped classroom experience and the speed of learning overall. In the survey, students were asked to rank their preferred method for learning (design) software and they were queried about the usefulness of both the online, as well as the in-class tutorials for this subject. Further students responded to the balance between online and in-class training and its effect on their speed of learning? Students were then given the opportunity to suggest improvements to both the online, as well as the in-class software training.

4.1. PREFERRED MEDIUM FOR LEARNING

Student responses about their preferred medium/method for learning design software revealed a broad spread of responses with no clear preference for any particular approach. Whereas students in the Computational Design course appeared to have a slight preference for finding targeted tutorials online, those attending the BIM course had a slight preference for being taught in class. Both groups of students agreed that printed training material was the least favorable source for learning software.

![Figure 2. Comparison between preferred method of learning Computational Design vs BIM.](image)

4.2. ACCEPTANCE OF THE BLENDED LEARNING MODE

Approximately 70% of students in the Computational Design course were very happy with the online training material provided via the pre-selected subscription service ArchiStar Academy with nobody questioning its usefulness. In contrast, only 50% of students attending the BIM course were that positive about the Lynda platform, with 10% declaring it ‘not particularly useful’. The quality of in-class software training received a positive response of between 80-85% of students across both courses.

Asked about the balance between online and in-class training opinions seemed divided. 35% of Computational Design Class students thought it to be ok, with 40% wanting more in-class tutorials, and 25% felt they needed more online tutorials. The split among BIM students was even more defined, with only 22% feeling the balance was right, 63% arguing they wanted more in-class tutorials, and 15% wanting the balance to shift more towards online training.
Reflecting to their blended learning experience, 85% of Computational Design students believe the flipped classroom model helped to speed up their learning (with the rest arguing they would have learned at the same speed with in-class only tutorials). The BIM subject students were more divided in their views, with 45% arguing the flipped classroom allowed them to learn faster, 41% feeling that traditional in-class teaching would have allowed them to learn at the same pace, and 14% assessing that the flipped model ultimately resulted in slower learning pace than an in-class only setting.

4.3. OPPORTUNITIES FOR IMPROVEMENT

When asked to respond to ways to improve the options for online, and in-class learning, student responses from both courses were identical: More choice of online training content was the most-desired improvement, followed by greater alignment between online and in-class tutorials. Students also wanted to be able to ask more questions in class, with greater flexibility to adjust content during in-class training.

Individual comments by students provide more explanation: Respondents from the Computational Design class noted the lack of structure across tutorials within Archi Star Academy and they suggested for the tutorials to be curated towards achieving specific practical outcomes. Ideally, those outcomes should tie in directly with course assignments. Further, students suggested more exclusive tutorials for specific Grasshopper plugins should be added to the system. Course
participants did highlight the lack interaction with others with one student suggesting: “It can be a place where students can have a chat (ask questions) and share their scripts. Like grasshopper3d website, however, more specific for parties that collaborate with Archistar Academy, such as for the university only, or the course”. Respondents from the BIM course found it difficult to locate the most appropriate learning material on Lynda that provided the best fit for 4D BIM tasks to be carried out in class. Better search-options were requested that help to avoid opening tutorials not relevant for the subject.

In reflection on their in-class software training, an overwhelming number of students (95%) from both courses agreed that access to a video recording of those sessions would be highly beneficial to their learning. Asked about the benefits to still attend classes if access to such recordings was given, students from both courses uniformly pointed towards the advantages of being able to ask questions in class, as well as communicating with their peers during the face-to-face sessions.

5. Conclusions

The research presented in this paper points towards a future where blended learning in a flipped classroom setting will play an ever-more important role in architectural education, in particular where software training forms part of a course’s learning outcomes. In reflection on the findings presented here, the semi-flipped classroom model offers clear advantages over in-class only software training, in particular if the course-delivery method gets fine-tuned to off-load repetitive tool-functionality tutorials online while focusing on more complex issues that require face-to-face interaction between tutor and students. At the same time, the research highlights that there is still ample room for improvement of the blended learning mix presented in the case study. As much as pre-configured third-party e-Learning platforms offer a solid back-bone for learning software, their use needs to be complemented with social network interfaces that allows students to exchange notes and discuss the material at hand. In addition, these platforms need to become more configurable and permeable to allow tutors more options to customise content to fit specific course content, as well as addressing specific assignment deliverables. In this context, students lamented the lack of such flexibility and specificity in particular with the Lynda system and they found it at times difficult to find the exact content required for the course. This observation raises another point: The need for tutors to carefully curate online content in conjunction with their own course structure and the limitations thereof, due to the added effort for customisation and updating content each semester. The demand for a permanent audiovisual record of in-class tutorials has clearly been expressed by students. The complexity inherent to Computational Design tools as well as BIM software makes it difficult for students to keep up with ‘live’ tutorials. Being able to go through content after class at their own pace would allow students to repeat the tutor’s instruction step by step, thereby gaining better understanding of the material presented. The installation of in-class recording equipment in all computer labs has since been commissioned in the author’s home institution.
References


