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A Socio-Cognitive approach to Knowledge construction in Design Studio through Blended Learning

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ABSTRACT

This paper results from an educational research project that was undertaken by the School of Architecture, at the University of Liverpool funded by the Higher Education Academy in UK. The research explored technology driven shifts in architectural design studio education, identified their cognitive effects on design learning and developed an innovative blended learning approach that was implemented at a master's level digital design studio. The contribution of the research and the proposed approach to the existing knowledge and practice are twofold. Firstly, it offers a new pedagogical framework which integrates social, technical and cognitive dimensions of knowledge construction. And secondly, it offers a unique operational model through the integration of both mediational and instrumental use of digital media. The proposed model provides a useful basis for the effective mobilization of next generation learning technologies which can effectively respond to the learning challenges specific to architectural design knowledge and its means of creation.

INTRODUCTION

The potentials to advance design education through the use of online digital media, Web 2.0 and computer-mediated collaborations have been extensively covered in literature (Bendar & Vredevoogd, 2006; Chen & You, 2010) with references to their diverse implementations in specific contexts such as in virtual and augmented design studios (Kvan, 2001; Laiserin, 2002; Reffat, 2007) and with implications on the design studio pedagogy (Osborne et al., 2011). The literature identifies several factors that contribute to the added value and efficacy of technology integration into design studio education especially when implemented within a blended learning context (Ham & Schnabel, 2011; Saghafi et al., 2012). The potentials of blended learning to enhance student learning experience and aiding the development of

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critical thinking and communication skills have commonly been acknowledged and widely published (Behling & Klingner, 2010; Garrison & Vaughan, 2008). However, the potentials of blended learning on collective knowledge construction have not yet been explored in a design studio context.

Design-studio lies at the heart of Architectural Design education which aims to simulate aspects of professional practice in a studio-based learning environment. Students are given a complex design problem (project) and are assisted by their studio tutors in developing solutions. The underlying pedagogical approach is very similar to problem-based learning but combined with "design-thinking" as its core methodology for creative problem solving. In a design studio, students learn through learning-by-doing, in a continuous dialogue with their tutors and peers and through continuous reflection on their action (Schön, 1983).

The integration of information technology into the specific context of architectural design-studio has two distinct dimensions and subsequent repercussions on design learning. First is the *mediational* dimension where digital media is used as a mediating platform within which formal or informal learning take place. Various social media and engagement tools, such as blogs, social-networking sites, open source platforms and wikis facilitate informal modes of interactions across a community of learners, providing various opportunities including skill building and access to various resources (Lane et al., 2015). A more formal use of mediational platforms are through the 'Virtual Learning Environments (VLEs) (e.g. Blackboard, WebCT), currently used across most higher education institutions, providing structured and administrative support for module delivery, student tracking, assessment and access to resources (Mizban & Roberts, 2008). However, a common observation is that a majority of the existing VLEs are based on top-down, instructionist principles (Cannings & Stager, 2003). This does not fit with the reflective, dynamic and situated knowledge building necessary for design learning inspired by the principles of constructivist and experiential learning (Kipcak, 2007).

The second is the *instrumental* dimension where various digital design media and software serve as a means or agency for generating disciplinary knowledge content, as well as aiding the conceptualization and actual production of designs and new design methods. Various digital and computational design and analysis software (Rhinoceros, Grasshopper, Revit, Sketch-up, AutoCAD, etc.) offer designers and learners the means to explore vastly complex building forms, and make possible to model complex behaviour, including environmental and structural performance, pedestrian flow, code compliance, and other systems which open up unprecedented possibilities in embedding intelligence into the conception and realization of designs.

This paper argues that an effective utilization of blended learning in architectural education requires careful consideration and effective integration of *mediational* and *instrumental*

dimensions of information technologies specific to the discipline and practice of Architecture, and as such, presents findings obtained through the development and implementation of a new pedagogical approach in the context of a master's level design studio. The paper will demonstrate:

- A new pedagogical framework which integrates *social, technical* and *cognitive* dimensions of *knowledge construction* in the development of an effective blended learning environment.
- A new approach to blended learning through the integration of both *mediational* and *instrumental* use of digital media under the same operational model.

The practical development of the proposed blended learning approach have been (i) founded on the theoretical principles of social (Spady, 2001) and cognitive construction of knowledge (Forman & Cazden, 1985); and (ii) formulated to aid the development of both *autonomous* and *distributed* cognitions in learners (Kocaturk et al., 2012). One of the motivations and rationale behind the formulation of this research is closely related to the recent changes and emerging themes in the professional and educational context of Architecture discipline which calls for a re-orientation of the design curriculum, new methods of delivery and pedagogical agendas (Allen, 2012) as described in the following section. The paper will then present the theoretical grounding of the proposed approach, formulation of the main research questions, followed by a detailed report on the development, implementation and analysis of the proposed blended learning environment.

EMERGING PEDAGOGICAL AND COGNITIVE CHALLENGES IN ARCHITECTURAL EDUCATION

When we look back over the past two decades of architectural education, we distinguish three distinct, yet interconnected, tendencies that have emerged and currently challenging the conventional norms and practices of architectural education. The first is a newly formed link between education and profession through social, technological and intellectual networks among (design) tool builders, practices and academy. Through various workshops, real design scenarios are collectively developed, modelled, computed, simulated and fabricated, opening paths to new agendas as well as experimenting with new ideas, theories, methods and techniques of educating the new digital designer. The second is the emerging modes of informal learning through online social media which is already becoming an integral part of student experience in higher education. Many online platforms and blogs provide online training and open-source design scripts, 3D models and other forms of information accessible by a global network of designers. These highly fragmented modes of informal web-based knowledge acquisition and sharing provide powerful inputs to knowledge/skill building, but the process is highly learner centric and driven by the needs and aspirations of the individual

learner(s). This contradicts with the existing top-down and controlled course structures of the formal architectural education with pre-defined learning outcomes. One of the main challenges today is, for students, to make sense of the highly complex, contradictory and very contextual knowledge they encounter without relevant frames of reference, and for the educator, to balance the freedom/ autonomy of individual learner with the critical interpretation of the captured information (Siemens, 2004). The third is the expansion of the profession's knowledge-base. An increasing emphasis is placed on architecture's instrumentality and ability to confront actual problems and integration of digital design media and multi-disciplinary values into the design education (Kocaturk et al., 2012). This has led to a diversity of skill sets and pluralist tendencies. Today, there is not a single dominating design direction or agenda, but a series of diverse intellectual agendas and points of views. This pluralism is contributed by the intrinsic methodologies implicitly embedded in the commercially available "digital design tools". A student working with various design media, such as Rhinoceros, Grasshopper, Generative Components, Autodesk Revit or Digital Project develop both complimentary and at times contradictory approaches to design tasks and become exposed to highly contextual, technology-bound and situated perceptions of the problems. The influence of tools on the way we think and design has never been of this magnitude and variety.

Both *instrumental* and *mediational* use of information technology in design education have led to the emergence of a highly 'tool-aided', 'socially shared' and 'situated' form of cognition commonly referred to in literature by developmental psychologists and learning theorists as "distributed cognition" (Hutchins et al., 1986) or "distributed intelligence" (Pea, 1993). The central idea in both theories is that the resources that shape and enable activity are distributed in configuration across people, environments, situations and artefacts (tools). In pointing out the mind-environment interface (Simon, 1996) in his seminal work: The Sciences of the Artificial, Simon questions whether what we often consider the complexity of some act of thought may have more to do with the complexity of the environment in which action takes place than the intrinsic mental complexity of the activity. He then suggests looking at problem solving as distributed between mind and the mediational structures that the world offers. This is a very distinct departure from earlier models and approaches to "design cognition" which has traditionally been perceived as residing in the head of the designers and traditional architectural education has commonly geared towards the development of individual (or autonomous) cognition. One of the main pedagogical dilemmas today can be grounded on the gap between *distributed* and *autonomous* dimensions of cognition that students are building, simultaneously, through various modes of knowledge acquisition without any explicit recipes of how to build the link between the two. This observation resonates with Salomon's description of the 2 distinct impact of technologies on individual cognition (Salomon, 1993):

- *Effects with* - intellectual partnership with technology through direct contact with digital media (Distributed Cognition)

- *Effects of* - transferrable cognitive impact that the aforementioned partnership leaves behind in the form of better mastery of skills and strategies; also referred as "meta-cognition" (Perkins, 1993) which not only informs the construction of an understanding of content-level knowledge (of the discipline), but also provides conscious use and development of skills.

An effective blended learning approach in architectural studio education should take into consideration both of the aforementioned impacts of technology on learning. This would imply that the added value of a blended learning approach in the design studio would not only be the development of essential skills to work with diverse design and communication technologies but also equipping the learner with an awareness and understanding of his/her own thought processes.

RESEARCH QUESTIONS AND CONTEXT

The aforementioned discussions provided the main theoretical and methodological grounding for the formulation of the following research questions with the aim of drawing conclusions that are of generic relevance to architecture educators.

- How can *mediational/instrumental* use of digital media and face-to-face interaction effectively be integrated in a studio context in support of collective "*knowledge construction*" and "*skill building*" that would not have been possible in a traditional studio approach?
- How to utilize this blended learning approach with the necessary social, technical and cognitive scaffolding to support the three crucial and highly complementary dimensions of learning (and cognition), *individual, collaborative and guided,* under the same pedagogical framework?

Implementations of blended learning in traditional design studios, through the integration of various *mediational* media are already common practice. In order to explore the integration of *meditational* and *instrumental* use of digital media under the same pedagogical framework, the research has been specifically set up in the context of a *digital design studio* where students were expected to embed various digital design and simulation media into the actual design process from conception through to physical production of their solutions/creations. The digital design studio was a semester long, campus based masters level design studio module with the following learning outcomes:

- Demonstrate a novel understanding of parametric and computational design thinking in an architectural design project.

- Demonstrate a critical understanding of how to select and apply appropriate design strategies and techniques to generate, represent and communicate innovative architectural design solutions.
- Critically appraise the limitations and opportunities in embedding generative design thinking in response to spatial, social, environmental and material investigations in Architecture.

The studio comprised of 30 students coming from diverse educational backgrounds relevant to the AEC (Architecture, Engineering and Construction) sector, primarily from Architecture, Building Surveying, Architectural Technology, Product Design and Civil Engineering backgrounds. One of the challenges we faced throughout the studio was to embed a complex computational design challenge in a design studio module with very specific learning outcomes, with students who have very little or no prior knowledge or skills of computational and parametric design, with only 2 hours contact time per week.

The design brief comprised of the design and development of a temporary pavilion through an "informed" and "collaborative" design process, in response to a range of design criteria such as day-lighting, energy use, structural stability, and local climate conditions. Parametric design process had been introduced as a means (instead of an end) in identifying, selecting, optimizing, controlling and linking parameters in the design and development of a pavilion design. Students had been given the freedom to work with any design, modelling and analysis software of their own choice. The brief required students to design in teams where each team member was assigned both individual and group tasks. Each team was composed of 3 members, composed of; a Design Architect, a Manufacturing and Sustainability Consultant, and a Knowledge and Communication Manager. Each team was expected to identify and collectively formulate cross-disciplinary challenges and problems, first, and then develop creative design solutions.

In addition to the design task, the second part of the design brief focused on the task of *knowledge construction*. Knowledge construction is one of the key activities of a design-based learning environment where students build and integrate different types of design knowledge (e.g. procedural, conceptual, factual) - individually and collectively. However, students are not always conscious about their knowledge building process as it occurs naturally during the design process. By embedding "knowledge construction" as an additional task into the brief, we aimed to make students consciously aware of the knowledge they use, generate, and exchange and, thereby, we placed knowledge construction (and its representation) at the heart of our blended learning framework. This approach required a thorough exploration of not only technological but also social configurations needed to achieve the "aid" a design studio could realistically benefit from a blended learning approach. In this regard, how digital technology could aid the mediation of collaborative and individual knowledge construction (and cognition) has been central to our enquiry.

The context surrounding the process of knowledge construction aimed to interlink both autonomous (individual) and distributed (collaborative) actions spanning across technological, social and cognitive scaffolding of the studio, including both on-line and off-line learning modes. For this purpose, each group has been assigned a blank Wiki group page, hosted under the relevant module of the University's official VLE – Blackboard - platform to manage, coordinate and document their knowledge construction and communication during the entire design process. This idea largely resonates with Gerry Stahl's work (Stahl, 2006) where computers and software technology had been explored according to the extent to which they support collaborative knowledge building for the development of shared understandings and new meanings. New knowledge and strategies gained through peer collaboration and by interpersonal discourse could then be documented through these Wiki sites, composed of both individual and team input, and shared by peers and tutors. Students have been required to "exploit" a wide range of and the most suitable representational modalities to assemble their Wiki sites. Team members were not only required to collaborate for the design of the pavilion, but also for the production, selection, preparation and curation of the relevant knowledge content they generated for their Wikis.

The teams had also embedded a "conversation page" into their Wiki sites where online communication of team members with tutors and each other could be recorded in support of the knowledge construction task (in addition to face-to-face interaction). At key times during the semester, teams were asked to share their Wikis across all teams where the entire studio could communicate online, share design ideas and provide peer feedback.

It is important to note that setting the research within the context of an existing studio module had posed a number of constraints in data collection and analysis. Firstly, the module had pre-defined learning outcomes which could not be altered. This meant that the research objectives had to be carefully aligned with the objectives of the brief. In order to do that we introduced two separate – yet interlinked – tasks into the design brief (one linked to the learning outcomes and the other linked to the research objectives). However, the additional task (knowledge construction) brought forth an additional workload for the students and therefore could not be introduced as an assessable component of the module. Although all teams were involved in the knowledge construction task, only half of the students volunteered for the interviews. The second constraint was with regards to the choice of the Wiki platform for knowledge construction which had to be the official VLE (virtual learning environment) of the University (Blackboard). Therefore the research set-up and the findings were somewhat influenced by the capabilities and shortcomings of this platform. Although we allowed students to use external web environments as and when needed; the links to these environments had to be created within the official University-based Wiki platforms.

METHODOLOGY

The study adopted an ethnographic approach which focused on gathering data on student and staff perceptions. Ethnographic based research encompasses participant observation, interviews, literature analysis and information gathering. It can be summarized as "the study of people in naturally occurring settings", and "involving the researcher participating directly in the setting", "in order to collect data", without meaning being imposed externally (Brewer, 2000). An ethnographic approach is most relevant when the study is carried out in situ and where the researcher takes a first hand view of phenomenon under investigation. It differs from similar types of qualitative study by its purpose to study people in their natural environments (Joel et al., 2005). Although data collection and analysis were predominantly qualitative in nature, we also referred to quantitative data analysis methods. This mixed approach has proved to be rather useful in our attempt to draw meaningful results from a large body of qualitative data with complex nature of inter-relationships between different factors. For example, the correlation between the frequency of cross-team interactions and the quality of the (design) content could have been effectively revealed through collection and cross-analysis of both quantitative (e.g. frequency of interaction captured by the Wiki platform) and qualitative data (e.g. student interviews and tutor perceptions). As a result of the different methods of data collection, data had been visualized and categorized in different ways which helped to identify the numerous factors that might have had a bearing on those components of the qualitative information that could not be easily interpreted.

Main data collection comprised of two sets of individual and group interviews and personal observations to gather different kinds of data. Data sources included field notes, audio recordings (of interviews) and Wikis (and the constituent sites) developed by students and data records obtained through the Blackboard system. A total of 5 hours of recordings were produced with 40 sheets of notes and 10 wiki sites. The interviews were transcribed verbatim, data-coded and analysed using comparative procedures where every response in the field notes and transcripts were labelled with terms that best captured what the main idea and concept was about. The wiki sites which were built by the students had also been comparatively analysed with respect to the utilization of various representational modalities in knowledge construction.

Two sets of semi-structured interviews were conducted at two separate times (mid-semester, and end-semester) with a random selection of 15 students for each interview. Students took part in the interviews on a voluntary basis. All signed ethical consent forms before each interview in compliance with the guidelines of the University of Liverpool and the British Educational Researchers Association (BERA, 2011) with respect to anonymity. Students had been interviewed both individually and with their team members (in groups of 3) to identify

patterns in data whilst enabling the collation of material on different views, motives, reasons and explanations. Semi-structured interviews were preferred over questionnaires with pre-defined questions for the following reasons, specific to the context of the study.

1) since this was an exploratory research, novel and unexpected emergent issues could also contribute to the data analysis and interpretation,
2) the students were from different nationalities (e.g. British, Indian, Ethiopian and Chinese) which required frequent clarifications of terms and rephrasing the questions - in some occasions several times - in order to convey the intended meanings correctly,
3) students' different understanding and interpretations of terms, such as "design process", "tools" or "models", due to their varying educational/disciplinary backgrounds and levels of experience, required additional clarifications of terms and concepts.

Every interview comprised of 3 stages: the explanation of the research project (aim and objectives), the signature of the ethical consent form and the interview which was digitally recorded using a laptop and a voice recording application. Interviews were conducted by one of the research assistants of the project who was not part of the tutoring team in the studio, to ensure student anonymity. The interviews focused on collating information on (i) students' background and motivations, (ii) their previous knowledge and skills in use of digital design and social media, and (iii) their reflection on own learning specifically focusing on individual, collaborative and guided learning experience – in line with the project objectives. Students were asked about their perceptions of the opportunity afforded by the on-line components of the blended learning, and also for their perceived level of engagement.

DISCUSSION OF FINDINGS

The primary modes of use of the Wikis sites were twofold: (i) creating content, and (ii) communication; which had been regarded as the main activities leading to knowledge construction. We monitored both modes of use on a regular basis to have an overview of the frequency of use, quality of the content uploaded, as well as team and cross-team interactions. Additionally, we captured the day and time of every comment made in the Wiki sites for the duration of Semester 1 (Figure 1).

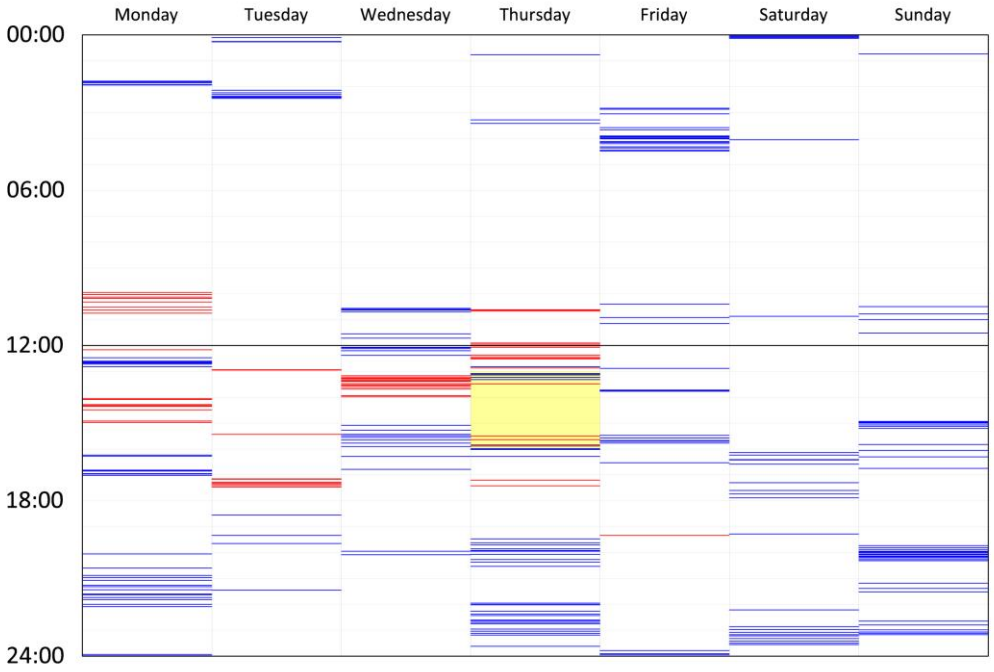

Figure 1 Distribution of comments made throughout the semester over a weekly calendar. Blue lines indicate student comments, red lines indicate tutor comments, and yellow highlight indicates the formal teaching hours

Figure 1 provides evidence of almost constant use of Wikis outside formal teaching hours throughout the semester. Clusters of comments can be identified as evidence of students' visits to various Wiki sites during a single visit. There is also clear evidence that tutors' comments are predominantly kept within working hours, although spread across different days of the week (outside teaching hours). According to the interviews, students outlined the main benefits of the Wikis as (i) communication with tutors outside working hours; (ii) organizing and recording their own work; (iii) reflecting back on their design process (iv) having access to other students' work and thinking; (v) communicating with peers and learning from them.

Cognitive Aid to Learning Through Multi-Modal Representations

Due to the richness of representations used, the Wikis in this particular project, can be regarded as a "learning portfolio" rather than a "reflective journal" (Roberts, 2013). While students made use of a very rich variety of representational modes, techniques and assemblies, different media were carefully chosen to convey the intended messages through the right content; including texts, 3D visualisations, sketches, diagrams, mind maps, animations among others. Additionally, some groups were able to embed videos using

external sites such as YouTube and provide hyperlinks to external presentations (e.g. Prezi). Texts and images were mainly used as descriptive and reflective resources or to transcribe group communications and meetings. However, Wiki sites also entailed prescriptive information, such as the use of a design software for modelling purposes. The below figure is a compilation of snapshots from different Wiki sites illustrating the richness of representational modalities used by different teams (Figure 2). Additional media resources (presentations and videos) were hosted outside the wikis but were embedded into the wikis through hyperlinks.

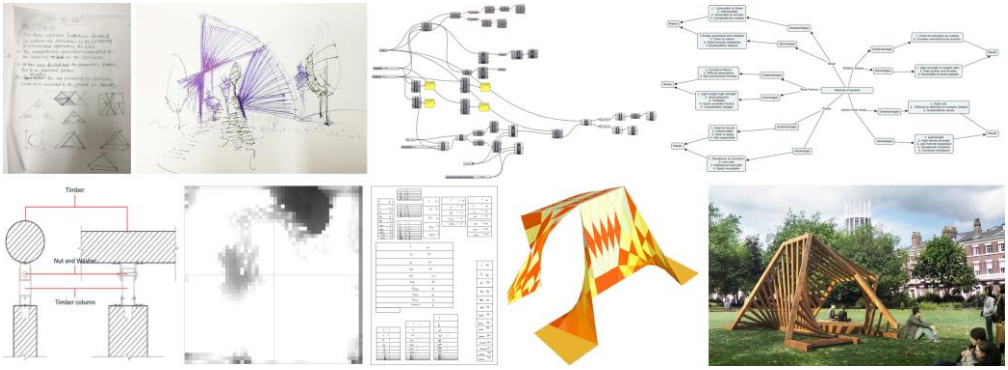

Figure 2: Different representations uploaded to the Wiki sites by students. From left to right and top to bottom: Notes from a group meeting (Group 10), handmade sketches (Group 10), Grasshopper modelling sequence (Group 10), mind-map (Group 5), building detail (Group 9), radiation map (Group 2), laser cutting patterns (Group 7), solar lighting analysis (Group 10) and realistic render (Group 10).

It is important to note that Wikis did not comprise of single or standalone representations of design ideas, but instead, they were intended to act as intelligently structured interactive platforms. Therefore, students were specifically instructed about the rationale behind constructing their Wikis where information/knowledge they gathered during the semester could be clearly linked to the evolution of their design ideas and solutions, with an easy-to-follow navigational path. And to this end, a rich variety of representational tools and media have been explored and utilized to assemble the sites.

Wikis acted as the primary *mediational platform* wherein students compiled and recorded various design ideas, information, insights and solutions that have been created either individually or as a team. In this process, students used a variety of digital media for generating and modelling the knowledge content. An analysis of the interview records indicates that there were clear differences in the way digital tools had been utilized, and which had been highly influenced by the students' personal experiences and backgrounds. For example, one mature student, with no formal training on digital design tools, was used to working with intranets to share files across different people in his practice. This past

experience helped him use and organize the Wiki pages much more effectively for recording and sharing design information. On the other hand, students with no collaborative working experience focused more on exchanging files through social media (such as QQ - a chinese social networking site similar to Skype) without much consideration to the semantics embedded in the files. In support of group interaction, social media was mostly used to chat (in real time) and to exchange files (both features not provided by Wikis). One group attempted to use Wikis as a real-time and synchronous communication platform however the lack of instant notifications makes Wikis unsuitable for this purpose. Other shortages of the Wikis were reported as lack of (i) real-time chat and (ii) instant file sharing functions. Therefore, Wikis could only aid the asynchronous modes of design communication, yet synchronous communication was sustained through social and other online media. The following diagram summarises the use of the following modelling/representational and communication tools by the students (Figure 3).

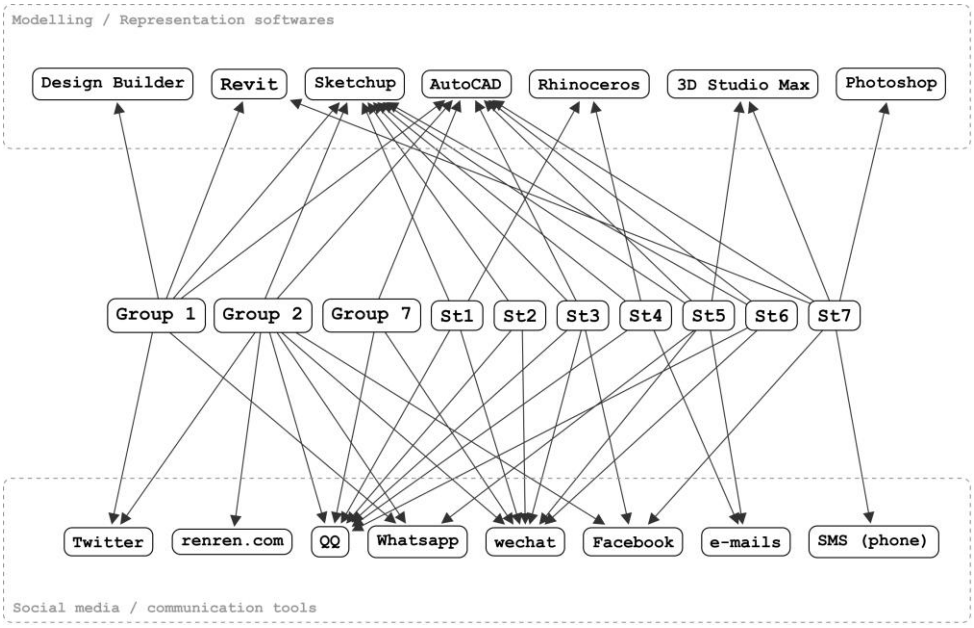

Figure 3 Use of different meditational and instrumental media during the semester

The versatility with which students made use of available media was aligned with the well-established studio tradition where different modes of representations are produced and presented (Iordanova & Tidafi, 2007). However the main added value obtained through the construction of Wiki sites was exposing students to a rich repertoire of representational modalities as a vehicle to convey the intended meaning to the intended audience (e.g. peers, instructor, team members) for a specific purpose.

In digital design studios, students spend considerable time in developing software skills in parallel to the design task. In order to remedy this, the tutors have created a dedicated space within the Blackboard environment where students could access to a selection of highly relevant video tutorials of the most preferred design/modelling software. Students were

expected to follow these tutorials in their own learning time but were given guidance in terms of the order with which they should follow these tutorials in line with the progression of their parametric design process. An anonymously shared view among students was that the most effective way to build their software skills was to share experiences with their peers through the Wiki sites. Indeed, Wiki pages with the highest number of comments and replies were those dedicated to strategic and operational use of the design and modelling software (e.g. Rhino/Grasshopper) in converting specific design ideas into 3D parametric models.

Collaborative Learning Versus Individual Learning

While collaborative work is considered a fundamental skill in contemporary higher education and particularly in architectural design, its use blurs the boundaries between individual and collaborative work, making individual contributions difficult to identify and assess (Trentin, 2009). Web-based tools can support this issue by facilitating the monitoring work, and sets of variables have been developed for monitoring collaborative and individual work such as "levels of learning" (Trentin, 2009) or quantitative estimations of both individual and group activities (Simoff & Maher, 2000). In our research, interview questions related to the estimation of individual and group work were mapped to students' roles in the team and the team dynamics. These questions were repeated both in group and individual interviews to identify potential discrepancies in student perceptions. Students perceived that their work for studio purposes entailed, on average, 16.7 hrs per week ranging from 5 up to 50 hrs across the interviewees. An interesting variable was, however, how much of this work was dedicated to collaborative work versus individual work. Students reported that a majority of the time dedicated to the studio work was spent on collaborative work, whereas an average of only 6.8 hrs a week was reported to be spent on individual work (which also includes software training time). The individual work in the design studio focused on the delivery of the tasks defined by the roles each student played in their teams. However, each role required different tasks which varied in terms of the time they consumed. Team work focused more on collective decision making on various matters. A more detailed, case-by-case analysis is required to set relationships across variables, however some initial observations suggests that there were obvious correlations between how the different roles in teams were adhered to and managed, as well as individual and team performances. Teams that did not clearly distinguish tasks associated with each role and tended to mix tasks on a "everybody-does-everything" basis had difficulty in progressing their projects and the designs. Conversely, groups with clearly defined roles – e.g. the knowledge manager responsible for updating the Wiki sites, or Design Architect spends more time on parametric modelling - seemed to work more efficiently. Although students themselves volunteered to take on their preferred role, in most cases their learning motivation went beyond their role description and led to conflicting perceptions of the time allocated for their team responsibilities and personal (individual) development.

The integration of formal and informal learning modes in a blended learning environment contributes significantly to the "self-directed" hours of design learning. However, the

perception of this additional workload varies significantly across students, especially in terms of the distribution of workload between individual and collaborative work, as indicated in Figure 4 below.

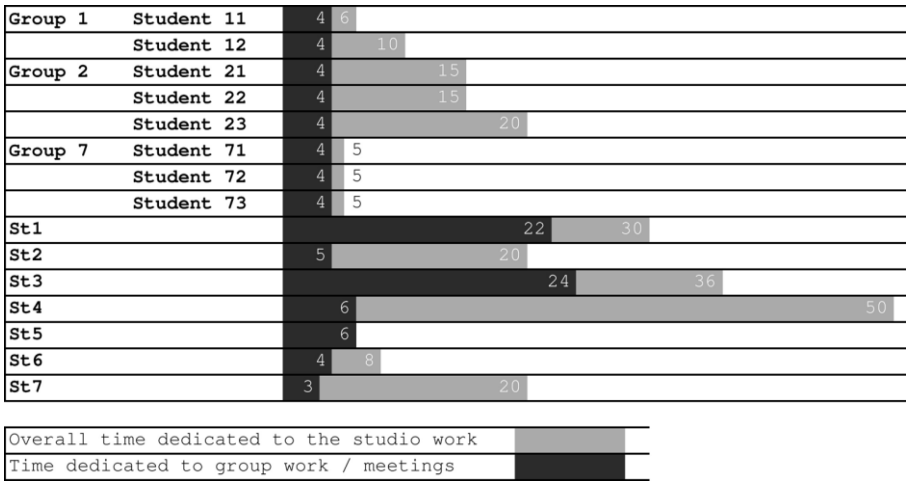

Figure 4 Variances in student's perceptions of their studio related workload

The graph is built upon students' perceptions of studio-related workload, expressed as hours per week. An interesting observation is the changing perceptions of individual and collaborative workload of the students within the same group. For instance, St1 and St2 worked in the same group, yet their workload perceptions vary more than 10 hrs per week and moreover, the collaborative work indicated by St1 is greater than the overall studio workload indicated by student St2. The most anomalous case is that of St4 and St5 who also worked within the same group. A possible explanation for this might be that St4 had the role of the "Design Architect" and spent a substantial amount of time, since the beginning of the semester, on software training which he also counts towards group work. However, St5 worked as the "engineering and manufacturing consultant" and did not prefer to spend any additional time on software training nor did he perceive his individual work differently than the collaborative work of his team. This is a typical example of a commonly observed phenomenon about blended learning, due to embedding new media environments into learning experience, which require students to apply higher levels of personal motivation and autonomy through high levels of student-led activity and as such are not suited to all students (Lane et al., 2015).

Tutors As Curators of The Individual And Collaborative Learning

The role of studio tutors focused predominantly on providing guidance on the conceptual organization of students' learning experience (Glaserfeld, 1983) through both face-to-face and online modes of blended learning. The first two weeks were front-loaded with face-to-face

seminars where all students were engaged in highly interactive discussions on the subject matter to form the foundational intellectual basis that was deemed minimum to build before they got engaged in any tool-driven design activity. Students were also encouraged to follow the online video tutorials for the essential modelling software at the pace and order suggested by the tutors. Wiki sites have been introduced and knowledge construction model was explained together with the design brief. The central aspect of tutor guidance was to support students' design knowledge construction and, to that end, create the necessary physical and online spaces where students could build, explore, and connect different knowledge elements and skill sets. The guidance provided to individuals and different groups varied according to specific requirements.

Referring to the taxonomy of (Blignaut & Trollip, 2003), the online guidance provided by tutors consisted of the following modes as described and exemplified with actual comments left by tutors on Wikis, in Table 1.

CATEGORY	**Posts by Tutors on the Wiki Communication pages**
Affective	*"… I think your group communication through this Wiki site is one of the best in the class. And [Student] is doing a great job stimulating the group to be more active on the Wiki…."*
Corrective	*"… could be done as a lofted surface... you may use the script i gave you last week for grasshopper" (referred to the 3D modelling of a design alternative, suggesting to modify the modelling technique).*
Informative	*"… the Grasshopper model still seems to be trying to copy the Rhino model. The contribution of the "parametric design process" to the evolution of the design is not very clear. The parametric model does not seem to be driving the process. Have you already tried to update your parametric model in respond to the feedback you received at the interim?"*
Socratic	*"… there is still lack of clarity about how the structure is actually going to work. The issues about ergonomy, and health/safety regarding the walking path in the pavillion are not fully resolved. However, the unique process you've followed from the very beginning is really interesting - the formation of the space and then subtracting it from the overall form to achieve the final form."*

Table 1 Modes of online guidance provided by the tutors

As previously mentioned in Figure 1, tutors interacted with the students outside formal teaching hours through the Wiki sites, which mostly entailed:

- Technical comments related to the operational use of certain design tools,
- Feedback and comments on the design product, process and representations,
- Requests for new uploads and content updates.

The use of Wikis varied over the course of the semester. Teams were given the control to adjust privacy settings to control the accessibility to their Wikis at certain times of the

semester (by fellow students). Such temporal dynamics was also guided by tutors to follow the natural sequence of the design process.

CONCLUSIONS

This educational research project reinforces two fundamental points. The first is the view that design knowledge is both a social and a cognitive construct. The second is that information technologies and design tools act as *cognitive tools* and influence the way people learn, share information, and construct knowledge (Kolbitsch & Maurer, 2006).

Setting the research within the context of an existing studio module posed a number of constraints which affected the research design and findings to a certain degree. Firstly, the pre-defined learning outcomes of the studio module could not be altered. In order to align the research objectives with the objectives of the brief, two separate – yet interlinked – tasks had been introduced into the design brief. However, the additional task (knowledge construction) brought about an additional workload for the students and therefore could not be introduced as an assessable component of the module. Although all teams were involved in the knowledge construction process, only 15 students volunteered for the interviews. The second constraint was with regards to the choice of the Wiki platform for knowledge construction. For ease of monitoring of student activity, and in order to adhere to the University regulations, the Wiki component of the official VLE of the University (Blackboard) had been adopted. Therefore the research set-up and findings were influenced by the capabilities and shortcomings of Wikis although some students created links to external web-environments which proved to have more representational capabilities in knowledge construction. In order to improve the conditions imposed by these two constraints, in the future, it will be useful to allow students to choose their preferred web-platform for knowledge construction and implement this in a studio setting where this additional task is also introduced as an assessable component of the module. This would help increase the student response, and increase the number of data to be used for the analysis.

As our findings suggest, blended learning does not merely imply adding information technology into an existing design studio practice but it changes and challenges some of the fundamental assumptions and practices of the traditional design studio. For instance, the construction of Wiki sites facilitated a deeper understanding of the crucial link between "design representation" and "knowledge representation" which introduced a radical shift of emphasis from a *product oriented* to a *process oriented* approach in design learning. Our pedagogical framework in support of the proposed blended learning model placed "knowledge construction" at the centre of the design studio (Figure 5) which proved to deliver an effective social, technical and cognitive scaffolding in support of the highly complementary dimensions of *individual learning*, *skill building* and *collective knowledge*

construction of the students in the design studio. This aspect helped bring to the foreground other types of knowledge (other than product knowledge) that are usually disregarded or left unnoticed in design education, namely; *procedural, declarative, domain specific, conceptual, structural,* etc. Through knowledge construction and representations, students became much more aware of the different types and qualities of knowledge they produced in relation to the different tasks associated with different phases of the design process.

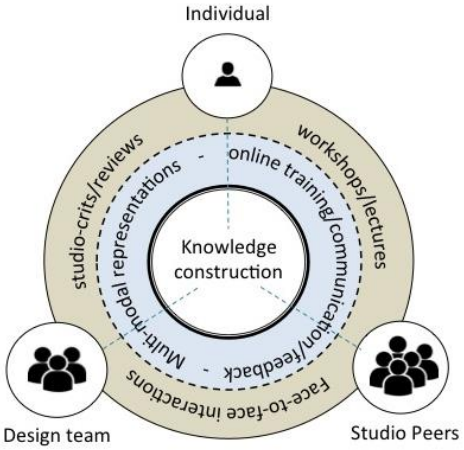

Figure 5 Pedagogical Framework which places individual and collective knowledge Construction at the centre of the learning process

One of the challenges tutors faced in the studio was to balance the reciprocal interplay between the development of both *autonomous* and *distributed* cognitions. This was closely related to the interplay of externalization and internalization processes associated with the process of knowledge construction and also raised a methodical question about how to distinguish variance that is due to individual learner and variance due to tutoring approach.

In summary, the main innovation introduced by the proposed pedagogical framework for blended learning in a design studio are three-fold:

- provides effective cognitive support to design learning through shared knowledge construction and representation among peers,
- integrates the different dimensions of collaborative and individual learning under the same pedagogical framework,
- provides effective support to design studio-tutors in curating students' learning experiences more effectively.

Evidently, what our study shows is that embedding new media and socio-technical environments into learning experience required students to apply higher levels of personal

motivation and autonomy through greater levels of student-led activity. An analysis of the interview records indicated that the way online media was utilized towards learning and skill building varied greatly among teams. Consequently, the benefits of the blended learning in the studio were experienced and exploited differently by each team. Various factors contributing to this variety had been identified, such as previous experience in teamwork, familiarity with digital media, personal motivation, and educational background. This variance had been observed to be strongly correlated to the discrepancies between students' perceptions of their workload even within the same team. This finding suggests that future work, in similar settings, should consist of variables that address both "expectations" and "perceptions" of students simultaneously.

In the short term, the research outputs are expected to accelerate the development of new online and blended learning strategies for the design studio teaching/learning. In the mid to long term, the proposed approach, especially with regards to the integration of *mediational* and *instrumental* dimensions of information technologies under the same operational model is anticipated to have a high impact potential. Currently, technologies that are used to "create content" in design disciplines are completely disconnected from the technologies which "mediate content". Although attempts have been made over the years by some of the CAD (computer aided design) software developers through the addition of communication features (e.g. file versioning, commenting function) into the software platform, for the most part, these attempts had minimal degrees of success, and certainly not in any substantial form which could be used as part of the pedagogical framework developed by this research.

The theoretical and practical model developed through this research was based on the integration of these 2 different groups of technologies under the same learning framework. A more impactful implementation of this model would be through the development of technologies that are intrinsically based on this integrative model. This would potentially lead to the design of mediational platforms with features aligned and interoperable with various design media which are used to create design content (3D models, 2D drawings, structural analysis, urban models, sketches, design scripts, etc.) This could, in turn, provide a basis for the next generation learning environments and next generation training technologies which can effectively respond to the learning challenges that are specific to the knowledge content and its means of creation.

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