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Fostering design collaboration: Novel ICT tools to support contemporary design pedagogy

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Abstract
Professional design practice is in a period of flux and transformation. Technology is rendering the design process increasingly collaborative, interdisciplinary, and cross-cultural, and design studios are increasingly dependant on information and communication technology (ICT). There is a need to reflect these changes in design education, and to train students in the new skills required for industry. This article examines how ICT may be incorporated into design education to enable more collaborative, modern and interactive learning processes to be introduced to better prepare students for professional careers. In addressing this topic, the article examines emerging research that seeks to integrate developments in ICT systems into the higher education design curriculum. The article suggests how such platforms can be adapted to meet the needs of students and tutors, whilst meeting the contemporary requirements of the creative industries. The authors conclude that ICT offers a means of enhancing and complementing existing modes of design pedagogy.

Keywords
design education
digital tools
design research and learning
design pedagogy
computer-supported collaborative learning

Introduction

The nature of design, in both practice and education, is currently in a time of great flux. There are several confluent factors which explain this fluidity, for example: rapid advances in the technologies of production and manufacture; the economic downturn and more competitive business environments; an emphasis on society, the environment and

sustainability; radical shifts in culture and society; and a subsequent rise of the economic importance of the creative industries. These changes are having a significant impact on all aspects of design practice, the profession and the education of future designers.

There is a growing acceptance of the contribution that creative industries make to economic growth (e.g. Cox and Dayan 2005), and this offers increased status to the innovation and ideation work undertaken by 'creative practitioners' (Matheson 2006). The design function is hence becoming integral to organizations. As such, the design discipline is at the forefront of addressing far-reaching market and customer requirements, and developing more meaningful and valuable products (Martin 2009).

For the design profession, this emerging direction requires new skills, methods and tools to enable designers to fulfil more complex requests and requirements. How this affects the work of designers has been the focus of attention in the design and product development literature. It has been suggested that designers are taking a new and an enlarged scope of responsibility throughout the new product development (NPD) process (Perks et al. 2005). This means that design studios are having to offer clients expertise across the entire process of bringing new products to market. In order to cope with new demands, design studios are having to offer clients expertise which extends across all the stages involved in bringing new products to market (Maciver 2012). This is manifest in three clear shifts. Firstly, in the current competitive and pressured business environment, there is the need to share and collaborate with other partners in NPD. Communication with clients and stakeholders is increasingly pronounced and important. This is suggested

as a mechanism for enhancing the NPD process, and increases the adequacy of the resultant product, and is thereby considered key to developing successful products and services (Dell'Era and Verganti 2010; Martin 2009). Secondly, as a result of collaboration, the design process has become more inclusive. While design has always been a collaborative process reliant on the input of a number of different disciplines, by collaborating with stakeholders from other fields and other locations, the design process becomes both cross-cultural and interdisciplinary. This again requires the exertion of expertise in cooperation and collaboration. Thirdly, new technologies are essential for the successful execution of this new paradigm, and designers require capabilities in the use of information and communication technologies (ICTs) together with expertise in computer-aided design (CAD). In sum, managerial skills and digital expertise are additions to the traditional craft-based skill set of the design profession.

These factors are indicating a shift in paradigm. As design studios are required to communicate and collaborate to an increasing extent with international partners when bringing new ideas to fruition, technology, and in particular ICT, is becoming central to the business operation of design organizations. In recent years, design firms have had to learn methods to transcend cultural and language barriers, and to learn the logistical possibilities of working alongside others in different continents and time zones (Yang et al. 2005).

Such profound developments in industry and professional design practice must be accompanied by changes in education, and there is a clear need for higher education

institutions to meet modern requirements for collaborative, interdisciplinary and technical competencies (Rodber and Wormald 2007). Since the creative industries are overtaking manufacturing in relation to their economic importance in most developed countries, there exists the need to formalize the skills required for new designers entering the creative industries workforce (Banks and Hesmondhalgh 2009). Despite calls for change in design education from a focus on craft skills to more human-centred awareness (Norman and Klemmer 2014), integration of new digital learning environments has been slow. Indeed, recent evidence highlights shortcomings in the preparation of students for the workforce and emphasizes the need for engagement with the tools of practice whilst in education (Ive 2014).

This article explores the application of emerging digital methods in design pedagogy. It is suggested that these can be integrated into the curriculum to enhance traditional studio teaching approaches. Examining the background behind new digital platforms, as well as the growing necessity for digital collaboration and communication in the business context, the article proposes ways in which technology can be used to enhance the learning experience for design students. Reporting on the pedagogical application of several emerging digital platforms, the article suggests how these platforms can enable students to engage with learning materials and participate in collaborative, interactive design projects. It is suggested that this concept has the potential to provide a fuller learning experience, meeting the needs of tutors and students, including those with learning differences, and providing adequate preparation for real-life design contexts.

Modernizing design pedagogical frameworks

There exists an urgent need to reshape design education to meet the demands of commerce. Higher education institutes (HEIs) often struggle to respond quickly and flexibly to producing new teaching and learning methods that cater to the changing demands of both students and industry. However, there exists the potential to develop novel, innovative and ground-breaking techniques to support collaborative learning strategies. Despite the symbiosis between the design and technology (D&T) and ICT disciplines (Spendlove and Hopper 2004), there is often disconnect between teaching and research in HEIs. This is particularly apparent in art and design institutions, where translating creative practice into practice-led research is problematic (Britt 2013).

As more and more institutions develop areas of expertise in art and design research, a range of different forms of practice-based research have emerged. One of the main characteristics of design research is that it tends to be pragmatic in nature, interventionist, and often operates within clearly defined boundaries, it may also be collaborative and interdisciplinary. The initial research questions and methods may borrow from a range of research paradigms including the sciences and social sciences. The development of artefacts may be a key method for exploring particular issues, for example, providing evidence for the effectiveness of a process. Art-based research may be more emergent and philosophical in nature, relying on the researcher to discover the key issues and refining methods as part of a reflective process in which the research questions become clearer and more focused as the research develops.

There is emergent evidence to suggest that art and design education is beginning to change in response to research and the contemporary context. The value of interdisciplinary work practices in education has been recognized as providing a solid foundation for students (Kearney and Harris 2013), and research has trialled and recommended the use of international collaborative projects in the design context (Bohemia and Ghassan 2012). In addition, many institutions are developing new design courses and modules responding to industry trends, such as service and experience design, design research methods, usability, and management, and there is a palpable shift in focus from three-dimensional workshop time to computer-based class time (Ive 2014). There is also a greater emphasis on constructivist learning, as students take a more active and dynamic role in generating course content and influencing learning methods (e.g. Malins et al. 2015; McLoughlin and Lee 2008; Winters 2011). Taken together, this evidence suggests a tentative shift to new methods and technologies in the teaching, study and practice of design subjects. It also hints at changes in student expectations for multimedia and interactive learning experiences.

Technology has the potential to modernize and enhance the learning ecosystem, and there has been effort to develop e-Learning frameworks especially for higher education (Littlejohn 2005). Virtual learning environments (VLE) such as Webex, Blackboard and Campus Moodle have become commonplace in institutions over the last decade. Such tools support staff-student communications, the uploading and downloading of learning content, group e-mails, and basic interaction between members of a group. Standard file

formats allow for documents created in commonly used office software to be shared. Examples of content which might be shared on a course directory include reading lists and assignment instructions in simple text format; articles and reading material in PDF documents; and course descriptors and student assignments composed in Microsoft Word. These platforms meet the needs of many types of learning situations. However, they have been designed for circumstances where learning materials are predefined by the tutor, where content is based on text, and where the curriculum is followed in a strict sequence. The needs of educators and students in subject areas that are founded upon tutor-to-student learning – for example, business studies, sciences and humanities subjects – are addressed by these systems. Since these subjects make up the majority of HEIs course repertoires, take up of VLEs has been strong (Browne et al. 2006).

Differing ICT requirements in design education

In practice-based subjects such as design, requirements differ. There is a distinction across the learning context in these subjects, for example in learning materials, methods and outcomes, assessment criteria, and types of coursework. In the design-learning environment, the emphasis is on experimentation, reflection, discussion, fieldwork, visuals, three-dimensional objects and process. This is acknowledged and reflected in many aspects of the design school composition, such as in the buildings, physical environment and the timetable structure, and typical features are studio space designed for practice rather than lectures, free-flowing and unstructured class time, low staff-student ratios, discourse in small group settings, and the prominence of practical

equipment and visual stimulus (Bender and Vredevoogd 2006; Fisher 2006). Since these requirements are profoundly different, it is unsurprising that digital tools also have a distinct application.

However, the tools commonplace in design schools do not meet the pedagogical requirements of design-related courses, and there has been a lack of uptake of digital teaching methods in this field. Bender (2005) identifies several barriers to the integration of technology in design teaching, for example, limited successful case study examples of online education in design; a reluctance on behalf of lecturers to teach in an online environment; and insufficient time to prepare content to support a virtual studio. Other problems such as a lack of adequate resources and lack of recognition from university administrations regarding new pedagogical requirements are more widespread (Stensaker et al. 2007). However, it has been argued that ICTs in fact enhance learning (e.g. Wang 2011). Since the design school composition has been constructed to fit its pedagogical requirements, it is logical that technology must also be designed to match its specific purpose, and address the needs of its users. By better meeting user requirements, it is suggested that VLEs and ICT can be integrated to enhance the new collaborative context in design schools.

Technologies are emerging from design and human computer interaction (HCI) research that are beginning to address the requirements of industry, students, educators and HEIs. There is a growing impetus for using the techniques of design as a mode of enquiry (Zimmerman et al. 2010), and design scholars are uniquely placed to be able to assess

what is working well at present and introduce pedagogical responses to the changes in the discipline. By including undergraduate students in the process of developing and piloting, or participation in data collection, new methodologies and the effectiveness of such tools can be tested and evaluated in a natural context. The following section examines how technology is supporting design education requirements, and outlines how connections can be made between innovation and technological research, and teaching methods.

Tailoring ICT to fit design pedagogical requirements

It is good design practice to understand the building blocks of the context and the needs of target users before beginning to innovate and reflect upon new products or services (Kumar and Whitney 2007). The requirements of industry were discussed in Section 1 of this article, and indicated that collaboration, interdisciplinary working and expertise in digital capabilities are paramount in the design profession. In Section 2.1, it was suggested why existing platforms do not cater to the needs of design students and tutors in contemporary situations. As a starting point for considering how new tools may be developed to improve this context, the key requirements of HEIs, students and tutors are summarized in Table 1. Three key themes emerge which need to be addressed in contemporary design learning: (1) collaborative working, (2) assessment and reflection on process and (3) interdisciplinary practice.

Table 1: Summary of varying requirements in design education.

Industry context	Student requirements	Tutor requirements
• Valuing *collaboration* • *Interdisciplinary* working practices • Reliance on digital platforms and methods	• Practical, industry-focused learning • Multisensory learning experiences • *Sharing* with peers • Recording ideas and working off campus • *Reflecting*, iterating, improving	• Enabling *collaborative* practice • Tracking individual contributions in group projects • *Assessing* individual student process

The rapidly developing learning environment calls for new tools to enable and enhance a richer learning context. Technology has the potential to become an enabler in addressing these requirements. Several recent research projects strive to improve design education. Marking the intersection of research and pedagogy, such studies develop understanding of the ways in which new technologies address the varying requirements of design education. The following sections explore how such technologies address the themes of collaborative working, assessment and improvement, and interdisciplinary practice.

Enabling collaborative working

The advent of Web 2.0 with its emphasis on communities, sharing, user-created content, and personalization lends itself to a new pedagogical approach (McLoughlin and Lee 2008). This is reflected in online learning platforms such as Wikipedia, the collaboratively constructed encyclopedia; Linux, the open source operating system; and FreeLearn, which offers courses certified by HEIs to online learners (Stokes et al. 2014). Since design has always been a collaborative process, the Web 2.0 is an ideal tool for enabling student collaborative practice.

Recent studies have researched the use of digital and web-based learning in design education. Bohemia and Ghassan (2012) describe the results of using Web 2.0 technologies, in a project entitled Global Studio, which enables design students from universities in seven countries to work collaboratively with one another across international boundaries. The authors' findings suggest that such modes of international and collaborative learning are essential for the development of design education by providing the foundations for students entering into international collaborative working environments. A similar study of architecture and interior architecture students collaborating between the Netherlands and Turkey emphasizes international and interdisciplinary collaborative project experience as vital in preparing students for the professional design contexts (Karakaya and Şenyapılı 2008). Park (2011) looks at design learning facilitated by an integrated Blackboard learning environment, and proposes that

a successful system must address three components: interactivity, open communication channels and learning evaluation.

The use of virtual, shared spaces enables new approaches to learning where content can continually be updated (Malins et al. 2015), and therefore tailored to the project and learning challenges. The interaction of many students with tutors enables the creation of 'shared objects' which can form the basis of coursework or final assessment. This mode of *trialogical* learning fosters sharing of understanding, engenders critical debate and peer-to-peer feedback, and ultimately encourages the generation of new learning content. These studies illustrate how using an online space, where student authored content can be shared, supports a student-centred learning approach. In this approach, the emphasis is on collaboration as the route to creating new knowledge (Paavola and Hakkarainen 2005), and a computer-supported collaborative learning (CSCL) environment is an apt vehicle for this knowledge-building process (Hakkarainen 2009).

In the field of architecture, Leon and Laing (2013) investigated the use of interactive surface table technology (Microsoft Pixelsense) as a vehicle for promoting efficient collaboration at the early stages of the building design process. The surface table allows a group of individuals to use touch and gestures to interact with content on a larger surface area – for example, drawings can be overlaid onto plans, diagrams or maps to illustrate ideas and concepts. The authors examined synchronous and asynchronous contexts for collaborative working, and suggest the development of tactile surface technology for applications that support distance learning and collaboration. Similarly, technology in

development in the Netherlands, reported by Van Beurden and Groneveld (2014), allows groups to use tablet systems to interact on glass surfaces. While not yet widely deployed in design education, shared interfaces are well aligned with the requirements of the discipline. The large surface area can support brainstorming activities, and students can review the development of ideas using the time lapse recordings made by an overhead camera. This technology takes into account the difficulty in planning for creativity, allowing students to record ideas when outside of the studio with the aid of tablets and smartphones and other mobile devices.

Assessing, reflecting, improving

Closely linked to the idea of collaboration is the issue of assessing, reflecting and learning at the level of the individual. Using solely digital methods means that work can easily be deleted or overwritten, making it difficult for tutors to gain insights into the student's thought and development processes. However, platforms can be developed in such a way that the development of ideas can be recorded during the project. This can be a valuable aid for assessing the student's creative processes, however it has yet to be fully developed as part of a commercial software product. A digital archiving tool is of value in this learning context. The technology for such a platform already exists in the form of a visual 'timeline', familiar to users of social networks such as Twitter and Facebook. Digital snapshots at designated milestones in the project can provide an alternative approach. The recording of the process, which can be filtered according to both

individual and group contributions, enables both the end result and the process of arriving at that point to be considered.

The archiving of material, and sharing of this data among peer groups, tutors and collaborators in projects, can be facilitated using a number of already established tools. There are many online platforms, such as Pinterest, which assist students to find, gather, and organize visual research materials to stimulate the creative process, often used by professional designers. These digital visual archiving platforms can be adapted for use in an educational context.

The sequence of planning, actioning, observing and reflecting on work completed is conventionally discussed in small groups between students and tutors (Zimmerman et al. 2010). While face-to-face discussions cannot be replicated in a virtual context, the present authors propose that the reality of a digital approach to design education could be a radical improvement on the traditional mode of iteration and reflection. They can be improved through helping to support reflective learning, and it is suggested that technology can enable this through archiving and presenting a historical overview of individual contributions to projects.

Facilitating interdisciplinary work practice

In commercial design practice, technology is being leveraged to facilitate a transparent approach to support cross-disciplinary collaborative effort. Transparency is a key concept, given the cultural, language and disciplinary boundaries traversed by designers

today. In education, shared interfaces, multimedia and webinars are examples of ways in which collaborators can freely engage with each other. Liapis et al. (2014) and Malins et al. (2014) report on research to create a design project 'space', entitled Collaborative, Creative Design Platform (COnCEPT), which connects an interdisciplinary community of practitioners, and which can be used for facilitating input to a specific project. The platform is intended primarily for use by product design professionals but has clear application to the educational context. Such a virtual space can enable discussions on project issues, the sharing of ideas and expertise, and can be used as a project management system.

In the context of designing virtually, collaboratively and with interdisciplinary partners, visual communications are imperative for the purpose of adequately conveying and building complex ideas with others. There are existing tools that are responsive to the needs of design in achieving this. For example, infinite digital whiteboard spaces, such as those found in the cloud presentation software Prezi, or in virtual Post-It note software, allow many ideas to be arranged and sorted. Dale (2006) discusses the benefits of digital 'design boards' to stimulate collaboration and interaction during long-distance projects. Such applications are suited to virtual collaboration between many participants. Similarly, virtual mind mapping can be digitized online using tools such as Mind42 and WebspirationPro.

The concepts, tools and research outlined in this article are unified by their aim to enhance virtual interaction and collaboration. What is noteworthy about the studies

described is that many are CSCL projects in their own right. As indicated by Malins et al. (2014), the interdisciplinary and collaborative process involved in developing and piloting new e-Learning tools in HEIs seeks in itself to forge a bond between research and learning. Such developments make for a dynamic and free-flowing educational experience, and has the benefit of allowing regular iterations, improvements and the renewal of learning content.

Discussion: Technology to enhance design education

Whilst acknowledging developments in digital research, we suggest that the integration of real-world, conventional design learning alongside emerging methodologies in digital learning offer a way forward to addressing the new requirements of design practice. This article draws together the various pedagogical requirements, and matches these to emergent and future digital design learning tools. Table 2 provides a summary of the concepts described and their resolution in emergent digital platforms.

Table 2: Requirements of design pedagogy and value of digital learning tools.

Requirements in design pedagogy	**Application/value of contemporary digital design learning tools**

Practical application, reliance upon visual data, three-dimensional outcomes, novel ways of working	Systems which allow the inclusion, gathering, sorting and viewing of visual data *(mood board tools, Pinterest, gesture-based surface table technologies)*
Path and process as important as the finished work. Tutor requirement to view historical and individual contributions within group projects	Enable the tracking of the history of the design process *(timelines, archiving)*
Student and tutor reflection on work and projects on completion	Ease of student(s)–tutor interaction, ease of student-student interaction, isolation of student contribution to projects *(timelines, digital snapshots)*
Tracking, planning and organizing in a highly individualized path and process	Flexibility and integrity of systems *(digital mind mapping, Mind42, virtual Post-It notes, Prezi, WebspirationPro)*
Interdisciplinary and collaborative learning	Fostering of virtual student interaction and interdisciplinary projects *(shared interfaces, COnCEPT, Global Studio, Pixelsense surface table technology)*
Keeping learning content current and updated	Student-authored content, peer-to-peer learning *(trialogical frameworks)*

This article suggests that, rather than the conventional and contemporary approaches to design learning being diametrically opposed, combining approaches and methods can provide a useful and enhanced pedagogical paradigm. This has several potential benefits for, and issues that need to be addressed by, design education.

The article proposes that new technologies are designed to match the context in which they are used. Rather than attempting to make use of existing ICT tools within design teaching, the authors suggest that technologies are developed which address the specific needs of design education. While there are many platforms and systems already in use, it is recommended that a single, shared interface is developed for design education, and this is already in the process of becoming reality (Liapis et al. 2014). Deployment of this tehnology in education can enable collaborative, interdisciplinary, transparent and cross-cultural learning with peers. It meets the requirement for the simulation of a real-world design student context, and provides good preparation for professional working.

The article also emphasizes the need for design educators to become more receptive to the potential of making use of web-based technologies to enhance student learning, and to build digital literacy. The work of contemporary design takes place in a global context, and therefore the provision of opportunities for students to experience cross-cultural working practices is considered of particular value.

The integration of digital alongside conventional methodologies addresses the expectations of new students. Multimedia is ingrained in the wider social realm, and it is

expected that design education will modernize in tandem. This has a wider impact on the development of appropriate learning materials, such as those intended for students with dyslexia and other learning differences. Learning in this context can be facilitated by a multisensory, interactive and experiential learning approach (Eide and Eide 2011). The presentation of information in the form of videos, interactive diagrams, mind maps and storyboards, and the encouragement of students to collect and share their own resources in new ways (e.g., using tablets with built-in cameras) fosters creative and innovative thinking. This idea is particularly significant since the diagnosis of different forms of neurodiversity has revealed a relatively high number of students with learning differences within art and design education.

Conclusion

Professional design practice is changing rapidly, and new and useful tools are emerging to support professional designers that are capable of responding to the changing needs of the profession. Since practice is evolving, it follows that the design curriculum and teaching techniques must also change to reflect the new terrain of industrial practice. Design education differs from other disciplines in its requirements for collaborative, interdisciplinary approaches that support constructivist learning and are often highly visual. Therefore, new tools and technologies are required that reflect these needs.

It is suggested that emergent technologies be adopted in design education to complement conventional studio-based teaching approaches. Emerging ICT tools provide an

opportunity to enhance design pedagogy and make it more relevant to contemporary practice by supporting interactive and collaborative approaches to learning. Such technologies have the benefit of ensuring the currency of learning material, as well as giving students the skills and experience necessary for entering the workforce. Learning through collaboration, in a combination of virtual and conventional methods, can also assist those with learning differences by providing a holistic learning environment based on visual interactions and the use of tools such as whiteboards and mind-mapping tools. Embracing of new platforms supporting students, educators and HEIs will unlock the widespread potential of these new technologies.

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